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Foreword

Ladies and gentlemen, colleagues and friends,

I am honoured to open the *joint conference Agrarian Perspectives XXI. + 131st EAAE Seminar* on behalf of the Scientific Committee. The conference *Agrarian Perspectives* has been traditionally organized by the *Faculty of Economics and Management* at the *Czech University of Life Sciences* since 1991. This year, the conference has already reached its 21st anniversary.

During the past two decades the conference has gradually evolved. What has, however, remained unchanged is the essence of this event driven by the common interest of scholars to better understand the issues related to countryside and rural areas. In comparison with the early years when the focus on the Czech context prevailed, the Conference has gained an international character. This year is the conference organized as a joint event with *131st EAAE Seminar*.

The *Agrarian Perspectives and EAAE Seminar* attracts scientists from a variety of social and economics disciplines. However, the major ones include agricultural economics. The theme of the *Agrarian Perspectives and EAAE Seminar* refers to innovation in terms of the agricultural innovation system (AIS) concept, i.e. as improvements of economic and social significance that are of a technical, managerial (organisational), institutional or policy nature, often involving their combination.

The presented collection of papers has resulted from careful evaluation (double-blind peer review) to ensure that they match the scope of the conference and meet the criteria of topicality and adequate academic standards. Papers of 77 participants from 14 different countries have been selected on this basis, and included in the proceedings that have already been published as part of the official conference programme. The book of proceedings is divided into five thematic parts that correspond with the conference topics – **(1) Assessing innovation processes that improve the competitiveness of agriculture and food industry; (2) Assessing the role of innovation in improving the economic viability of rural areas; (3) Assessing the importance of innovation for greening agriculture and environmental conservation; (4) Discussing institutions of innovation; and (5) Evaluating the effectiveness and efficiency of policies promoting innovation (research, transfer of knowledge, investment, education), conflict or complementarity of policies.**

I am taking this opportunity to express my thanks for the work of all the people, who took part in the organization of this event, particularly the members of the Programme Committee, my colleagues and professional partners, and also the academic staff of the Faculty.

Professor Jan Hron
Head of the Programme Committee

Economy and Investments

Assessing dynamic efficiency of the Spanish construction sector pre- and post-financial crisis

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Abstract: This paper estimates dynamic efficiency in the Spanish construction industry before and during the current financial crisis over the period 2001-2009. Static efficiency measures are biased in a context of a significant economic crisis with large investments and disinvestments as they do not account for costs in the adjustment of quasi-fixed factors. The results show that overall dynamic cost inefficiency is very high with technical inefficiency being the largest component, followed by allocative and scale inefficiency. Moreover, overall dynamic cost inefficiency is significantly larger before the beginning of the financial crisis than during the financial crisis. Results also show that larger firms are on average less technically and scale inefficient than smaller firms, but have more problems in choosing the mix of inputs that minimizes their long-term costs. Firms that went bankrupt, on average have a higher overall dynamic cost inefficiency and scale inefficiency than firms that did not go bankrupt.

Keywords: dynamic efficiency; construction sector

1. Introduction

A competitive sector often depends on its firms meeting their production potential and minimizing waste. Focusing on the growth in returns to factors employed, more competitive firms are able to attract resources away from less competitive firms. Sustaining competitiveness over the long run involves attention to growth prospects associated with the innovations needed to keep pushing the competitive envelope, and the efficiency gains needed to ensure that implemented technologies can succeed. The construction sector in both emerging and mature economies is a classic case in point. In most cases, the expansion a nation's economic fortunes are fueled by the construction sector. The sector draws on a significant capital base as well as being an economy's significant employer and an important contributor to the nation's GDP.

Spain has the largest construction sector among the EU countries (Eurostat). Until very recently, the Spanish construction sector enjoyed a period of constant growth, reaching a 10% share of national GDP in 2006, which is twice the overall comparable figure for the EU, and employing 2.9 million persons (13% of the labor force). During the last decade, the expansion of this industry was a driving force behind the Spanish economic growth. Until 2007, Spain was recording higher annual new home construction completions than France, Germany and Italy combined. In the face of rising interest rates, oversupply, oversize, stricter lending conditions, and the emerging global financial crisis, Spain's construction industry collapsed in 2007 with many firms exiting the sector (Spanish Ministry of Public Works and Transport; Bielsa and Duarte, 2010). The construction downturn negatively impacted on both output and employment and both of them contracted by about one third through the end of 2009 (Eurostat). Given this sector's central role in promoting Spain's competitiveness and economic growth, this study focuses on the construction sector's economic performance.

Figure 1 presents the pattern of construction permits granted and construction completion between 2001 and 2010. The emerging crisis is clearly foretold during 2006 by the building permits granted which is a leading economic indicator of macroeconomic performance. Conversely, the pattern of construction completion presents a lagging indicator of economic performance. Several economic policy levers are available to stimulate this sector's economic activity. Examples include monetary policy impacting interest rates changes, banking policies that can impact mortgage activity, zoning regulation, investment in amenities complementing building activities (such as green space, entertainment opportunities).

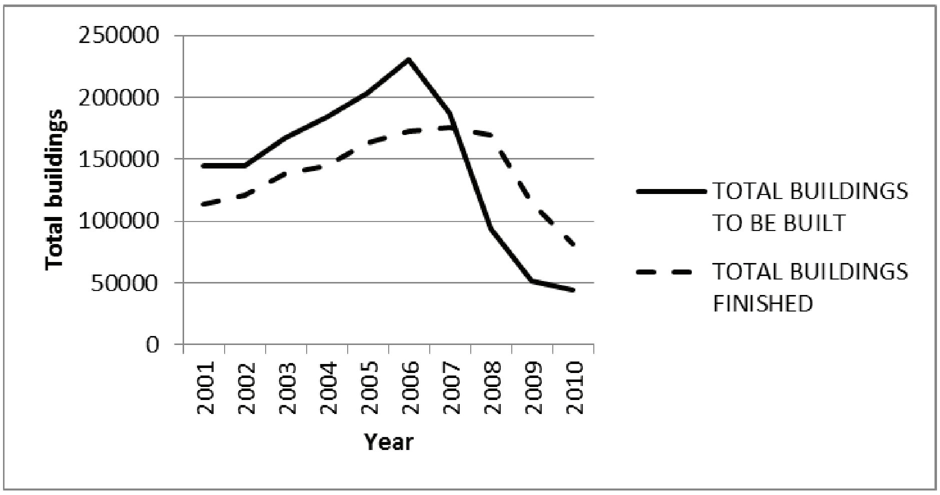

Fig.1. Pattern of construction starts and finishing rates.
Source: elaborated based on the information from the Spanish Statistical Office

The economic performance of the construction sector is the focus of considerable work. Using a growth accounting approach with country level data, Abdel-Wahab and Vogl (2011) compare the Germany, France, UK, USA and Japan constructions sectors over 1990-2005. These analyses suggest this sector growth lags behind the growth in all industries, with Germany and Japan presenting negative growth rates in construction. Li and Liu (2010) find the productivity of the Australian construction sector over 1990-2007 is modest at 1.1%; however, wide fluctuations are observed over time and by different Australians states. In contrast, productivity growth in the Chinese construction sector presents wide differences across regions with an industry average of 4.25% annually (except for the 2001-2002 period which presents an unexplained anomaly) (Xue, et al., 2008).

Country studies report a wide range of efficiency levels employing production- and financial-based frameworks. These range from a low of around 50% for Canadian firms (Pilateris and McCabe, 2003), approximately 60% for Portuguese firms (Horta et al., 2012), to higher estimates of 93% for Greek firms (Tsolas, 2011) and 98% for Chinese firms (Xue et al., 2008). The case of Korea in the late 1990s presents an interesting case in contrast to the Spanish case. The Korean construction sector was impacted by an economic crisis in November 1997. Using a Data Envelopment Analysis (DEA) approach for the period 1996-2000, You and Zi (2007) focus on leverage ratio, export weight, institutional ownership, asset size and receivables overdue turnover and find these factors impact all efficiency measures. However, the declining allocative inefficiency is the major component leading to lower efficiency over the crisis suggesting the agency problem between managers and owners is at fault.

The literature on efficiency traditionally focuses on the static efficiency measures and only recently we observe a number of important contributions on dynamic efficiency modeling with applications to the agricultural/food and energy sectors (Rungsuriyawiboon and Stefanou, 2007; Silva and Stefanou, 2007; Serra et al., 2011). Being a capital intensive sector, the Spanish construction industry presents an interesting case study for dynamic inefficiency analysis in the period before and during a significant economic crisis. Static measures are biased in a context with large investments and disinvestments as they do not account for adjustment costs.

Against this background, the objective of this paper is to assess dynamic cost, technical, allocative and scale inefficiencies in the Spanish construction industry before and during the current crisis and to compare results for different size classes as well as firms that are active and that disband in the time-period considered. With the construction sector being heavily embodied in capital, the adjustment of these stocks is sluggish and cannot be expected to change instantaneously to revised long-run equilibrium levels that come about from the changing macroeconomic environment.

The paper proceeds with the next section presenting the conceptual model based on the intertemporal cost minimization and the presentation of the dynamic cost efficiency measures, followed by the description of the database of financial accounts of Spanish construction firms. The section to follow presents the results comparing the efficiency patterns by different size of firms and firms that are active and that disband, and the decomposition of efficiency. The final section offers concluding comments and some potential policy implications.

2. Conceptual model

Consider a data series representing the observed quantities of M outputs (y), N variable inputs (x), F investments (I) and quasi-fixed factors (K) and N, and F prices of variable and quasi-fixed factors (w and c) of $j = 1,..,J$ firms at time t. At any base period $t \in [0,+\infty)$, the firm is assumed to minimize the discounted flow of costs over time subject to an adjustment-cost technology. The intertemporal cost minimization problem is given by:

$$W(k,w,c,y)=\min_{x,I}\int_{t_o}^{\infty} e^{-es}\left[w_s'x_s+c_s'K_s\right]ds$$

s.t. (1)

$$\dot{K}=I-\delta K, K(t_o)=k$$

$$\vec{D}_i(y(s),K(s),x(s),I(s);g_x,g_I)\geq 0,\ \ s\in[t,+\infty)$$

where *W(·)* represents the discounted flow of costs in all future time periods. The subscript *s* denotes the (future) time periods; subscripts of variables have been suppressed if they represent the current time period *t*. The directional distance function $\vec{D}_i(\cdot)$ measures the distance of *x* and *I* to the frontier in the direction defined by the directional vectors g_x and g_I, respectively.

Expressing (1) in terms of the current value gives the Hamilton-Jacobi-Belman equation:

$$rW(y,K,w,c)=\min_{x,I,\gamma}\left[w'x+c'K+W_K{}'(I-\delta K)\right]$$

s.t. (2)

$$\vec{D}_i(y,k,x,I;g_x,g_I)\geq 0,$$

where $W_K=W_K(y,K,w,c)$ is the vector of shadow values of quasi-fixed factors. Note that the shadow value of quasi-fixed factors is determined endogenously in the model. Equation (2) is represented by the following DEA model:

$$rW(y,K,w,c)=\min_{x,I,\gamma}\left[w'x+c'K+W_K{}'(I-\delta K)\right]$$

s.t. (3)

$$\sum_{j=1}^{J}\gamma^j y_m^j\geq y_m,\ \ m=1,...,M;$$

$$x_n\geq\sum_{j=1}^{J}\gamma^j x_n^j,\ \ n=1,...,N;$$

$$\sum_{j=1}^{J}\gamma^j(I_f^j-\delta_f K_f^j)\geq I_f-\delta_f K_f,\ \ f=1,...,F;$$

$$\gamma^j\geq 0,\ j=1,...,J;$$

$$x_n\geq 0,\ n=1,...,N;$$

$$I_f\geq 0,\ f=1,...,F;$$

where γ is the $(J\times 1)$ intensity vector. A solution of (3) requires a value for (W_K)[1].

[1] In this paper, the shadow values of dynamic factors are generated using a quadratic specification of the optimal value function and rewriting it as: $w'x=rW(y,K,w,c)-c'K+W_K{}'(I-\delta K)$. After fitting this specification, the shadow values of quasi-fixed factors are obtained using the parameter estimates.

Using the solution of (3) a dynamic cost inefficiency (*OE*) measure is generated as (see Silva and Oude Lansink, 2012):

$$OE = \frac{w'x + c'K + W_K(.)'(I - \delta K) - rW(y,K,w,c)}{w'g_x - W_K(.)'g_I} \tag{4}$$

The dynamic directional input distance function, measuring dynamic technical inefficiency for each firm is:

$$\vec{D}(y,K,x,I;g_x,g_I \mid C) = \max_{\beta,\gamma} \beta$$

s.t.

$$\begin{aligned} & y_m \le \sum_{j=1}^{J} \gamma^j y_m^j, \;\; m = 1,...,M; \\ & \sum_{j=1}^{J} \gamma^j x_n^j \le x_n - \beta g_{x_n}, \; n = 1,...,N; \\ & I_f + \beta g_{I_f} - \delta_f K_f \le \sum_{j=1}^{J} \gamma^j (I_f^j - \delta_f K_f^j), \; f = 1,...,F; \\ & \gamma^j \ge 0, \; j = 1,...,J. \end{aligned} \tag{5}$$

The direction vector adopted in this paper is $(g_x, g_I) = (x, \delta K)$, i.e. g_x is the actual quantity of variable inputs and g_I is the depreciated quantity of capital. Further, the dynamic directional input distance function in (5) assumes constant returns to scale. The dynamic directional input distance function under variable returns to scale (i.e., $\vec{D}(y,K,x,I;g_x,g_I \mid V)$) is obtained by adding the constraint $\sum_{j=1}^{J} \gamma^j = 1$ to (5). The difference between $\vec{D}(y,K,x,I;g_x,g_I \mid V)$ and $\vec{D}(y,K,x,I;g_x,g_I \mid C)$ is a measure of scale inefficiency (*SE*).

Finally, following Silva and Oude Lansink (2012), dynamic overall cost inefficiency is decomposed into the contributions of technical inefficiency under variable returns to scale, scale inefficiency (*SE*) and a residual term defined as allocative inefficiency (*AE*):

$$OE = \vec{D}(y,K,x,I;g_x,g_I \mid V) + SE + AE \tag{6}$$

with $AE \ge 0$.

3. Data

The data used in this study come from the SABI database, managed by Bureau van Dijk, which contains the financial accounts of Spanish companies. The study sample includes the firms belonging to the category of firms in construction of residential and non-residential buildings (NACE Rev. 2 code 4120). This study focuses on the medium-sized firms which are among the most adversely impacted by the crisis as reflected by the significant reduction in the number of firms (Laborda, 2012). Also, focusing on medium-sized firms results in a data set with firms that are comparable in size. The medium-sized firms are those that employ between 50 and 249 employees and that have an annual turnover between 10 and 50 million euros, following the European Union definition.

After filtering out companies with missing information and after removing the outliers[2], the final data set consists of 775 medium-sized firms that operated in Spain in at least one year during the period from 2001 to 2009. Choosing this time span we are able to analyze the years before and after the start of the financial crisis in Spain. The panel is unbalanced and it sums up to 2,460 observations.

One output and three inputs (material costs, labor costs and fixed assets) are distinguished. Output was defined as total sales plus the change in the value of the stock and was deflated using the price index of residential buildings. Material costs and labor costs were directly taken from the SABI database and were deflated using the price indexes of materials of residential buildings and labor costs in construction, respectively. Fixed assets are measured as the beginning value of fixed assets from the balance sheet (i.e. the end value of the previous year) and are deflated using the industrial price index for capital goods. All prices used to deflate output and inputs are obtained from the Spanish Statistical Office (various years). Gross investments in fixed assets in year t are computed as the beginning value of fixed assets in year $t+1$ minus the value of fixed assets in year t plus the value of depreciation in year t. Table 1 provides the descriptive statistics of the data used in this study, for the whole period 2001-2009 and for the periods before and after the start of the financial crisis (from 2001 to 2006, and from 2007 to 2009).

Table 1
Descriptive statistics of input-output data, pre- and post-financial crisis.

Statistic / Variable	Mean	Std. dev.	Min	Max
	2001-2006 (N=1,548)			
Fixed assets	2.523	4.838	0.020	101.416
Employee cost	2.566	1.188	0.463	7.787
Material cost	12.115	6.512	1.518	43.092
Investments	0.730	1.807	-8.514	36.003
Production	17.886	8.663	3.552	71.386
	2007-2009 (N=912)			
Fixed assets	4.793	9.800	0.039	95.977
Employee cost	2.555	1.213	0.716	8.086
Material cost	11.071	6.183	2.406	46.152
Investments	0.806	3.212	-29.048	60.387
Production	16.035	7.822	0.363	54.604
	2001-2009 (N=2,460)			
Fixed assets	3.365	7.177	0.020	101.416
Employee cost	2.562	1.197	0.463	8.086
Material cost	11.728	6.411	1.518	46.152
Investments	0.758	2.425	-29.048	60.387
Production	17.200	8.407	0.363	71.386

The data in Table 1 show that in the period after the start of the financial crisis, the value of output and material costs have been shrinking by almost 10% compared to the period before

[2] Outliers were determined using ratios of output to input. An observation was defined as an outlier if the ratio of output over any of the three inputs was outside the interval of the median plus and minus two standard deviations.

the financial crisis. The cost of employees maintains almost the same, suggesting that firms have less flexibility in adapting the costs of labor, which is likely due to the legal protection of labor. Furthermore, Table 1 indicates that the size of fixed assets is larger in the period after the start of the financial crisis than before. This figure may reflect the change in the composition of the group of medium-sized firms. Firms that were categorized as large firms before the crisis have scaled down and enter the medium-sized firm category after the crisis. However, the financial crisis is reflected in the ratio of investment over fixed assets. This ratio decreased from 29%, on average before the crisis to 17% after the crisis. Also, the volatility, as measured by standard deviation of investments normalized by the mean, is much larger after the crisis than before the crisis, reflecting that firms reacted very differently to the crisis.

4. Results

This section presents the decomposition of overall dynamic inefficiency in the Spanish construction industry for the period pre- and post-financial crisis. Furthermore, dynamic efficiency indicators are compared between firms that differ in size as well as companies that are active versus those that went bankrupt in the time-period analyzed. Differences in overall, technical, scale and allocative inefficiencies between groups of construction firms are tested using the test proposed by Simar and Zelenyuk (2006)[3] denoted as the S-Z test.

Figure 2 presents the Kernel density estimates[4] of overall cost inefficiency for the time-period before and after the beginning of the financial crisis (from 2001 to 2006, and from 2007 to 2009).

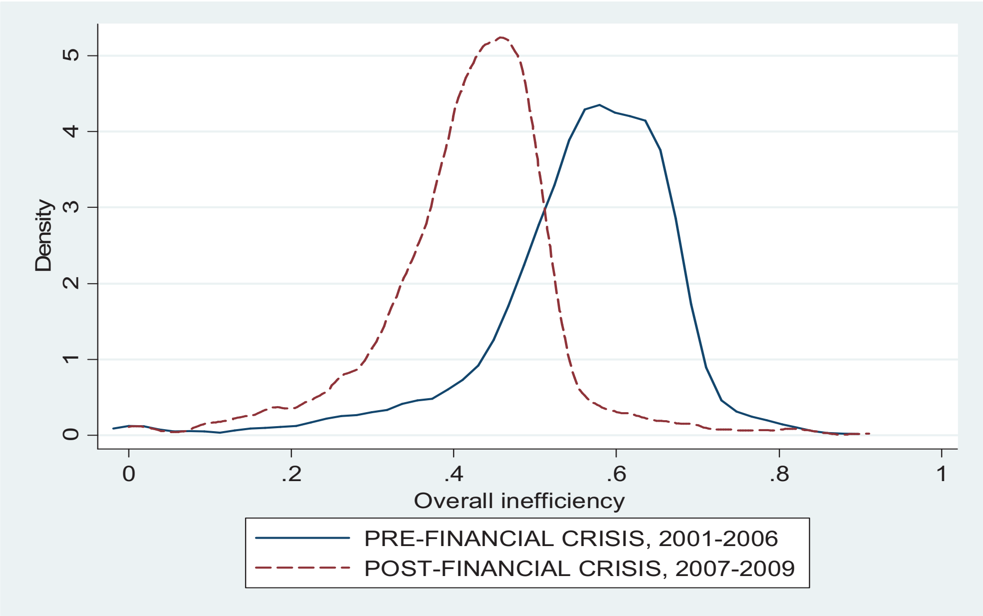

Fig. 2. Kernel density estimates for overall inefficiency, pre- and post-financial crisis.

[3] The Simar and Zelenyuk test adapts the nonparametric test of the equality of two densities developed by Li (1996). Simar and Zelenyuk (2006) propose its adaptation to reckon with the specificity of DEA efficiency scores: bounded support of the distribution and the fact that estimated rather than 'true' efficiencies are used. In particular, they propose two algorithms and among them they found the Algorithm 2 to be more robust, hence we apply it here. In essence, the algorithm is based on computation and bootstrapping the Li statistic using DEA estimates, where values equal to unity are smoothed by adding a small noise. The implementation of this algorithm is done in R using 1000 bootstrap replications.

[4] In all subsequent density estimates, we use Gaussian kernel function and Silverman's (1986) rule of thumb to determine the bandwidth.

At a first glance, the graphs in Figure 2 suggest a higher overall cost inefficiency of Spanish construction firms in the period before the financial crisis rather than during the financial crisis: the distribution of the period before financial crisis is located to the right of the distribution for the period after the beginning of the financial crisis. The decomposition of overall cost inefficiency in Table 2 provides more insights into the causes of this difference.

Table 2

Evolution of overall, technical, scale and allocative inefficiency, pre- and post-financial crisis (S-Z-statistics and p-values of the differences between two time-periods).

Year	N	Overall inefficiency	Technical inefficiency CRS	Technical inefficiency VRS	Scale inefficiency	Allocative inefficiency
2001-2006	1,548	0.557^{a}	0.432^{b}	0.335^{c}	0.098^{d}	0.124^{e}
2007-2009	912	0.420^{a}	0.321^{b}	0.266^{c}	0.055^{d}	0.010^{e}
2001-2009	**2460**	$\mathbf{0.506^{a}}$	$\mathbf{0.391^{b}}$	$\mathbf{0.309^{c}}$	$\mathbf{0.082^{d}}$	$\mathbf{0.115^{e}}$
S-Z-statistic		280.458	142.474	41.484	98.261	33.551
p-value		0.000***	0.000***	0.000***	0.000***	0.000***

***statistically significant differences at 1% level

a, b, c, d, e statistically significant differences at 1% level

Using Table 2, one can note that the decrease in overall cost inefficiency of Spanish construction firms in the post financial crisis period is due to a decrease in all its components. Moreover, the inefficiency distributions show significant differences between both periods as indicated by the S-Z test results: the estimated p-values are equal to 0, so the null hypotheses of equality of efficiency distributions are rejected. Three possible interpretations can be derived from this result: 1) some inefficient firms might have been forced to disappear from the market due to, for example, the decrease in demand caused by the crisis; 2) the crisis has worked as a disciplining factor and firms became sharper in allocating resources; and 3) as large firms contract to become medium-sized firms, they bring an additional dimension of experience in construction management to the group of firms in this category. All explanations imply the decrease of firms' inefficiencies in the period of financial crisis. Interestingly, further investigation suggests that the allocative inefficiency decreased dramatically during the years of financial crisis as compared to pre-crisis period. This suggests that Spanish construction firms better succeed in allocating resources so as minimize long-run costs during the financial crisis. Finally, exploring the sources of CRS technical inefficiency decrease in post-crisis period, one can conclude that it occurred mainly due to a decrease in scale inefficiency rather than a decrease in VRS technical inefficiency. Therefore, the main reason behind the improvement in CRS technical efficiency is the fact that the firms' combination of inputs and outputs became less scale inefficient.

Overall for the 2001-2009 time-period, the findings suggest that substantial cost-savings can be realized in the Spanish construction industry; i.e., the combined effect of dynamic technical and allocative factors shows that the average overall cost inefficiency for construction firms is 0.506. Such a high level of inefficiency, on the one hand, is due to the factors under managers' control, and on the other – it might be related to uncertainty in construction delivery which is out of the control of the firm (for example, weather conditions, obstacles in natural conditions of the ground). This relatively high level of overall cost inefficiency is mainly due to technical inefficiency under CRS (0.391) rather than allocative inefficiency (0.115). Average technical inefficiency allows for an improvement of 39.1% in reducing the inputs and increasing investments at a given level of outputs. The average allocative inefficiency of 0.115 suggests that construction firms can reduce costs by 11.5% through a better mix of variable and dynamic factors of production at given prices.

To compare the efficiencies of Spanish construction firms differing in size, two size population classes among medium-sized firms are devised according to the annual sales turnover. The group of small medium sized firms is defined as firms with a turnover that is between 10 and 30 million euros (size class 1), whereas large medium sized firms are defined as firms with a turnover between 30 and 50 million euros (size class 2)[5]. Figure 3 presents the Kernel density estimates of overall inefficiency for these two categories of firms' size for the period from 2001 to 2009.

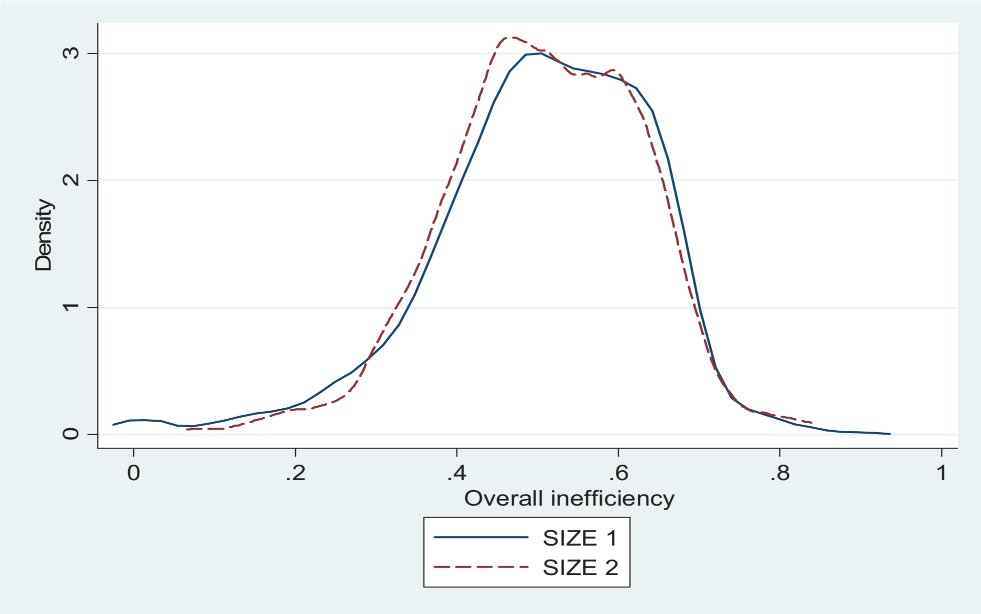

Fig. 3. Kernel density estimates of overall inefficiency for small (1) and large (2) medium sized firms, 2001-2009.

It is clear from the graphs on Figure 3 that the distributions of overall inefficiency for small and big medium-sized construction firms are similar suggesting that overall inefficiency may not be associated with firms' size. Table 3 further elaborates this finding by providing the decomposition of overall inefficiency as well as the results of S-Z test of significance of differences in inefficiency between the two size classes.

[5] The descriptive statistics of input and output variables for size categories can be obtained from the authors upon request.

Table 3

Differences in inefficiency between size classes, pre- and post-financial crisis (S-Z-statistics and p-values of the differences between sizes).

Size	N	Overall inefficiency	Technical inefficiency CRS	Technical inefficiency VRS	Scale inefficiency	Allocative inefficiency
			2001-2006			
1	1,329	0.554	0.441	0.335	0.106	0.112
2	219	0.574	0.376	0.330	0.047	0.197
S-Z-statistic		-0.442	2.754	2.226	48.119	3.106
p-value		0.312	0.000***	0.000***	0.000***	0.000***
			2007-2009			
1	720	0.417	0.328	0.274	0.053	0.090
2	192	0.432	0.296	0.235	0.062	0.136
S-Z-statistic		-1.464	-0.660	5.581	2.358	3.133
p-value		0.635	0.024**	0.000***	0.000***	0.000***
			2001-2009			
1	2,049	0.506	0.401	0.314	0.087	0.104
2	411	0.507	0.339	0.285	0.054	0.169
S-Z-statistic		-1.580	7.168	8.158	27.038	2.836
p-value		0.400	0.000***	0.000***	0.000***	0.000***

***statistically significant differences at 1% level, **statistically significant differences at 5% level

The results in Table 3 clearly provide a support that overall inefficiency of Spanish construction firms is not associated with firm size for both the pre- and post-financial crisis period. The estimated p-values of the S-Z test ranges from 0.312 to 0.635, indicating that the null hypothesis of equality of distributions cannot be rejected. Technical and scale inefficiencies decrease with size: mean inefficiency is lower for larger than for smaller construction firms; however, the difference in magnitude is not large. This result holds in the pre-crisis period and during the financial crisis (from 2007 to 2009 with exception for scale efficiency). Therefore, the results confirm that smaller construction firms are farther away from efficient frontier and are less scale efficient than larger companies. However, the results for allocative inefficiency in Table 3 suggest that larger construction firms have more problems with choosing the mix of inputs and output that minimizes long-run cost than smaller construction firms.

Further insights can be achieved by splitting the sample of efficiency estimates into construction firms that are active versus those that exit the sector due to bankruptcy. Figure 4 visualizes the distributions of overall inefficiency of these two groups of firms during the analyzed period.

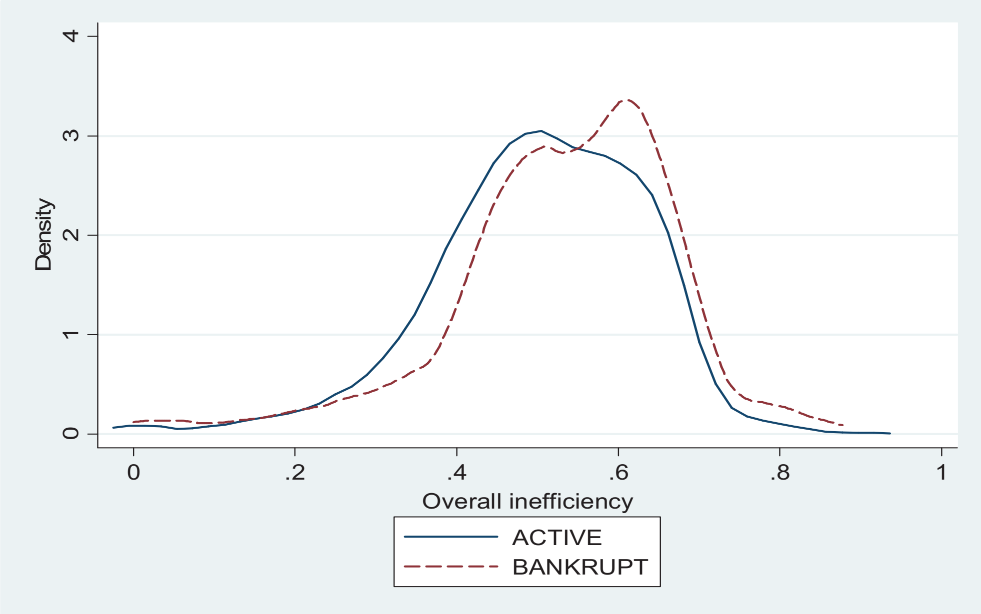

Fig. 4. Kernel density estimates for overall inefficiency, active versus bankrupt firms, 2001-2009.

Figure 4 suggests that overall inefficiency is slightly higher for construction firms that went bankrupt than for active firms. The distribution of overall inefficiency of bankrupt companies is located to the right of the distribution of active companies. However, the differences in distributions of overall inefficiency observed on the graph are not very substantial. Table 4 presents the results of the S-Z test for differences in overall inefficiency and its components for active companies and companies that went bankrupt.

Table 4

Active versus dissolving firms, pre- and post-financial crisis (S-Z-statistics and p-values of the differences).

Activity	N	Overall inefficiency	Technical inefficiency CRS	Technical inefficiency VRS	Scale inefficiency	Allocative inefficiency
			2001-2006			
Active	1,309	0.556	0.433	0.338	0.094	0.124
Bankrupt	239	0.557	0.429	0.313	0.115	0.128
S-Z-statistic		2.798	5.113	2.667	2.667	10.460
p-value		0.168	0.069*	0.214	0.214	0.565
			2007-2009			
Active	834	0.418	0.319	0.264	0.055	0.099
Bankrupt	78	0.448	0.345	0.291	0.054	0.103
S-Z-statistic		3.931	2.333	1.592	4.970	3.018
p-value		0.001***	0.024**	0.217	0.818	0.183
			2001-2009			
Active	2,143	0.502	0.388	0.309	0.079	0.114
Bankrupt	317	0.530	0.408	0.308	0.100	0.122
S-Z-statistic		7.039	6.692	2.449	33.970	12.528
p-value		0.002***	0.002***	0.577	0.004***	0.298

***statistically significant differences at 1% level, **statistically significant differences at 5% level, *statistically significant differences at 10% level

Table 4 shows that overall inefficiency during the 2001-2009 time-period is lower for active construction firms rather than for firms that went bankrupt. In this period, although all inefficiency components are lower for active firms rather than for firms that went bankrupt, only for CRS technical inefficiency and scale inefficiency these differences are statistically significant. Comparing the periods of pre- and post-financial crisis, again in general the lower inefficiencies are observed for active firms, although many differences are not statistically significant. After the beginning of the financial crisis, the differences in overall inefficiency and CRS technical inefficiency between active and bankrupt firms are significantly different, but all other components are not. In the period before the beginning of the financial crisis, the difference in overall inefficiency is not statistically significant, but one of its components, the difference in CRS technical inefficiency is significant.

5. Conclusions

This paper estimates dynamic inefficiency of Spanish construction firms before and after the beginning of the financial crisis and compares the performance of firms of different sizes and for firms that went bankrupt versus those that were not. The empirical application used accountancy data from medium sized construction firms in the period 2001-2009.

The medium sized construction firms in our sample have an almost 10% lower output and material costs in the period after the financial crisis than before. Also, the investment ratio is much lower in the period after the beginning of the financial crisis, while labor cost does not change.

Overall dynamic cost inefficiency is 0.506 in the period under investigation with technical inefficiency (0.309) being the largest component, followed by allocative (0.115) and scale inefficiency (0.082). Overall inefficiency is significantly larger before the beginning of the financial crisis than during the financial crisis; the improvement is mainly due to lower allocative inefficiency. Large medium sized firms are, on average less technically and scale inefficient than small medium sized firms, but have more problems in choosing the mix of inputs that minimizes their long-term costs. In the period after the beginning of the financial crisis, large medium sized firms have a lower technical and allocative inefficiency, whereas small medium sized firms have a lower technical and scale inefficiency. Firms that went bankrupt in the period 2001-2009, on average have a higher overall dynamic cost inefficiency and scale inefficiency than firms that did not go bankrupt.

The implications of our results for the construction firms are that these firms have a substantial scope for improving their technical performance. Better management of their resources can contribute to a reduction of technical inefficiency. Further research is needed though to investigate the factors that are underlying poor technical performance. Also, our results imply that particularly larger firms suffer financial losses due to a poor allocation of resources at given input prices. Big firms and firms pursuing a growth strategy need to pay more attention to this source of inefficiency, e.g. by choosing less costly combinations of inputs.

Our results on scale inefficiency imply that firms need more flexibility in adjusting the size of their operation. Lack of flexibility in adjusting the size due to e.g. legal constraints contributes to the persistence of scale inefficiency. Our data suggest that construction firms have less flexibility in adjusting the size of the labor force. Policy makers can increase labor flexibility by reforming the labor market such that firms can more easily lay off people in times of financial distress.

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Dynamic Productivity Growth in the Spanish Meat Industry

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Abstract: This paper develops a dynamic Luenberger productivity growth indicator and decomposes it to identify the contributions of technical change, technical efficiency change and scale change. The Luenberger productivity growth indicator is estimated using Data Envelopment Analysis. The empirical application focuses on panel data of Spanish meat processing firms over the period 2000-2010. The dynamic Luenberger indicator shows productivity decrease of on average -0.003 in the period under investigation, with technical regress being the main driver of change, despite technical and scale efficiency growth.

Key words: directional distance function, dynamics, Luenberger TFP, meat processing.

1 Introduction

The characterization and measurement of economic performance in both theory and practice continues to claim considerable attention in the literature. The major attention of these economic performance measures continues to address the measurement of efficiency and productivity growth. The economics literature on efficiency has produced a wide range of productivity growth measures (see e.g. Balk (2008) for a comprehensive treatment).

The setting of the decision environment plays a crucial role in the modeling framework and the characterization of results. The static models of production are based on the firm's ability to adjust instantaneously and ignore the dynamic linkages of production decisions. The business policy relevance to distinguishing between the contributions of variable and capital factors to inefficiency or productivity growth is clear. For example, when variable factor use is not meeting its potential, remedies can include better monitoring of resource use; when asset use is not meeting potential, remedies can include training programs to enhance performance or even a review of the organization of assets in the production process to take advantage of asset utilization. The weakness underlying the static theory of production in explaining how some inputs are gradually adjusted has led to the development of the dynamic models of production where current production decisions constrain or enhance future production possibilities.

The characterization of dynamic efficiency can also build on the adjustment cost framework that implicitly measures inefficiency as a temporal concept as it accounts for the sluggish adjustment of some factors. In a nonparametric setting, Silva and Stefanou (2007) develop a myriad of efficiency measures associated with the dynamic generalization of the dual-based revealed preference approach to production analysis found in Silva and Stefanou (2003). In a parametric setting, Rungsuriyawiboon and Stefanou (2007) present and estimate the dynamic shadow price approach to dynamic cost minimization.

An intriguing prospect is to incorporate the properties of the dynamic production technology presented in Silva and Stefanou (2003) into the directional distance function framework, which can exploit the Luenberger productivity growth measurement. The directional distance function offers the powerful advantage of focusing on changes in input and output bundles, inefficiency and the technology. Such a productivity measure based on the directional distance function has its origins in Chambers, Chung and Färe (1996) who defined a Luenberger indicator of productivity growth in the static context. A growing literature employing this approach has emerged more recently[1]. However, in the presence of adjustment costs in quasi-fixed factors of production, the static measures do not correctly reflect productivity growth. Recently, Oude Lansink, Stefanou and Serra (2012) proposed a dynamic Luenberger productivity growth measure based on an econometrically estimated dynamic directional distance function and decomposed this into the contribution of technical change and technical inefficiency change.

This paper extends the dynamic Luenberger productivity growth measure of Oude Lansink, Stefanou and Serra (2012) to make a richer decomposition into the contributions of technical efficiency change, scale efficiency change and technical change. The empirical application uses a nonparametric method (Data Envelopment Analysis) to estimate the dynamic directional distance function. The focus of the application is on panel data of Spanish meat processing firms over the period 2000-2010. The meat processing industry is the most important food sector in Spain, generating approximately 20% of total sales and employment within food industry and 2% of Spanish GDP in 2009 (National Association of Meat Industries of Spain). Its significance is emphasized by the fact that it is one of the main exporting sectors of Spain. The Spanish meat industry is characterized also by a low level of innovations and by the predominance of small and medium-sized enterprises (European Commission, 2011). The period analyzed concerns the time of increasing regulation in the European Union (EU) with regard to food safety, consumer information, the mandatory adoption of environmentally-sustainable practices and the functioning of internal market. In order to cope with the increasing regulation, European firms had to undertake additional investments and deal with more administrative burdens (European Commission, 2004; Wijnands, Van der Meulen and Poppe, 2006). Another impacting event is the increase in production costs of meat producers resulting from the increase in the costs of animal feed in 2007 and 2008. This increase in feed costs decreased the supply of slaughter cattle which serves as an input for the meat industry. Finally, from 2008 onwards the Spanish meat industry is being affected by the economic crisis as reflected by the decrease in the demand for meat.

The next section develops the measures of dynamic productivity growth and its decomposition. This is followed by the empirical application to the panel of Spanish meat processing firms showing productivity change and its decomposition. The final section offers concluding comments.

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[1] See Chambers, Färe and Grosskopf (1996), Boussemart, et al. (2003), Färe and Primont (2003), Briec and Kerstens (2004), Färe and Grosskopf (2005), Balk (2008).

2 The Primal Luenberger Indicator of Dynamic Productivity Growth

The primal Luenberger indicator of dynamic productivity growth is defined through a dynamic directional distance function. Let $\mathbf{y}_t \in \Re^{M}_{++}$ represent a vector of outputs at time *t*, $\mathbf{x}_t \in \Re^{N}_{+}$ denote a vector of variable inputs, $\mathbf{K}_t \in \Re^{F}_{++}$ the capital stock vector, $\mathbf{I_t} \in \Re^{F}_{+}$ the vector of gross investments, and $\mathbf{L}_t \in \Re^{C}_{++}$ a vector of fixed inputs for which no investments are allowed. The production input requirement set can be represented as $V_t(\mathbf{y}_t : \mathbf{K}_t, \mathbf{L}_t) = \{(\mathbf{x}_t, \mathbf{I}_t) : (\mathbf{x}_t, \mathbf{I}_t) \text{ can produce } \mathbf{y}_t \text{ given } \mathbf{K}_t, \mathbf{L}_t\}$. The input requirement set is defined by Silva and Oude Lansink (2012) and assumed to have the following properties: $V_t(\mathbf{y}_t : \mathbf{K}_t, \mathbf{L}_t)$ is a closed and nonempty set, has a lower bound, is positive monotonic in $\mathbf{x}_t$, negative monotonic in $\mathbf{I}_t$, is a strictly convex set, output levels increase with the stock of capital and quasi-fixed inputs and are freely disposable.

The input-oriented dynamic directional distance function $\vec{D}^i_t(\mathbf{y}_t, \mathbf{K}_t, \mathbf{L}_t, \mathbf{x}_t, \mathbf{I}_t; \mathbf{g_x}, \mathbf{g_I})$ is defined as follows:

$$\vec{D}^i_t(\mathbf{y}_t, \mathbf{K}_t, \mathbf{L}_t, \mathbf{x}_t, \mathbf{I}_t; \mathbf{g_x}, \mathbf{g_I}) = \max\{\beta \in \Re : (\mathbf{x}_t - \beta\mathbf{g_x}, \mathbf{I}_t + \beta\mathbf{g_I}) \in V_t(\mathbf{y}_t : \mathbf{K}_t, \mathbf{L}_t)\},$$
$$\mathbf{g_x} \in \Re^{N}_{++}, \ \mathbf{g_I} \in \Re^{F}_{++}, (\mathbf{g_x}, \mathbf{g_I}) \neq (\mathbf{0}^N, \mathbf{0}^F) \qquad \textbf{(1)}$$

if $(\mathbf{x}_t - \beta\mathbf{g_x}, \mathbf{I}_t + \beta\mathbf{g_I}) \in V_t(\mathbf{y}_t : \mathbf{K}_t, \mathbf{L}_t)$ for some β, $\vec{D}^i_t(\mathbf{y}_t, \mathbf{K}_t, \mathbf{L}_t, \mathbf{x}_t, \mathbf{I}_t; \mathbf{g_x}, \mathbf{g_I}) = -\infty$, otherwise. The distance function is a measure of the maximal translation of $(\mathbf{x}_t, \mathbf{I}_t)$ in the direction defined by the vector $(\mathbf{g_x}, \mathbf{g_I})$, that keeps the translated input combination interior to the set $V_t(\mathbf{y}_t : \mathbf{K}_t, \mathbf{L}_t)$. Since $\beta\mathbf{g_x}$ is subtracted from $\mathbf{x}_t$ and $\beta\mathbf{g_I}$ is added to $\mathbf{I}_t$, the directional distance function is defined by simultaneously contracting variable inputs and expanding gross investments. As shown by Silva and Oude Lansink (2012), $\vec{D}^i_t(\mathbf{y}_t, \mathbf{K}_t, \mathbf{L}_t, \mathbf{x}_t, \mathbf{I}_t; \mathbf{g_x}, \mathbf{g_I}) \geq 0$ fully characterizes the input requirement set $V_t(\mathbf{y}_t : \mathbf{K}_t, \mathbf{L}_t)$, being thus an alternative primal representation of the adjustment cost production technology.

Building on the Luenberger indicator of productivity growth defined by Chambers, Chung and Färe (1996) to the dynamic setting by using the dynamic directional distance function (assuming CRS) leads to:

$$L(\cdot) = \frac{1}{2}\left\{\begin{matrix}[\vec{D}^i_{t+1}(\mathbf{y}_t, \mathbf{K}_t, \mathbf{L}_t, \mathbf{x}_t, \mathbf{I}_t; \mathbf{g_x}, \mathbf{g_I}) - \vec{D}^i_{t+1}(\mathbf{y}_{t+1}, \mathbf{K}_{t+1}, \mathbf{L}_{t+1}, \mathbf{x}_{t+1}, \mathbf{I}_{t+1}; \mathbf{g_x}, \mathbf{g_I})] + \\ [\vec{D}^i_t(\mathbf{y}_t, \mathbf{K}_t, \mathbf{L}_t, \mathbf{x}_t, \mathbf{I}_t; \mathbf{g_x}, \mathbf{g_I}) - \vec{D}^i_t(\mathbf{y}_{t+1}, \mathbf{K}_{t+1}, \mathbf{L}_{t+1}, \mathbf{x}_{t+1}, \mathbf{I}_{t+1}; \mathbf{g_x}, \mathbf{g_I})]\end{matrix}\right\} \qquad \textbf{(2)}$$

This indicator provides the arithmetic average of productivity change measured by the technology at time *t*+1 (i.e., the first two terms in equation 2) and the productivity change measured by the technology at time *t* (i.e., the last two terms in equation 2).

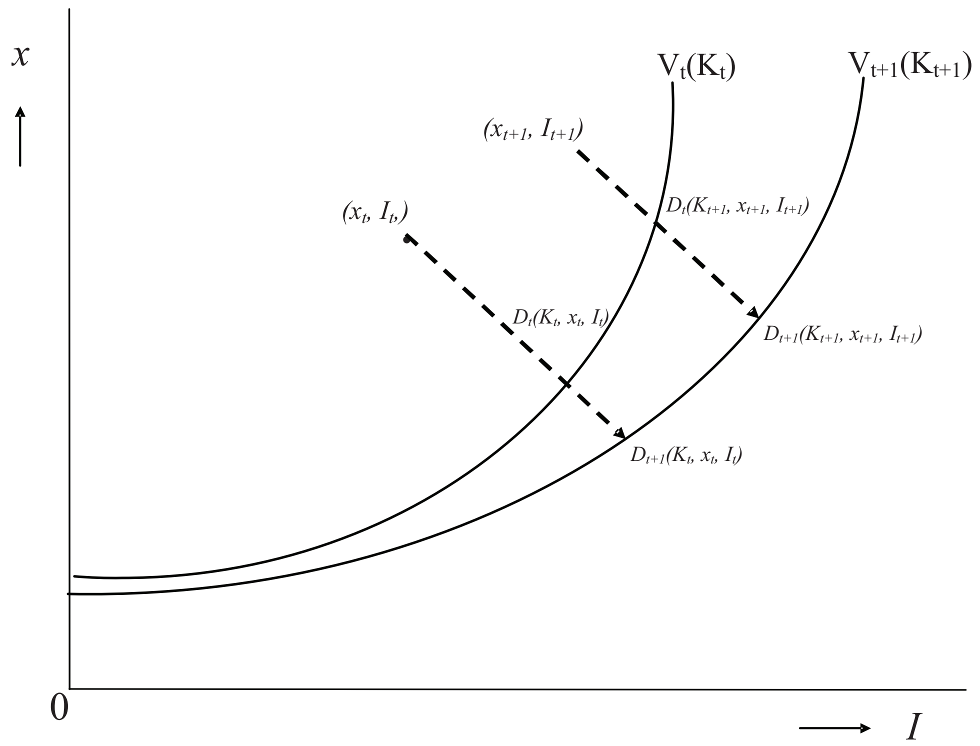

Fig.1. Luenberger indicator of dynamic productivity growth.

The Luenberger indicator of dynamic productivity growth is illustrated graphically in Figure 1. The quantities of inputs and investments at time t and time t+1 are denoted as $(\mathbf{x}_t, \mathbf{I}_t)$ and $(\mathbf{x}_{t+1}, \mathbf{I}_{t+1})$, respectively. The dynamic directional distance function measures the distance to the isoquants at time t and time t+1, which is denoted as $\vec{D}^i_{t+1}(\mathbf{y}_t, \mathbf{K}_t, \mathbf{L}_t, \mathbf{x}_t, \mathbf{I}_t; \mathbf{g_x}, \mathbf{g_I})$. The Luenberger indicator of dynamic productivity growth can be decomposed into the contributions of technical inefficiency change (ΔTEI) and technical change (ΔT):

$$L(\cdot) = \Delta T + \Delta TEI \tag{3}$$

The decomposition of productivity growth is obtained from (2) by adding and subtracting the term $\left[\vec{D}^i_{t+1}(\mathbf{y}_{t+1}, \mathbf{K}_{t+1}, \mathbf{L}_{t+1}, \mathbf{x}_{t+1}, \mathbf{I}_{t+1}; \mathbf{g_x}, \mathbf{g_I}) - \vec{D}^i_t(\mathbf{y}_t, \mathbf{K}_t, \mathbf{L}_t, \mathbf{x}_t, \mathbf{I}_t; \mathbf{g_x}, \mathbf{g_I})\right]$. Technical change is computed as the arithmetic average of the difference between the technology (represented by the frontier) at time t and time t+1, evaluated using quantities at time t (first two terms in (4)) and time t+1 (last two terms in (4)):

$$\Delta T = \frac{1}{2}\left\{\begin{matrix} [\vec{D}^i_{t+1}(\mathbf{y}_t, \mathbf{K}_t, \mathbf{L}_t, \mathbf{x}_t, \mathbf{I}_t; \mathbf{g_x}, \mathbf{g_I}) - \vec{D}^i_t(\mathbf{y}_t, \mathbf{K}_t, \mathbf{L}_t, \mathbf{x}_t, \mathbf{I}_t; \mathbf{g_x}, \mathbf{g_I})] \\ +[\vec{D}^i_{t+1}(\mathbf{y}_{t+1}, \mathbf{K}_{t+1}, \mathbf{L}_{t+1}, \mathbf{x}_{t+1}, \mathbf{I}_{t+1}; \mathbf{g_x}, \mathbf{g_I}) - \vec{D}^i_t(\mathbf{y}_{t+1}, \mathbf{K}_{t+1}, \mathbf{L}_{t+1}, \mathbf{x}_{t+1}, \mathbf{I}_{t+1}; \mathbf{g_x}, \mathbf{g_I})] \end{matrix}\right\} \tag{4}$$

Technical change can be seen in Figure 1 as the average distance between the two isoquants. This involves evaluating the isoquants using quantities at time t, $\vec{D}^i_{t+1}(\mathbf{y}_t, \mathbf{K}_t, \mathbf{L}_t, \mathbf{x}_t, \mathbf{I}_t; \mathbf{g}_x, \mathbf{g}_I) - \vec{D}^i_t(\mathbf{y}_t, \mathbf{K}_t, \mathbf{L}_t, \mathbf{x}_t, \mathbf{I}_t; \mathbf{g_x}, \mathbf{g_I})$ and quantities at time t+1,

$\vec{D}^{i}_{t+1}(\mathbf{y}_{t+1},\mathbf{K}_{t+1},\mathbf{L}_{t+1},\mathbf{x}_{t+1},\mathbf{I}_{t+1};\mathbf{g}_{\mathbf{x}},\mathbf{g}_{\mathbf{I}}) - \vec{D}^{i}_{t}(\mathbf{y}_{t+1},\mathbf{K}_{t+1},\mathbf{L}_{t+1},\mathbf{x}_{t+1},\mathbf{I}_{t+1};\mathbf{g}_{\mathbf{x}},\mathbf{g}_{\mathbf{I}})$. Dynamic technical inefficiency change is the difference between the value of the dynamic directional distance function at time *t* and time *t*+1:

$$\Delta TEI = \vec{D}^{i}_{t}(\mathbf{y}_{t},\mathbf{K}_{t},\mathbf{L}_{t},\mathbf{x}_{t},\mathbf{I}_{t};\mathbf{g}_{\mathbf{x}},\mathbf{g}_{\mathbf{I}}) - \vec{D}^{i}_{t+1}(\mathbf{y}_{t+1},\mathbf{K}_{t+1},\mathbf{L}_{t+1},\mathbf{x}_{t+1},\mathbf{I}_{t+1};\mathbf{g}_{\mathbf{x}},\mathbf{g}_{\mathbf{I}}) \qquad \mathbf{(5)}$$

Technical inefficiency change is easily seen from Figure 1 as the difference between the distance functions evaluated using quantities and technologies in period *t* and period *t+1*.
We can decompose the Luenberger measure further to allow for scale efficiency change (ΔSEI). With the Luenberger measure historically being developed in the context of constant returns to scale, this further decomposition relaxes the technology assumptions of constant returns to scale to permit variable returns to scale.
From a primal perspective, the technical inefficiency change component in (5) can be decomposed as follows**:**

$$\begin{aligned}
\Delta PEI &= \vec{D}^{i}_{t}(\mathbf{x}_{t},\mathbf{I}_{t},\mathbf{k}_{t}\mathbf{y}_{t};\mathbf{g}_{x},\mathbf{g}_{I} \mid VRS) - \vec{D}^{i}_{t+1}(\mathbf{x}_{t+1},\mathbf{I}_{t+1},\mathbf{k}_{t+1},\mathbf{y}_{t+1};\mathbf{g}_{x},\mathbf{g}_{I} \mid VRS) \\
\Delta SEI &= \vec{D}^{i}_{t}(\mathbf{x}_{t},\mathbf{I}_{t},\mathbf{k}_{t}\mathbf{y}_{t};\mathbf{g}_{x},\mathbf{g}_{I} \mid CRS) - \vec{D}^{i}_{t}(\mathbf{x}_{t},\mathbf{I}_{t},\mathbf{k}_{t}\mathbf{y}_{t};\mathbf{g}_{x},\mathbf{g}_{I} \mid VRS) \\
&- \left[\vec{D}^{i}_{t+1}(\mathbf{x}_{t+1},\mathbf{I}_{t+1},\mathbf{k}_{t+1},\mathbf{y}_{t+1};\mathbf{g}_{x},\mathbf{g}_{I} \mid CRS) - \vec{D}^{i}_{t+1}(\mathbf{x}_{t+1},\mathbf{I}_{t+1},\mathbf{k}_{t+1},\mathbf{y}_{t+1};\mathbf{g}_{x},\mathbf{g}_{I} \mid VRS)\right]
\end{aligned} \qquad \mathbf{(6)}$$

Where ΔPEI is technical inefficiency change under variable returns to scale and ΔSEI is scale inefficiency change.

3 Data

The data used in this study come from the SABI database, managed by Bureau van Dijk, which contains the financial accounts of Spanish companies. The study sample includes the firms belonging to the category of firms in processing and preserving of meat and production of meat products (NACE Rev. 2 code 101). This study focuses on firms of all size categories: micro, small, medium-sized and large. After filtering out companies with missing information and after removing the outliers[2], the final data set consists of between 928 and 1527 firms that operated in Spain at least two consecutive years during the period from 2000 to 2010. The dataset is unbalanced and it sums up to 13103 observations (in total 26206 observations if we consider that each observation is repeated two times in two consecutive years).

One output and three inputs (material costs, labour costs and fixed assets) are distinguished. Output was defined as total sales plus the change in the value of the stock and was deflated using the industrial price index for output in meat processing industry. Material costs and labour costs were directly taken from the SABI database and were deflated using the industrial price index for consumer non-durables and labour cost index in manufacturing, respectively. Fixed assets are measured as the beginning value of fixed assets from the balance sheet (i.e. the end value of the previous year) and are deflated using the industrial price index for capital goods. All prices used to deflate output and inputs are obtained from the Spanish Statistical Office (various years). Gross investments in fixed assets in year *t* are computed as the beginning value of fixed assets in year *t+1* minus the value of fixed assets in year *t* plus the value of depreciation in year *t*. Table 1 provides the descriptive statistics of the data used in this study, for the whole period 2000/2001-2009/2010.

[2] Outliers were determined using ratios of output to input. An observation was defined as an outlier if the ratio of output over any of the three inputs was outside the interval of the median plus and minus two standard deviations.

Table 1. Descriptive statistics of input-output data, 2000/2001-2009/2010.

Variable	Mean	Std. dev.	Min	Max
Fixed assets	2066.131	15233.260	0.134	896472.800
Employee cost	671.038	3465.618	1.420	87188.160
Material cost	5064.267	23834.010	0.333	737417.900
Investments	375.900	4609.822	-41366.180	400870.600
Production	6465.920	30897.880	0.490	859756.100

Note: the values of variables are presented in thousands of euros, constant prices from 1999.

The data in Table 1 shows that the average meat processing company in our sample is relatively small in terms of the EU size classification, with a mean turnover of approximately 6 million euros. On the other hand, the standard deviations relative to their respective means are relatively high showing that the firms in our sample differ considerably in size.

4 Results and Discussion

Table 2 summarizes the arithmetic means of dynamic Luenberger productivity indicator and its decomposition for the pairs of consecutive years. It should be noted that the mixed directional distance functions used to compute dynamic Luenberger indicator might not have a bounded solution. Literature mentions two possible solutions to this problem in the context of static Luenberger, which can be adapted to the dynamic context: (1) to omit the infeasible observations in the computation of averages or (2) to assign to the indices the value equal to no change in indicator (in our case the value equal to 0), which is the strategy we have followed. In general, Briec and Kerstens (2009) recommend reporting the infeasibilities that occurred in the empirical application as shown in Table 2. Out of 13103 observations, only 204 observations are found to be infeasible (that is 1.6% of the entire sample).

Table 2. Evolution of dynamic Luenberger productivity change.

Period	**Number of firms**	**Luenberger productivity change**	**Technical change**	**Technical inefficiency change**	**Scale inefficiency change**
2000/2001	1000	-0.018	0.043	-0.083	0.023
2001/2002	1157	0.009	0.083	-0.006	-0.069
2002/2003	1340	-0.003	-0.099	0.093	0.002
2003/2004	1418	-0.001	0.014	-0.008	-0.008
2004/2005	1465	-0.001	0.021	0.009	-0.031
2005/2006	1499	-0.003	-0.070	0.012	0.054
2006/2007	1527	-0.002	-0.078	0.040	0.037
2007/2008	1412	-0.012	-0.131	0.090	0.029
2008/2009	1357	-0.003	0.000	0.036	-0.039
2009/2010	928	0.004	-0.057	0.002	0.059
Arithmetic mean 2000/2001-2009/2010	**13103**	-0.003	-0.031	0.022	0.005

Note: Out of 13103 observations, 204 (1.6%) were found to be infeasible.

The results show consistently a decline in dynamic productivity in Spanish meat processing industry. However, there is a productivity growth from 2001 to 2002 and an upward trend of productivity growth from 2008 to 2010. From 2007 to 2008 the dynamic productivity decline has a mean value of -0.012, from 2008 to 2009 of only -0.003, but from 2009 to 2010 there is a productivity growth with mean value of 0.004. From the three components of dynamic Luenberger productivity change we can observe that the negative growth of productivity is mainly due to technological regress observed in most years. Especially the period from 2005/2006 to 2009/2010 is characterized by a consistent technological regress (with an exception of 2008/2009 when technical stagnation is observed). This finding might be interpreted that in these periods the technology eliminates some productive options that were previously available for the firms in the Spanish meat processing industry. Under the regulatory environment of EU with regard to food safety, the firms are forced to adapt to new standards by undertaking additional investments and absorbing additional costs without a productive impact. As a result some production practices could not be undertaken anymore after the new regulation and consequently the situations of technical regress are produced. In the period from 2006 to 2007 and from 2007 to 2008, especially high technical regress is observed. In these years, the increase in animal feed costs occurred and also the financial crisis added its negative effects on the Spanish meat processing sector. These two factors may also explain the highest decline occurring from 2007 to 2008. On the other hand, the period under investigation is characterized by inefficiency decline, with exception of 2000/2001, 2001/2002 and 2003/2004. The decrease in technical inefficiency might reflect the reaction of the firms in the meat processing industry to the new regulations. Therefore, summarizing, although the best practice frontier moved back, the firms in the sample moved towards the frontier.

Overall, Table 2 indicates a decline in productivity over the 2000-2010 time-period (the Luenberger productivity indicator has a mean value of -0.003), which can be attributed to technological regress (the technical change indicator with a mean value equal to -0.031), not being fully compensated by a positive technical inefficiency change (mean value of 0.022) and a positive scale inefficiency change (mean value equal to 0.005).

Figure 2 shows the evolution of dynamic Luenberger productivity growth and its decomposition into technical change, technical inefficiency and scale inefficiency change.

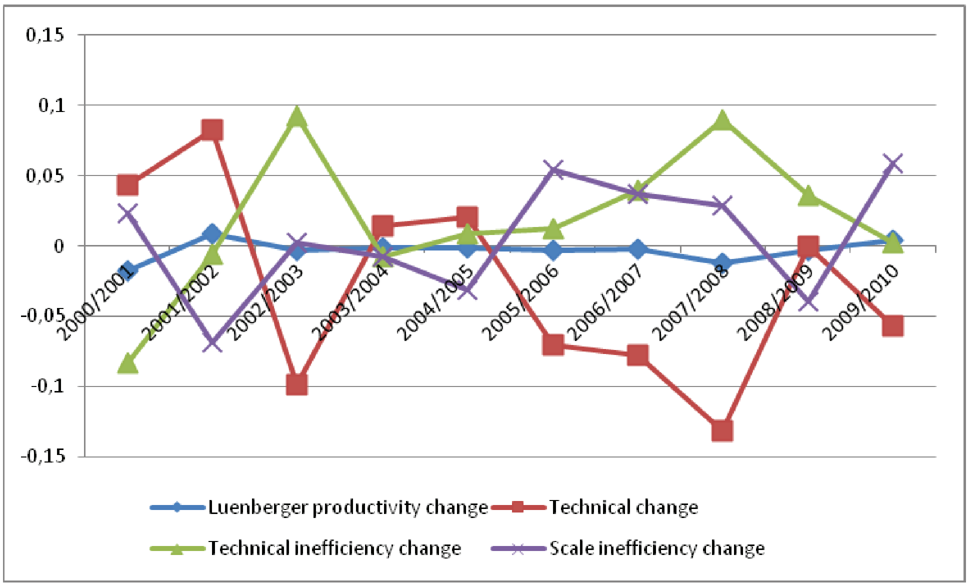

Fig. 2. Evolution of Luenberger and decomposition.

Figure indicates that dynamic Luenberger productivity indicator varies only slightly between pairs of years. The biggest changes are associated with technical inefficiency and technical inefficiency change. Efficiency growth clearly dominates the analyzed period with the highest increase between 2002 and 2003. On the other hand, the technical regress is observed in most periods with highest decline in 2007/2008.

Dynamic productivity change and its decomposition by firm size is analyzed next and reported in Table 3. The comparison is made across four firms' size intervals: micro, small, medium-sized and large. Following EU definition, the category of micro/small/medium firms in made up of enterprises which employ less than 10/50/250 employees and which have an annual turnover not exceeding 2/10/50 million euros, respectively. The firms with more than 250 employees and an annual turnover exceeding 50 million euros are defined as large. Differences in the components of Luenberger productivity growth between these groups are assessed using the test proposed by Simar and Zelenyuk (2006)[3].

[3] Simar and Zelenyuk (2006) adapt the nonparametric test of the equality of two densities developed by Li (1996). In particular, they propose two algorithms and among them they found the Algorithm 2 to be more robust, hence we apply it here. In essence, the algorithm is based on computation and bootstrapping the Li statistic using DEA estimates, where values equal to unity are smoothed by adding a small noise. As productivity change and its decomposition indices are not truncated, we omit the step of smoothing in the algorithm. The implementation of this algorithm is done in R using 1000 bootstrap replications.

Table 3. Dynamic Luenberger productivity growth by firms' sizes (2000/2001-2009/2010).

Size class	Number of firms	Luenberger productivity change	Technical change	Technical inefficiency change	Scale inefficiency change
Large	378	0.005[a]	-0.026[a,b]	-0.003[a]	0.033[a]
Medium	1499	-0.003[b]	-0.030[a]	0.000[b]	0.026[b]
Small	5932	-0.003[b]	-0.031[c,b]	0.020[c]	0.009[c]
Micro	5294	-0.004[c]	-0.031[c]	0.034[d]	-0.006[d]

[a,b,c,d]) *difference between a,b,c and d significant at 5% level.*

The results reveal that during 2000/2001-2009/2010 large firms experience productivity growth, while medium, small and micro firms experienced a productivity decline. Productivity growth decreased more for micro rather than for small and medium-sized firms. With regard to technical change, although all groups of firms experience technical regress, the difference between size classes is not always significant. Finally, both technical inefficiency change and scale inefficiency change differ significantly across size groups. Technical inefficiency change decreases with size: micro firms experience the highest contribution of technical inefficiency change, while large companies had a negative contribution of technical inefficiency change. The opposite pattern is observed with respect to the change in scale inefficiency as micro firms undergo scale inefficiency increase and large firms have the highest scale inefficiency decline. We also note that technical regress observed in the entire sample is driven mainly by medium, small and micro firms, while technical efficiency growth in the sample is due to micro and small firms.

5 Conclusion

This paper extends the dynamic Luenberger productivity growth indicator to decompose it into the contributions of technical efficiency change, scale efficiency change and technical change. The empirical application focuses on panel data of Spanish meat processing firms over the period 2000-2010. The results show that dynamic Lueberger productivity growth was overall small but negative in the period 2000-2010. Technical change made a large (on average 3%) negative contribution to TFP growth, particularly in the years after the beginning of the financial crisis. Technical inefficiency reduced on average in the period under investigation, to make 2% positive contribution to TFP growth. The analysis of results for firms in different size classes showed that productivity growth has been more favorable on large firms than small firms. Large firms benefitted from a positive contribution of scale inefficiency change yielding an overall productivity improvement of 0.5% over analyzed period; medium, small and micro firms all had productivity decreases ranging from -0.3% to -0.4% on average over analyzed period.

The results suggest that the introduction of hygiene regulations in the slaughter industry have caused a negative technical change in the period under investigation. Hence, policy makers should be aware of the negative impacts on competitiveness of on-going regulation. The results also suggest that the financial crisis had a large negative impact on the productivity of the meat processing sector.

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Technological change in the Czech food processing industry: What did we experience in the last decade?

Lukas Cechura

Annotation: The paper examines the contribution of technological change to changes in technical efficiency and TFP (Total Factor Productivity). The results show that the technological change did not contribute significantly to the development of efficiency in all analyzed sector. However, the distribution of technical change suggests that the gap between the best and worst food processing companies increased within the analyzed period. On the other hand, the technological change was an important factor determining the TFP increase in all sectors.

Key terms: Technological change, Technical efficiency, TFP, Czech food processing industry

1 Introduction

What did we experience in the last decade? The Czech food processing industry went through significant institutional and economic changes. Accession to the European Union and the accompanying implementation of CAP principles called for the modernisation and enlargement of some processing capacities. Food processing companies had to modernize their production due to the acquisition of acquis communautaire in advance of the EU enlargement. The new standards forced financially poor companies to drop out of the market (Putićová, Mezera, 2008). Since the EU enlargement, processing companies have been operating on the common market. Tariffs and other barriers were removed either before or upon the entrance of the Czech Republic into the EU, which resulted in a significant increase in both the export, and especially the import, of food products (Šafaříková, Pohlová, 2008; Svatoš, Smutka, 2009). Export and import quantities became a significant determinant of production. The increasing trend in imports exceeded that of exports in the slaughtering, fruit and vegetable processing, and milling industries, and this resulted in a drop in production in these sectors. The figures and results of previous studies (Čechura and Hockmann, 2010 and 2011) suggest that some companies have problems with a competitive environment, and instead of taking advantage of opportunities in the common market, they are falling behind. Moreover, the high intrasectoral heterogeneity suggests that further adjustment processes will occur, and some Czech food processing industries will reduce their size (Čechura, Hockmann, 2011).

Since technological change is an important factor in a firm's competitiveness, we examine its contribution to changes in TFP (Total Factor Productivity) as well as its determinants. In particular, the following questions will be explored. The first question relates to technical change and technical efficiency. The aim is to identify which food processing industries are following a path of sustainable development, characterized by the adoption of innovation and reduced waste of resources due to inefficient input use, and to identify the factors which determine developments in the analyzed industries. The second question concerns the contribution of technological change to productivity development. The aim is to assess the extent to which technological change contributed to changes in TFP. The last question concerns sector-specific development. The aim is to assess the inter- and intra-sectoral specifics of technology, efficiency and TFP development.

2 Data and Methodology

The questions will be explored by estimating a joint stochastic frontier production function model for the Czech food processing industry. The estimation of a stochastic frontier production function model for the Czech food processing industry follows Čechura (2009). Čechura (2009) showed that the presence of significant heterogeneity in firms overestimates technical inefficiency. Considering both the theoretical criteria of the production function and significant heterogeneity of firms, the author suggests using the Fixed Management model. This paper will use the same data set, and therefore the Fixed Management model is considered to be a proper choice.

The analysis is based on the assumption that production possibilities can be approximated by a frontier production function which has the translog form. Following Álvarez et al. (2003 and 2004), the Fixed Management model in a translog form is specified as follows:

$$\ln TE_{it} = \ln f\left(t, \mathbf{x}_{it}, m_i; \boldsymbol{\beta}\right) - \ln f\left(t, \mathbf{x}_{it}, m_i^*; \boldsymbol{\beta}\right) \leq 0 \quad , \quad \ln TE_{it} = -u_{it} \quad , \tag{1}$$

and

$$\begin{aligned} \ln y_{it} &= \ln y_{it}^* + v_{it} - u_{it} = \ln \alpha_0 + \ln f\left(t, \mathbf{x}_{it}, m_i^*; \boldsymbol{\beta}\right) + v_{it} - u_{it} = \alpha_0 + \beta_m m_i^* + \frac{1}{2}\beta_{mm} m_i^{*2} + \\ &+ \left(\beta_t + \beta_{tm} m_i^*\right)t + \frac{1}{2}\beta_{tt} t^2 + \left(\beta_x + \beta_{xt} t + \beta_{xm} m_i^*\right)' \ln \mathbf{x}_{it} + \frac{1}{2} \ln \mathbf{x}_{it}' \mathbf{B}_{\mathbf{xx}} \ln \mathbf{x}_{it} + v_{it} - u_{it} \end{aligned} \tag{2}$$

where $\mathbf{x}_{it}$ is a vector of inputs containing $K=3$ production factors - Labour (A_{it}), Capital (C_{it}) and Material (M_{it}). Indices i, where $i = 1, 2, \ldots, N$, and t, where $t \in \Im(i)$, refer to a particular food processing company and time, respectively, and $\Im(i)$ represents a subset of years T_i from the whole set of years T ($1, 2, \ldots, T$), for which the observations of the i-th food processing company are in the data set. α is an intercept (productivity parameter). $\boldsymbol{\beta}$ are parameters to be estimated that determine the production function f. Technical efficiency, $TE_{i(t)}$, with $0 \leq TE_{i(t)} \leq 1$, captures deviations from the maximum achievable output. v_{it} captures statistical noise in the data and $u_{i(t)}$ is the inefficiency term. The random error (statistical noise) v_{it} and technical inefficiency term $u_{i(t)}$ of the stochastic frontier production function model are assumed to be $v_{it} \sim iid\ N(0, \sigma_v^2)$, $u_{i(t)} \sim iid\ N^+(0, \sigma_u^2)$ and to be distributed independently of each other, and of the regressors (for further references see Kumbhakar and Lovell, 2000). $m_i^* \sim \bullet(0,1)$ represents unobservable fixed management. The symbol $\bullet$ expresses that m_i^* could possess any distribution with zero mean and unit variance (Hockmann and Pieniadz, 2008). The difference between real (m_i) and optimal (m_i^*) management determines the level of technical efficiency /see relation (1)/. Technical efficiency is defined by:

$$\ln TE_{it} = \gamma_0 + \gamma_t t + \boldsymbol{\gamma}_{\mathbf{x}}' \ln \mathbf{x}_{it} \quad , \tag{3}$$

where

$$\gamma_0 = \beta_m (m_i - m_i^*) + \frac{1}{2}\beta_{mm}\left(m_i^2 - m_i^{*2}\right)$$

$$\gamma_t = \beta_{tm}\left(m_i - m_i^*\right)$$

$$\boldsymbol{\gamma}_{\mathbf{x}} = \boldsymbol{\beta}_{xm}\left(m_i - m_i^*\right)$$

The technical efficiency consists of three components:

(i) time-invariant, firm-specific effect – management – γ_0,

(ii) interaction of m^* with time – technological change – γ_t,

(iii) interaction of m^* with the inputs quantity and quality – scale effect – $\boldsymbol{\gamma_x}$.

Álvarez et al. (2004) showed that u_{it} can be estimated, according to Jondrow et al. (1982), as (4) with simulated m_i^* according to relation (5).

$$E\left[u_{it}\middle|\varepsilon_{it},m_i^*\right]=\frac{\sigma\lambda}{\left(1+\lambda^2\right)}\left[\frac{\phi\left(-\left(\varepsilon_{it}\middle|m_i^*\right)\lambda/\sigma\right)}{\Phi\left(-\left(\varepsilon_{it}\middle|m_i^*\right)\lambda/\sigma\right)}-\frac{\left(\varepsilon_{it}\middle|m_i^*\right)\lambda}{\sigma}\right], \qquad (4)$$

where $\lambda=\dfrac{\sigma_u}{\sigma_v}$, $\sigma^2=\sigma_u^2+\sigma_v^2$ and $\varepsilon_{it}=v_{it}-u_{it}$.

$$\hat{E}\left[m_i^*\middle|\mathbf{y}_i,\mathbf{X}_i,\boldsymbol{\delta}\right]=\frac{\frac{1}{R}\sum_{r=1}^{R}m_{i,r}^*\hat{f}\left(\mathbf{y}_i\middle|t,m_{i,r}^*,\mathbf{X}_i,\boldsymbol{\delta}\right)}{\frac{1}{R}\sum_{r=1}^{R}\hat{f}\left(\mathbf{y}_i\middle|t,m_i^*,\mathbf{X}_i,\boldsymbol{\delta}\right)} \qquad (5)$$

The Fixed Management model is fitted with a maximum simulated likelihood using NLOGIT version 4.0 - LIMDEP version 9.0 (Green, 2007). In the model, all variables are divided by their geometric mean. That is, fitted coefficients represent the production elasticities evaluated on the geometric mean of a particular variable.

Total factor productivity is calculated in the form of the Törnqvist-Theil index (TTI) (see, e.g., Čechura, Hockmann, 2010). The Törnqvist-Theil index exactly determines the changes in production resulting from input adjustments having a production function in the translog form (for the proof see Diewert, 1976). Furthermore, Caves et al. (1982) showed the TTI extension for multilateral consistent comparisons.

Changes in TFP can be expressed (Čechura, Hockmann, 2010) as either a ratio (on the mean) of the output and input index (for CRS), or a multiplication of TFP components, i.e., scale effect (SE), technical efficiency effect (TE), technological change effect (TCH) and management effect (MAN).

$$\ln TFP_{it}=\ln\psi_{it}-\ln\iota_{it}^{CRS}=\underset{SE}{\ln\iota_{it}}+\underset{TE}{\ln\upsilon_{it}}+\underset{TCH}{\ln\tau_{it}}+\underset{MAN}{\ln\mu_{it}}, \qquad (6)$$

where[1]

$$\ln\psi_{it}=\ln y_{it}-\overline{\ln y_{it}}, \qquad (7)$$

[1] A bar over a variable specifies the arithmetic mean over all observations. If no aggregation is needed, i.e., only the development of one variable is depicted, the index simplifies into the deviation from the mean of the variables.

$$\ln \iota_{it}^{CRS} = \frac{1}{2}\sum_{j=1}^{K}\left[\left(\frac{\varepsilon_{it,j_0}}{\sum_{i=1}^{K}\varepsilon_{it,j_0}} + \frac{\bar{\varepsilon}_j}{\sum_{i=1}^{K}\varepsilon_{j_0}}\right)\left(\ln x_{it,j} - \overline{\ln x_j}\right) + \frac{\bar{\varepsilon}_j}{\sum_{i=1}^{K}\varepsilon_{j_0}}\overline{\ln x_j} - \overline{\frac{\varepsilon_{it,j_0}}{\sum_{i=1}^{K}\varepsilon_{it,j_0}}\ln x_{it,j}}\right], \tag{8}$$

$$\ln \iota_{it}^{VRS} = \frac{1}{2}\sum_{j=1}^{K}\left[\left(\varepsilon_{it,j_0} + \bar{\varepsilon}_j\right)\left(\ln x_{it,j} - \overline{\ln x_j}\right) + \bar{\varepsilon}_j\,\overline{\ln x_j} - \overline{\varepsilon_{it,j_0}\ln x_{it,j}}\right],$$

$$\text{with} \quad \varepsilon_{it,j_0} = \frac{\partial \ln f\left(t, x_{it,j}; \boldsymbol{\beta}\right)}{\partial \ln \mathbf{x}_{it,j}} \tag{9}$$

$$\ln \iota_{it} = \ln \iota_{it}^{VRS} - \ln \iota_{it}^{CRS} \quad , \tag{10}$$

$$\ln \upsilon_{it} = \ln TE_{it} - \overline{\ln TE_{it}} \ , \tag{11}$$

$$\ln \tau_{it} = \frac{1}{2}\left[\left(\varepsilon_t + \bar{\varepsilon}_t\right)\left(t - \bar{t}\right) + \bar{\varepsilon}_t\bar{t} - \overline{\varepsilon_t t}\right], \quad \textit{with} \quad \varepsilon_t = \frac{\partial \ln f\left(x_{it,j}, t, m_i\right)}{\partial t} \ , \tag{12}$$

$$\ln \mu_{it} = \frac{1}{2}\left[\left(\varepsilon_{m_0} + \bar{\varepsilon}_m\right)\left(m_i - \bar{m}_i\right) + \bar{\varepsilon}_m\bar{m}_i - \overline{\varepsilon_m m_i}\right], \quad \textit{with} \quad \varepsilon_m = \frac{\partial \ln f\left(x_{it,j}, t, m_i\right)}{\partial m_i} \ . \tag{13}$$

Data set

The panel data set is drawn from the database of the Creditinfo Monitor of Companies, collected by Creditinfo Czech Republic, s.r.o. The database contains all registered companies and organisations in the Czech Republic. The analysis uses information from the final accounts of companies whose main activity is food processing in the period from 2000 till 2007. After the cleaning process (removing outliers and negative values of the variable of interest), the unbalanced panel data set contains 1,375 food processing companies with 6,473 observations, covering the period from 1998 to 2007.

The following variables, as defined above, are used in the analysis: Output, Labour, Capital and Material. Output is represented by the total sales of goods, products and services of the food processing company. Output was deflated by the index of food processing prices (2005=100). The Labour input is total personnel costs per company, divided by the average annual regional wage in the food processing industry (region = NUTS 3). Capital is represented by the book value of tangible assets and is deflated by the index of processing (industry) prices (2005=100). Finally, the Material variable is used in the form of total costs of material and energy consumption per company, and is deflated by the index of processing prices (2005=100).

3 Results and Discussion

3.1 Parameter estimates

Table 1: Parameter estimates

Fixed Management model							
Variable	Coefficient	Std. Error	P[│Z│ >z]	Variable	Coefficient	Std. Error	P[│Z│ >z]
Means for random parameters				TT	0.00887	0.00102	0.0000
Constant	-0.05543	0.00349	0.0000	AT	0.01360	0.00136	0.0000
A	0.28800	0.00343	0.0000	CT	-0.00498	0.00079	0.0000
C	0.04557	0.00217	0.0000	MT	-0.00130	0.00094	0.1684
M	0.66928	0.00236	0.0000	AA	0.15032	0.00475	0.0000
T	0.02208	0.00108	0.0000	CC	0.02304	0.00135	0.0000
Coefficient on unobservable fixed management				MM	0.16616	0.00214	0.0000
Beta_m	0.13439	0.0021	0.0000	AC	-0.00171	0.00187	0.3624
A	0.06573	0.00257	0.0000	AM	-0.13543	0.00314	0.0000
C	0.05000	0.00142	0.0000	CM	-0.01886	0.00113	0.0000
M	-0.18721	0.00205	0.0000				
T	0.00054	0.00110	0.6204				
Beta_mm	-0.18987	0.00283	0.0000				
Log likelihood function	845.0026			Lambda	7.85261	0.44175	0.0000
No. of parameters	23			Sigma	0.25356	0.00108	0.0000
Sigma v	0.03203			Sigma u	0.25152		

Source: own calculations

Table 1 provides the results of parameter estimates. The estimated production elasticities imply theoretical consistency of the estimates. That is, the elasticities are positive (monotonicity), and diminishing marginal productivity (quasi-concavity) for each input was estimated ($\beta_{rr} + \beta_r^2 - \beta_r < 0$, for *r = A, C* and *M).*

Production elasticities were also found to be robust under different model specifications (see Čechura, 2009). Material has the highest impact on production, with production elasticities (β_M) 0.66928, which is also consistent with empirical observations. Labour elasticity (β_A) is 0.2880, which corresponds to the ratio of personnel costs to total output. The production elasticity of Capital is 0.04557, which is a lower intensity than we would expect. This could be caused by two factors working together. First, the accounting data does not contain information about leasing, which is an important source of capital in the Czech Republic. Second, a food processing company can face capital market imperfections.

Technical change has a strong positive impact on production, and it accelerates over time. On average, the production possibilities increased by 2.2% per year. The hypothesis that the parameters are time-invariant (H_0: $\beta_T=\beta_{TT}=\beta_{AT}=\beta_{LT}=\beta_{CT}=\beta_{MT}=0$) [2], as well as the null hypothesis about the Hicks neutral technological change (H_0: $\beta_{AT}=\beta_{LT}=\beta_{CT}=\beta_{MT}=0$)[3], was

[2] LR test: FM model (LR = 291.2976); $\chi^2_{1-0.05}(5) = 11.070$.

[3] LR test: FM model (LR = 86.5034); $\chi^2_{1-0.05}(3) = 7.815$.

rejected at a 5% level of significance. The technological progress was characterized as Labour-using, and Capital- and Material-saving.

The parameter lambda is significant at a 5% significance level, and its value implies that variation in the u_{it} is more pronounced than variation in the random component v_{it}. This suggests that efficiency differences among firms are an important reason for variations in production.

The monotonicity requirements on management imply that the first derivatives of the production function with respect to management, $\frac{\partial y_{it}}{\partial m_i} > 0$, are positive for all companies. Verification of this requirement using the level of actual management, m_i, calculated from relation (3), shows consistency with theoretical requirements, i.e., an increase in management implies an increase in production for all companies.

Coefficients of unobservable fixed management (β_m ,β_{mm} ,β_{Am} ,β_{Cm} ,β_{Mm}) are statistically different from zero, even at a 1% significance level, which is evidence of correctly choosing the Random Parameter model as opposed to the conventional stochastic frontier approach. The insignificance of Technological Change implies that Technological Change did not contribute to the change in management productivity in the analyzed period (β_{Tm} = 0). Moreover, the positive sign on management $\beta_m > 0$ and negative on squared management $\beta_{mm} < 0$ implies that management determines production positively (see monotonicity) but with decreasing effect. Finally, an increase in management causes an increase in production elasticity and the marginal productivity of Material ($\beta_{Mm} < 0$), and a decrease in production elasticity and the marginal productivity of Labour and Capital ($\beta_{Am} > 0$, $\beta_{Cm} > 0$).

In terms of technical efficiency (Álvarez et al., 2004), the change in technical efficiency resulting from a change in management and inputs is given by:

$$\frac{\partial \ln TE_{it}}{\partial m_i} = \beta_m + \beta_{mm} m_i + \beta_{tm}\mathbf{t} + \boldsymbol{\beta}_{xm}\mathbf{lnx}_{it} \quad ,$$

$$\frac{\partial \ln TE_{it}}{\partial \mathbf{lnx}_{it}} = \boldsymbol{\beta}_{xm}\left(m_i - m_i^*\right) \quad \text{and} \quad \frac{\partial \ln TE_{it}}{\partial t} = \beta_{tm}\left(m_i - m_i^*\right) . \qquad (13)$$

Relation (13), together with $\beta_m > 0$ and $\beta_{mm} < 0$, implies that an increase in m_i has a positive but decreasing effect on technical efficiency. An increase in Material implies a higher technical efficiency for a given level of management. Labour and Capital have an opposite effect.

Table 2 provides production elasticities with optimal and actual management calculated on the mean of the sample. The production elasticities with optimal management (m_i*), i.e., on the production frontier, are very close to the means of the random parameters. This is especially due to the fact that coefficients of unobservable fixed management (β_{rm}, for $r = A, C, M$) are very low compared to the means of random parameters. Since the mean of actual management is different from the mean of optimal management, the production elasticities calculated with actual management differ significantly compared to means of random parameters.

Table 2: Production elasticities with optimal and actual management

	Production elasticities with m_i*	Production elasticities with m_i
A	0.28889	0.23230
C	0.04343	0.00038
M	0.67157	0.83276
RTS (Returns to Scale)	1.00388	1.06544

Source: own calculations

The sum of production elasticities with optimal management is equal to 1.00388, and with actual management to 1.06544. That is, for the average company in the full sample, there is no indication of economies of scale for optimal management. However, if actual management is considered, there is an indication of increasing returns to scale.

Table 3 presents information about the production elasticities in selected branches of the food processing industry. The results suggest that there is no indication of economies of scale in the selected branches on the sample mean, except for the beverages industry. However, Table 4 shows that the differences among companies are large in all branches.

Table 3: Production elasticities (with m_i*) and Returns to Scale[4]

	A	C	M	RTS	Cases
Slaughtering	0.21255	0.03667	0.76545	1.01467	465
Dairy	0.20685	0.04891	0.75093	1.00668	252
Milling	0.21611	0.03286	0.75948	1.00846	134
Feedstuffs	0.22691	0.04495	0.73785	1.00970	222
Beverages	0.35725	0.07027	0.54493	0.97244	354

Source: own calculations

Table 4: Descriptive statistics of Returns to Scale

	Mean	Std.Dev.	Minimum	Maximum	Cases
Food processing industry	1.00388	0.06225	0.68607	1.20800	2298
Slaughtering	1.01467	0.04014	0.77930	1.13119	465
Dairy	1.00669	0.06043	0.78168	1.10678	252
Milling	1.00846	0.04570	0.86151	1.10771	134
Feedstuffs	1.00970	0.04559	0.85445	1.08468	222
Beverages	0.97244	0.07694	0.74594	1.20800	354

Source: own calculations

Finally, if management is considered to be a production factor, there is a dramatic change in economies of scale. The direct effect of management is given by:

$$\frac{\partial \ln y_{it}^{(*)}}{\partial m_i^*} = \beta_m + \beta_{mm} m_i^{(*)} + \beta_{tm}\mathbf{t} + \boldsymbol{\beta}_{xm}\mathbf{lnx}_{it} \quad . \tag{14}$$

For the average company in the full sample, the direct effect of management is 0.1489 for optimal management and 0.3123 for actual management. This suggests that if management enters the production function as a production factor, the food processing company has increasing returns to scale. However, the interpretation of marginal values of management is difficult, since management does not have explicitly defined units. On the other hand, the results suggest that management could be considered an important determinant of food processing production.

[4] The calculations are carried out on the sample mean of the given branch.

3.2 Technical efficiency development

The development of technical efficiency and its components for the food processing industry and its selected individual branches is shown in Figure 1. Technical efficiency in the food processing industry did not change significantly within the period from 2000 to 2007. The rather volatile development of technical efficiency at the beginning of the analyzed period can be attributed to the low number of observations in these years (see unbalanced panel data set). That is, changes in the data set at the beginning of the analyzed period can be a severe problem. In our comments, therefore, we take into consideration the period after 2000.

The stable development of technical efficiency in the food processing industry contradicts our expectations. The adjustment processes connected with accession to the European Union, accompanied by important changes in the institutional and economic environments, were supposed to translate into adjustments in the organizational structure and structure of inputs of food processing companies, which would have an impact on technical efficiency. The breakdown of technical efficiency into its components does not provide any information about a significant change either. Technological change did not contribute to the development of technical efficiency, and the scale and management effect changed only slightly in the analyzed period. However, the situation is different in individual branches of the food processing industry.

The development of technical efficiency in slaughtering is almost identical to the development in the food processing industry. The only differences are a small decline at the end of the analyzed period, and the contribution of the management and scale effect. The negative effect of management suggests that companies in the slaughtering industry have problems with the adjustment processes. On the other hand, the positive scale effect suggests that the companies were improving the scale of production. The dairy industry experienced the same development trends as slaughtering. The only difference is a small positive change in technical efficiency in the last year. The development of technical efficiency in the milling industry was quite volatile, with a significant decrease in technical efficiency at the end of the analyzed period. Changes in technical efficiency were determined by both the management and scale effects. The contributions of these effects were rather random. The main factors determining the developments in the milling industries were the exploitation of unused production capacities and the impact of weather on the quality of raw materials. Technical efficiency in feedstuffs increased significantly in 2005; however, this positive change was almost reversed by a decrease two years later. The changes in technical efficiency were determined by the management and scale effects. Their contribution was largely volatile. Whereas management contributed positively and the scale effect negatively in 2005, the opposite was true in 2007. The rather random development in this industry is the result of changes in the quantity of production. Finally, the development of technical efficiency in beverages has a slightly decreasing trend, which was positively determined by the management effect and negatively by the scale effect. The decreasing trend in technical efficiency in beverages is largely a result of considerable structural changes in the industry.

As far as technological change is concerned, the common feature of all analyzed branches of the food processing industry is that it did not contribute significantly to the development of efficiency in the analyzed period. However, the distribution of technical change suggests that the gap between the best and worst food processing companies increased within the analyzed period.

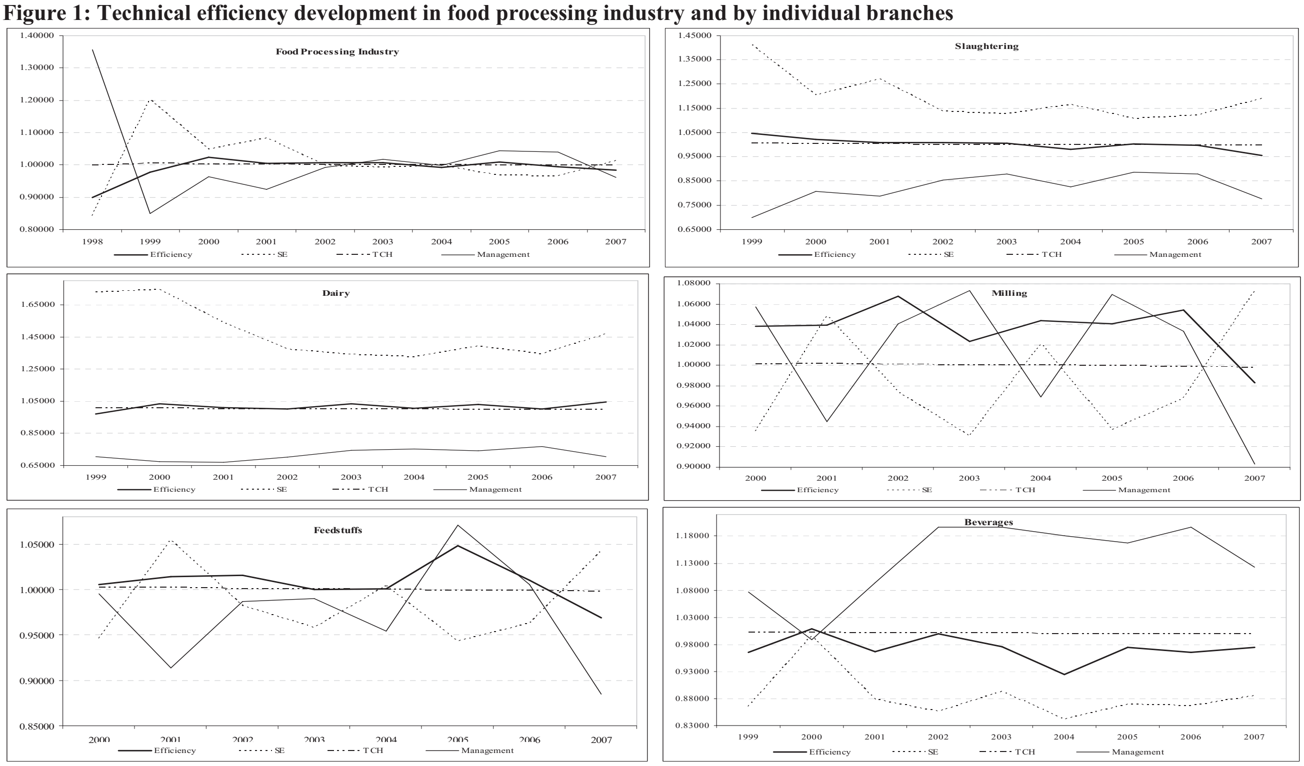
3.3 TFP development

Figures 2a through 2f present the development of TFP in the food processing industry, according to its branches. The figures on the left-hand side provide TFP development without the technical efficiency component. The figures on the right-hand side show the TFP with all its components. The technical efficiency component is added using the decomposition of technical efficiency into technological change, management effect and scale effect.

TFP development in the food processing industry shows an increasing trend. An increase in productivity was positively determined by technological change and the management effect, especially in the last three years. The positive effect of technological change on productivity is a common feature for all analyzed industries at the end of the analyzed period. That is, we cannot observe sector-specific effects. This suggests that the improvement in production possibilities was due more to the diffusion of knowledge generated in another part of the economy, or imported from abroad, than to the sector's own research and development. Moreover, since all companies had to comply with the acquis communautaire, significant investment was needed in all sectors. On the one hand, this explains the relatively high impact of technical progress on the period under investigation. On the other hand, the compliance process can be regarded as one reason why productivity changes were mainly homogeneous among sectors and companies.

In addition, the figures for individual sectors show some differences among the analyzed sectors. The drop in technical efficiency in slaughtering at the end of the analyzed period lowered the positive change in productivity. This suggests that an increasing trend in the import of meat products can have a significant negative impact on the competitiveness of slaughtering companies. The dairy industry experienced a calm positive trend in TFP, with a significant positive contribution from scale effect and a negative contribution from management effect. TFP development in the milling and feedstuffs industries was significantly determined by a rather random development in technical efficiency. Unlike in the slaughtering and dairy industries, the management effect contributed positively, and the scale effect negatively, to productivity development in the milling, feedstuffs and beverages industries.

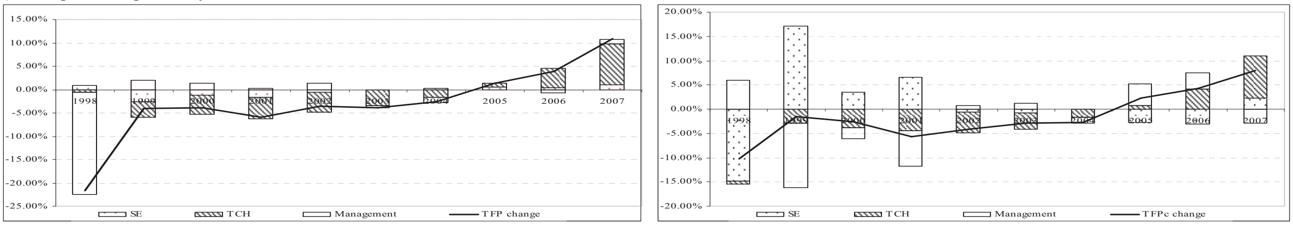
Figure 1: Technical efficiency development in food processing industry and by individual branches



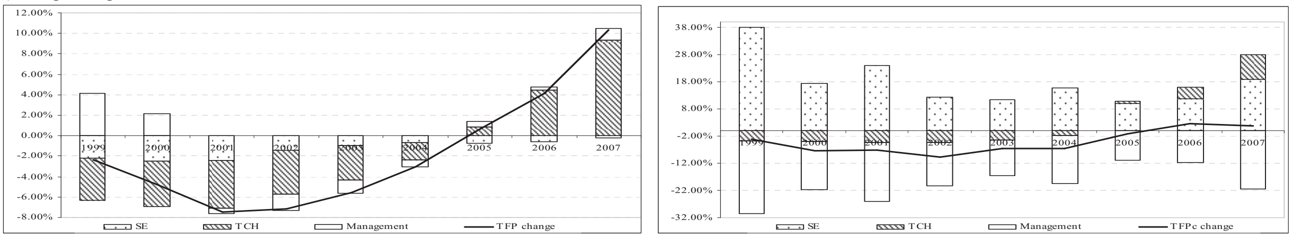
Source: own calculations

Figure 2: TFP development in food processing industry and by individual branches

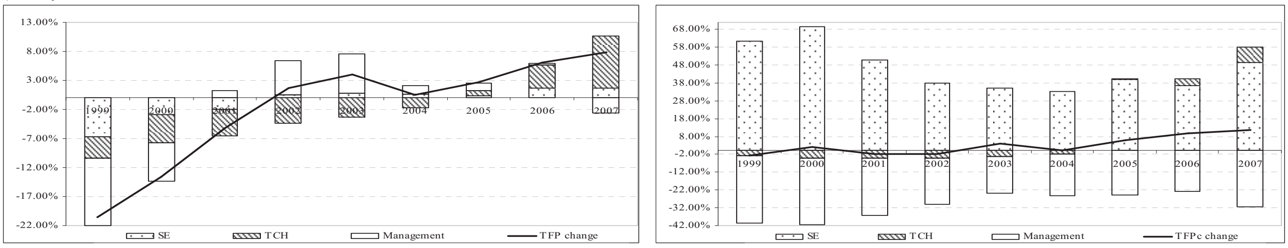
a) Food processing industry



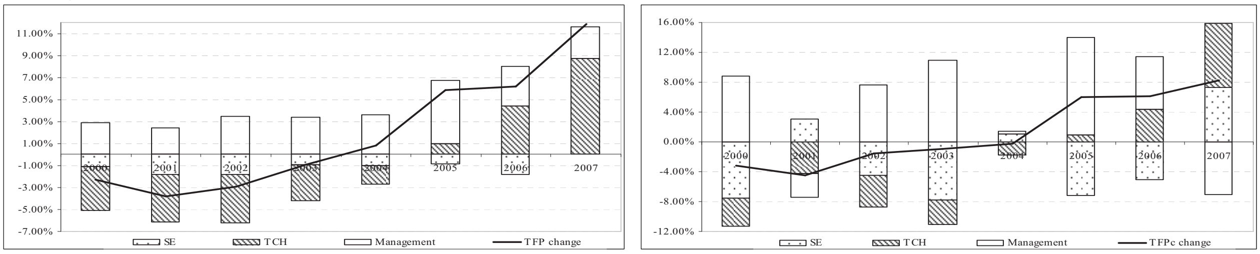
b) Slaughtering



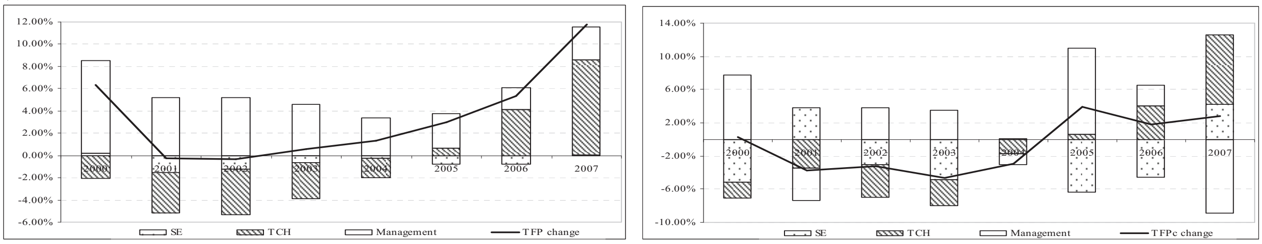
c) Dairy



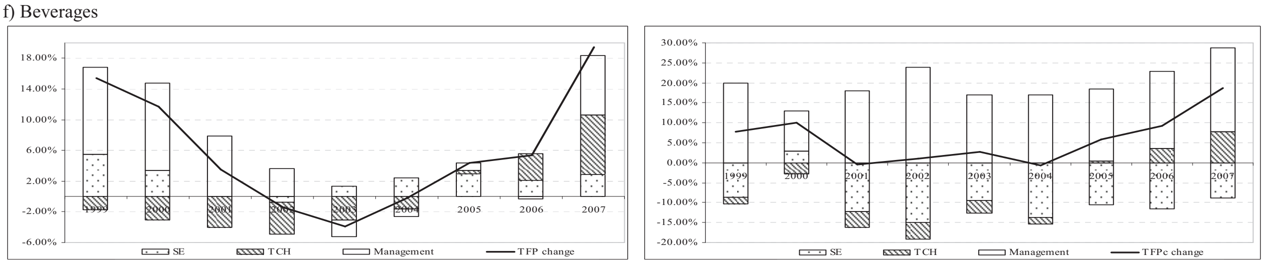
d) Milling



e) Feedstuffs



f) Beverages



Source: own calculations

4 Conclusion

In this section we will concentrate on the questions raised in the introduction, namely the ones regarding the identification which food processing industries are following a path of sustainable development, characterized by the adoption of innovation and reduced waste of resource due to inefficient input use, and the identification of factors determining the development in analyzed industries, regarding the contribution of technological change to productivity development and the assessment to which extent the technological change contributed to the changes in TFP.

Technical efficiency in the food processing industry did not change significantly within the period from 2000 to 2007. The same holds for slaughtering and dairy industry. Milling, feedstuffs and beverages experienced rather random development of technical efficiency. The common feature of all analyzed branches of the food processing industry is that the technological change did not contribute significantly to the development of efficiency in the analyzed period. However, the distribution of technical change suggests that the gap between the best and worst food processing companies increased within the analyzed period.

TFP in the food processing industry significantly increase within the analyzed period. The technological change was an important factor determining the TFP increase at the end of the analyzed period. Since the positive effect of technological change on productivity was a common feature for all analyzed industries this implies that we cannot observe sector-specific effects. This suggests that the improvement in production possibilities was due more to the diffusion of knowledge generated in another part of the economy, or imported from abroad, than to the sector's own research and development. The reason can be found in the compliance process as well as strong economic growth.

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Innovation and Power in Food Supply Chains: The Case of the Potato Sector in the UK

Cesar Revoredo-Giha, Philip Leat, Alan Renwick and Chrysa Lamprinopoulou-Kranis[1]

Abstract: This paper deals with innovation in supply chains and discusses the effects that its organisation (e.g., bargaining power along the chain) might bring on innovation and ultimately to the sustainability of the chain. The analysis was carried out considering the case of the UK potato sector and by comparing three case studies: the first two consider the situation of a supply chain that sells fresh potatoes to retailers (one in South England and another in Scotland), whilst the third one consists of a supply chain that produces potatoes to be further processed. The results indicate that the supply chain leader plays an important role in both in the organisation of the chain and in the initialisation, management and success of the innovation.

Key words: Innovation, agri-food supply chains, potato sector, UK agriculture.

1 Introduction

As the Common Agricultural Policy (CAP) evolves towards a model where the broad objectives of sustainable management of natural resources and a more balanced territorial development become as important as the incentive of food production (although viable food production is still envisaged as one of the broad objectives of the future CAP), the sustainability of farming will necessarily become more dependent on the supply chains within which it operates.

Within this context, business decisions, including those relating to innovation, are expected to depend not only on individual factors affecting the willingness to adopt (e.g., see Feder et al., 1985 for a survey of some of the individual factors affecting individual adoption of innovations) but also on the characteristics of the business environment in which farmers operate. The fact that power imbalances in the supply chain may affect the size and distribution of research benefits is not new, it can be found in Alston et al. (1997) who considered a setting where processing firms operated under oligopsony power in buying raw farm products and oligopoly power in selling processed food products.

A recent European Communication on the operation of supply chains (EC, 2009) stated that an important problem in the food supply chain is that relationships between the different actors are sometimes conflicting. A specific feature of food supply in Europe is that it includes very different economic agents: farmers, either independent or in cooperatives; food producers, from SMEs to large international groups; and distributors, from small corner shops to large supermarkets chains. In fact, according to the Communication, "contractual imbalances associated with unequal bargaining power have a negative impact on the competitiveness of the food supply chain as smaller but efficient actors may be obliged to operate under reduced profitability, limiting their ability and incentives to invest in improved product quality and innovation of production processes." (EC, 2009, p. 6).

In the UK a small number of supermarket chains now provide the primary interface between 60 million consumers and the industry that produces their food (Cabinet Office, 2008). Over

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time, and with consolidation, power in the food supply chain has shifted towards the small number of major retailers that now account for an estimated two-thirds of all food sales.

Under the described context, the question discussed in this paper is whether the organisation of the supply chains and its characteristics are important for innovation to occur and what the possible effects of imbalances of power in the supply chain may have. We focus the analysis on the potato supply chain in the UK, not only because it is an important crop within the country but because conflicts between retailers and other chain participants have been more visible, and the formers' power has been more explicit than in other chains.

The paper is structured as follows: first we provide a brief overview of innovation in supply chains. Next, we provide a short description of the UK potato sector. This is followed by a description of the three case studies in terms of their background, organisation and innovation. In the next section, we compare the three cases highlighting the relationship between supply chain organisation and innovation. Finally, we present conclusions.

2 Innovation and the food supply chain in the literature

The focus of this paper is on innovation in the food supply chain. The main reason for this, is the acknowledgement that increasingly food is produced within supply chains and less within a sequence of markets ((e.g., producer markets, wholesale markets, retail markets). Innovation also tends to occur in sort of organised way, in many cases being a focal company or the captain of the supply chain the one that initiates the introduction of new products.

Yakovleva and Flynn (2005) the food supply chain is a system of stages, which represent particular sequence of economic activities, through which resources and materials flow downstream for the production of goods and the provision of services for ultimate consumption by the consumer. Thus, a typical food supply chain tends to consist of the following stages: origin of resource, agricultural production, primary processing, further processing, final manufacturing, wholesale, retail, food service and domestic consumption.

The food supply chain is perceived as a network of organisations that have primary economic, but also social relationships with each other that enable the functioning of the supply chain to produce goods and services.

As regards the meaning of innovation used in this paper, as in the case of Omta (2002), we use the broad definition describing it as the creation of new combinations. These new combinations can be a new product, a new technology for an existing application, a new application of a technology, the development or opening of new markets, or the introduction of new organisational forms or strategies to improve results. This means that an innovation can be not only a new product, but a new production process, a far-reaching re-organisation of production and distribution, or even an improved way to achieve innovations, for example by means of venture capitalism (Omta, p. 73).

It is in the context of a supply chain (or a network) that a successful innovation entails not only a new product, but the satisfaction of new demands on quality, quantity, transparency with regard to the origin of natural resources (the suppliers), timeliness (logistics and distribution) and the availability of the product (e.g. at the supermarket).

According to Omta (2002) the success of innovations in the chain depends on three related elements, namely the context, cooperation characteristics, and the critical success factors for innovation at company level. However, the aspect that we want to highlight in this paper is the importance of balance of power between suppliers and buyers (Porter, 1985) and its interrelation with leadership in a supply chain (Little, 1970). These factors have effects on innovation as a supply chain where the power relationships are balanced; the leader can play the role of facilitator identifying innovation opportunities, organising it along the chain, and sharing the gains and losses with the other participants in a way that they find it fair. This behaviour feedback of the chain increasing the trust and commitment of the participants, which increases the uptake of innovations.

In the next section we aim to study the interaction of these factors on the UK spotato supply chain.

3 The UK potato sector

The purpose of this section is to present some trends of the UK potato market in England and Wales and Scotland with the purpose of providing a context where for the supply chains studied in the paper operate.

Figures 1 to 4 present key variables of the potato production in Great Britain. As shown in Figure 1, the area under potatoes in England and Wales has been decreasing since 1982, whilst in Scotland it has been growing at slow pace. This is reflection of the elimination of the potato supply quotas. The total number of hectares was in 2010 about 126 thousand hectares of which 110 thousand hectares were planted in England and Wales.

Figure 2 show the potato yields in England and Wales and in Scotland. Although cyclical, the yields, which are close all over Great Britain, have kept an increasing trend, which have compensated the decrease in area and kept the volume of main crop potatoes relatively stable in 5,793 thousand tonnes in 2010. Domestic prices for mainware potatoes (see Figure 4) show a slightly increasing trend although with similar cycles as observed in yields (109 £/tonne in Scotland and 139 £/tonne in 2010).

As pointed out in Yakovleva and Flynn (2005) as regards the potato varieties, the most popular one is planted in Great Britain is Maris Piper, which is a main crop variety and it accounted for almost one quarter of the total planted area of potatoes in Great Britain in 2003. It is considered to produce the higher quality chips than other potato varieties. Estima, which is an early crop variety, is the second most popular variety grown and accounted for 8.8 per cent of the total planted area of potatoes, Lady Rosetta is the third (4.8 per cent), closely followed by Maris Peers (4.7 per cent).

Maris Piper, which is the most popular variety used for home cooking and by chip fryers, is the most planted potato variety; hence this could indicate that the most popular processing of potatoes in Britain is chip frying. According to the information from British Potato Council, However, Maris Piper is very susceptible to diseases and pests, therefore is very rarely grown extensively in organic production. Maris Piper exists only in the form of a conventional potato.

As shown in Figure 5, most of the domestic consumption of potatoes is domestically supplied. Imports of potatoes to the UK have grown over time and they constitute approximately 29 per cent of the consumption for human purposes. The major suppliers of potatoes from abroad are France, Germany, Israel, the Netherlands, Egypt, Spain and Cyprus.

Figure 6 shows the disposition of potatoes destined through retailers and food service. The majority of harvested potatoes are sold on the fresh produce market, however, over 2 million tonnes of potatoes (approximately 30 per cent of the UK annual harvest) are sent for processing (Yakovleva and Flynn, 2005). Within potato processing industry, the production of frozen and chilled potato products has steadily increased over the last decade (see Figure 6).

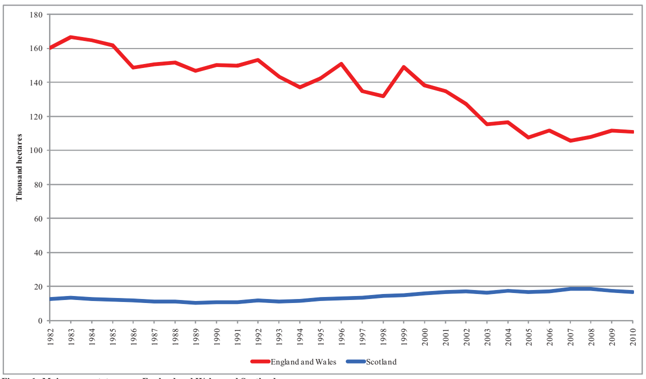

Figure 1: Main crop potato area - England and Wales and Scotland

Source: Agriculture in the UK and Economic Report on Scottish Agriculture

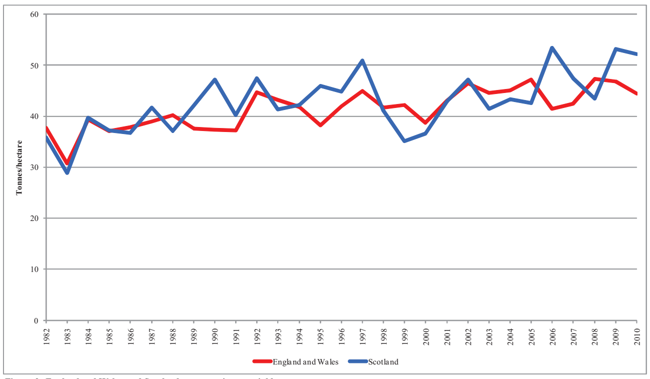

Figure 2: England and Wales and Scotland potato main crop yields

Source: Agriculture in the UK and Economic Report on Scottish Agriculture

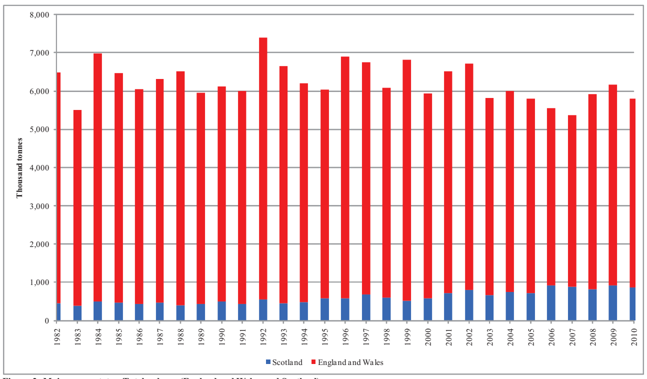

Figure 3: Main crop potato - Total volume (England and Wales and Scotland)

Source: Agriculture in the UK and Economic Report on Scottish Agriculture

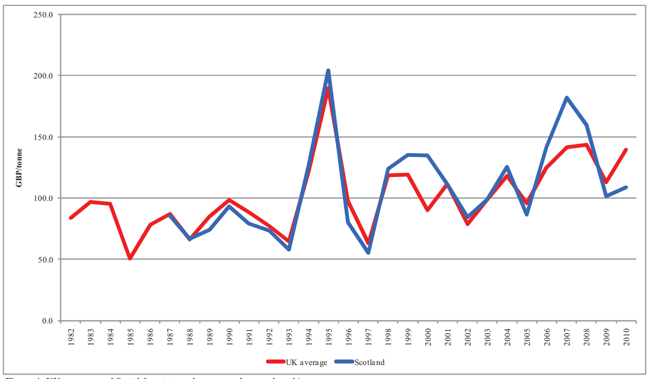

Figure 4: UK average and Scottish potato main crop producer prices 1/

Source: Agriculture in the UK and Economic Report on Scottish Agriculture

Notes

1/ Average price paid to registered producers.

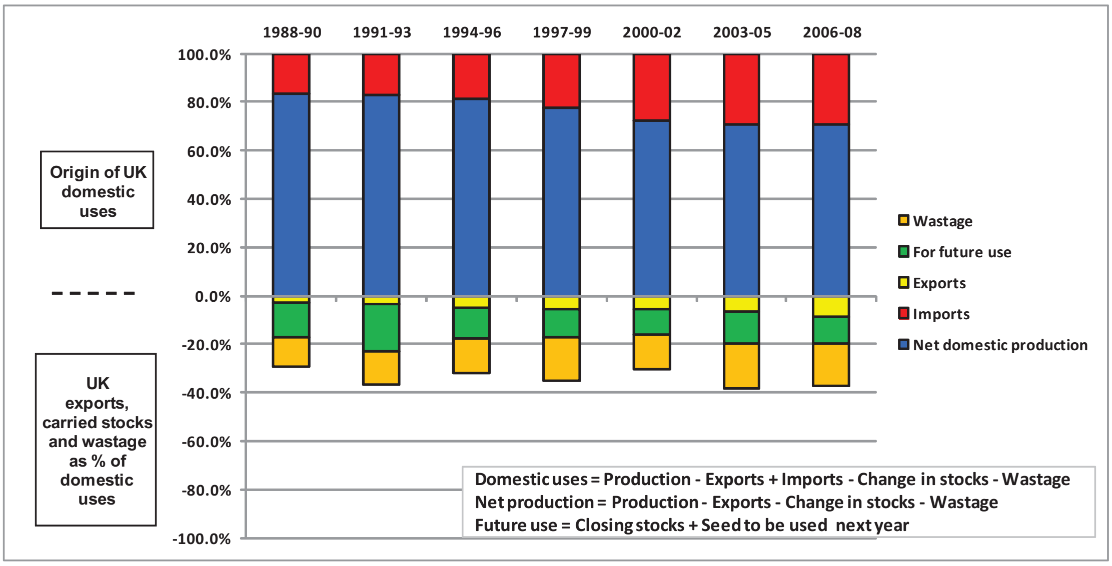

Figure 5: Origin of UK potato domestic uses 1/
Source: Based on AHDB data.
Note:
1/ Underlying data corresponds to the seasons from 1st June of year shown to 31st May of following year.

As pointed out by Yakovleva and Flynn (2005) the market for canned and dehydrated potatoes has remained stable. It is important to note that the UK potato market is not only supplied by domestic potato processors, but also by processors from abroad, which have been increasing at a fast pace. The majority of imports are frozen and chilled potatoes.

As shown in Figure 6, there is decreasing trend in the consumption of fresh potatoes, compensated by the consumption of processed potatoes.

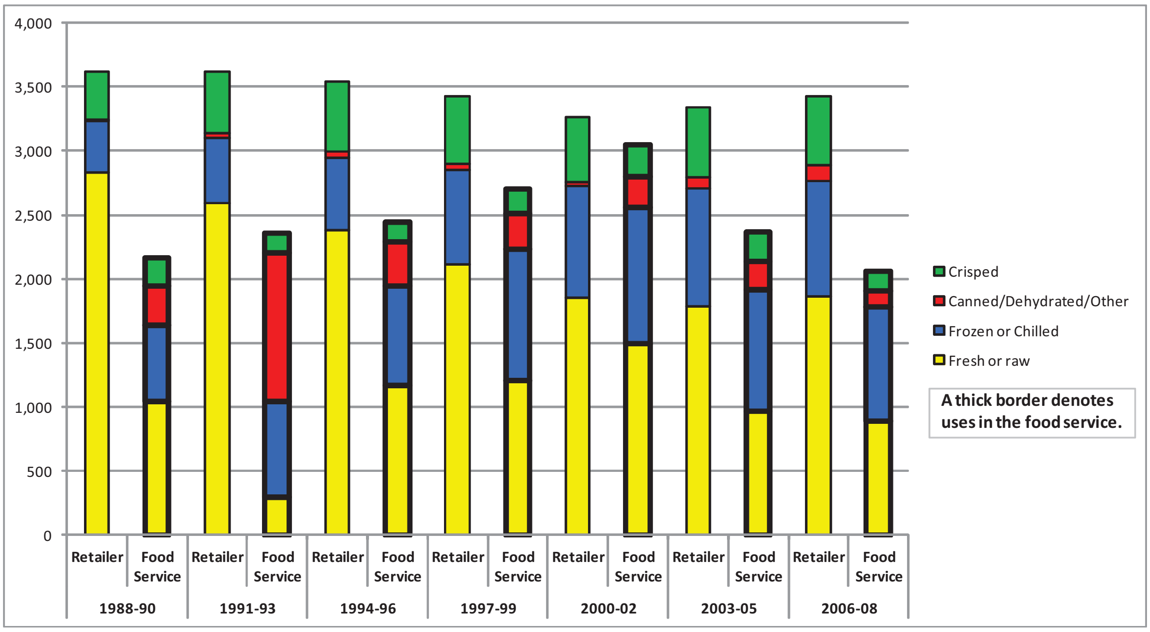

Figure 6: UK disposition of potatoes 1988-2008 through retailers or food service
Source: AHDB.

4 Empirical work

4.1 Methodology

The methodological approach, in the absence of detailed statistical data, comprised two elements: first, to present three case studies: (1) the relationship between a Scottish processor (who also fronts a group of producers) and a multiple retailer, and (2) that between a processor in Southern England and a leading multiple retailer and (3) a supply chain where the focal company is potato processor. Three aspects are analysed in each chain, based on secondary information publicly available in newspaper and journals, namely: the business history, the organisation of the supply chain and the innovation related activities.

The second aspect of the methodology consists first, a theoretical analysis of the different elements that comprise a collaborative supply chain, as in our view, this is key for the development of innovations along the chain. Second, aspects of this collaborative supply chain are compared with the three case studies in order to extract lessons.

4.2 Case studies

This section comprises the description of three case studies. Two of the case studies correspond to fresh potato supply chains whilst the third one is of a processed potato supply chain. It should be noted that the first two cases are of interest because the relationships between processors and retailers were not very successful. Therefore, they can provide lessons as regards elements that are important when establishing a relationship with a powerful agent, within which investments will be made. In addition, they are both cases where the weaker party made investments over time; therefore, despite the imbalanced power situation innovation still took place. In contrast, the third case is a successful case where the power is more balanced and the processor behaves as the captain of the supply chain organising it and proposing and developing innovations.

4.2.1 Scottish case study

Business history

In the 1980s, there was a move from buying potatoes unwashed in bulk to the washed, pre-packed form as buyers wanted even more convenience and new ideas. This meant even more challenges for the declining number of potato growers, pre-packers and processors aggravated by the increasing demand for pasta and rice-based meals. Marketing developments led to the disappearance of traditional grades and the emergence of user-friendly tags. This reinforced the decline in demand for fresh potatoes, but led to the growth of the added-value market, such as prepared mash potatoes.

The company that is centre of this case, Taypack, began in 1986 when Russell Taylor and his son, George, diversified into supplying washing quality potatoes to local packers, who then supplied supermarkets. In 1993 they shortened the supply chain and installed their own washing line at Moncur, packing baking potatoes for the Scandinavian market. Two years later George Taylor established the grower group Taygrow Produce, with 15 members and 1,000 acres. At the same time a new grading system was installed as well as two new washing lines. Contracts were established with supermarkets and in 1998 Taypack bought out Stokes

Bomford in Fife, which was packing for Asda's distribution depot in Grangemouth. The business was brought to Moncur and the company handled most of the production from 8,000 acres of potatoes in Perthshire, Angus and Fife, supplying Asda depots at Grangemouth, Washington and Wigan, which collectively service 94 stores from Elgin in the north to mid-Wales.

In 2008 Taypack Potatoes, after several years supplying ASDA, decided to end their agreement with it in an attempt to protect the long-term future of the company and its growers. It is believed Taypack's misgivings over the contract began some time ago but came to a head recently when Asda, which paid the company around 180 per tonne, demanded more potatoes were supplied, forcing the growers to buy in potatoes at 230-300 a tonne. Growers also pointed to two fuel rise prices over the past 12 months and a threefold increase in fertiliser, which had not been acknowledged by the supermarkets.

George Taylor, chief executive of Taypack, presented a two-year proposal, based on the true cost of production, which was not accepted by ASDA, which was reluctant a sustainable price in a year when uncontracted supplies of potatoes are trading at a substantial premium. ASDA moved to replace the 80,000 tonnes a year of potatoes with produce from other suppliers.

The aftermath was that Taypack's plant was bought by QV Foods, based in East Anglia. The deal, meant an increase in production, to create more than 100 jobs and safeguard hundreds of others in the Scottish potato-growing sector. Taypack continues growing, sourcing and procuring potatoes to supply the Inchture packing facility, as well as other processing facilities, and has also benefited from the increased distribution opportunities in the South arising from the new venture with QV Foods. The supermarkets being supplied by QV in Scotland includes Asda. It also supplies Aldi, Lidl, Iceland, Morrisons, Co-operative shops and Spar shops.

Organisation of the chain

The "Taypack supply chain" comprised a group of 100 growers from East of Scotland, which produce about 100,000 tons of potatoes that are packed each year at the packer plant. Of those growers, 50 were committed to Taypack exclusively and within that number 26 were members of Taygrow, a growers co-operative set up specifically to supply the Inchture packhouse. This cooperative provides 1,900 ha of the 3,000 ha required.

The packing plant used to employ 220 people at its base at Inchture, Perth. Its business represented 9 per cent of the UK's annual 1.5-million-tonne fresh potato market. Asda was the major customer of the firm, taking about 80 per cent of the 100,000 tonnes of the product for distribution to its stores in Scotland and the north of England (40 per cent of Asda's UK fresh potato business).

In addition to Asda, Taypack used to supplies supermarkets and wholesale customers in Europe and Scandinavia. Aldi's Scottish fresh potato business which remains unaffected. Taypack in 2007 acquired a 25 per cent shareholding in a Ukraine-based farming company. 700 ha of potatoes were planted in Ukraine in spring 2007.

Innovation related activities

Three innovation or improvement in the supply chain can be found: First, the establishment of a modern packing plant by Taypack; second, a training programme supported by ASDA to strengthen the supply chain and third a potato breeding agreement with the James Hutton Institute (former Scottish Crop Research Institute).

As regards the Taypack plant, this was supported by a £ 500,000 grant from the Scottish Executive's processing and marketing scheme for agricultural produce and costed a total of £ 3.5 million facility. The plant was built at Moncur Farm, near Inchture (Angus). The plant was described as impressive in terms of quality control, traceability and automation.

The second type of innovation was a national training programme covering 270 fresh produce growers (not only potato growers) throughout Scotland, England and Wales organised by ASDA that started in 2005. This was a £ 350,000 three-year scheme involving the whole supply chain. In Scotland the initiative involved SAC and Taypack Potatoes and around 70 potato producers linked to the Taypack group.

The third innovation is associated to a breeding potato programme associated to the former Scottish Crop Research Institute. It started in 2005 (also as part of the Scottish research Programme). This breeding programme has left a legacy of hundreds of crosses which will be available for further use, but attention has recently focused on an unnamed selection which is very near to commercialisation and is grown on a field scale. The variety coming from the breeding programme was multiplied by the Brown family at West Adamston, near Dundee and is showing good tuber blight and blackleg resistance. It also shows partial resistance to pallida, a type of potato cyst nematode. There is also good immunity to virus Y and powdery scab.

It should be noted that QV Foods, Pseedco & Taylor Food Group have just signed a five year breeding deal to continue the work with the James Hutton Institute's Mylnefield Research Service (MRS) subsidiary. It is expected that new work will use the latest technological advances, including the recent mapping of the potato genome to develop new varieties from salad potatoes to baking potatoes.

4.2.2 South of England case study

Business history

The Romney Marsh Potato Company was founded in 1950 by Jules Sleap who began serving London greengrocers after reading that housewives had to queue for rationed potatoes. It started to supply Tesco with potatoes since 1959. The family-run Kent company packed potatoes for Tesco for 47 years, when the retailer ended a packing contract with the family-run firm. A total of 81 of the 108 workers at the Romney Marsh Potato Company, in New Romney, Kent, were made redundant.

In words of Peter Thake, Romney Marsh's procurement director: "I can't understand Tesco's thinking. It has admitted we have done everything for it that we should have done, and our quality record and service records are second to none. "This was our total business. We only supplied Tesco, because that's the way they wanted it. We want to find another contract, but these days most supermarkets are reducing their packers rather than looking for extra" (The Grocer, 2005).

From the Tesco's side a spokeswoman for retailer said: "We acknowledge the service of Romney Marsh Potato Company. We remain committed to buying potatoes from Kent and supporting Kentish potato growers." (The Grocer, 2005). The termination of its contract with the Romney Marsh Potato Company was part of Tesco's rationalisation of its potato supply base.

After the end of the contract with Romney Marsh Potato Company, packing companies in Lincolnshire and Somerset (i.e., Premier Foods' Branston, QV Foods, Greenvale AP and St Nicholas Court Farms) were used to pack up potatoes grown in Kent. Branston manages the Tesco potato supply account with QV Foods as well as itself; these two firms now supply Tesco with two-thirds of its fresh potatoes. Tesco will continue to source potatoes from Kent, Sussex and Essex but packing operations have moved to Branton's plant in Lincolnshire. It is interesting to note that another Kent firm, St. Nicholas Court Farms, will have its packing contract with Morrison's cut in July but will continue to pack for Tesco, along with Greenvale AP (Farming News Review - April 2005).

The Romney Marsh Potato Company went out of the potato business and ended up letting their facilities (i.e., their transport fleet and 4,000 tonnes of cold store).

Organisation of the chain

The supply chain involved farmers from Kent selling potatoes to the Romney March Potato Company and this packing them and selling to Tesco.

The relationship between the packer and the retailer was based mostly on a long term informal relationship. As pointed out by Mr Sleap, manager of the packing company, in all those years of business, he could not recall any written agreements with Tesco that could be considered sales contracts. The main paperwork, he said, was a letter sent to Tesco each year agreeing to pay Tesco an "overrider" - a percentage of its turnover. The company never queried the payment, because he believed all his competitors paid it too. In the last year of business Mr Sleap said that the overrider rose from 2 per cent to 3¼ per cent of turnover, though there was no increase in tonnage bought. Such payments were investigated by the Office of Fair Trading (OFT) in its audit of the supermarket code of practice and Tesco was given a clean bill of health.

Tesco said all such payments from the Romney Marsh Potato Company would have been agreed in advance. Safeway, however, was criticised for demanding up to £2.5m in "loyalty" payments from suppliers, in 44 instances, prior to its acquisition by the supermarket Morrisons. Although they were a violation of the code of practice, there was no evidence suppliers had complained about them, the OFT said.

Innovation related activities

The potato company innovation related activities consisted into two: first, an investment in state-of-the-art machinery of £ 2.2 million in the three years before the end of the contract with Tesco. The second activity was the organisation of an agronomic service for the farmers supplying the company.

4.2.3 Potato processor case study

Background

McCain is a privately own Canadian company own by a family that started in 1957. They have fifty five plants in six continents. Great Britain was the first market that the company moved out of Canada first with imports of Canada and in 1968 they built a factory in Scarborough. Now the company has five factories and a potato seed factory in Montrose.

Employment in Great Britain reaches 2000 people and turnover of 400 million GBP. The company buys around 13 per cent of the British potato crop.

Organisation of the chain

The company is a leading player in three main channels: retail market, catering or food service marketing, and quick service restaurants. They are best known for their retail business. Since they started in business they build markets, they build categories. According to the McCain CEO Mr. Nick Vermont, the key elements of their strategy as regards their customers consist of:

- **Building markets** – instead of buying businesses the company considers that it is a better strategy to build markets.
- **Diversification by channel and by customer** – As mentioned by the McCain CEO the benefit of a strong relationship is the ability to say "no" when the relationship is not satisfactory. Furthermore, in this way the company dilutes the power exercised by retailers.
- **Relevant differentiation** – The Company puts emphasis in understanding what customers want, as that is the source of value creation and in differentiated their products in the eyes of consumers.
- **Delivering value to customers and consumers** – Whatever they do, it starts with understanding of how consumers shop, how they prepare food, how food fit in their diet. It is important to match the need of their customer (quick service restaurant or the local fish and chips).
- **Innovation on products and processes.**

As regards their supplier the company aims to maintain a long term relationship. The company is organised by growers groups that produce the required varieties for McCain. The latter behaves as a captain of the chain overseeing all the operation and organising all the activities from what consumers want to ways to streamline their suppliers operations.

Innovation related activities

The innovation on the McCain supply chain can be found in two areas: introduction of new products and organisation of the supply chain to support innovation and create value.

As regards the introduction of new products, while the McCain company spends 20 million a year on advertising and it is a top 20 brand; they are keen on keep innovating through the introduction of new products. Examples of innovations in Great Britain and their year of introduction are: oven chips (1978), micro chips (1985), home fries (1997), rustic oven chips (2006), microwavable potato jackets (2012).

With respect to the organisation of the supply chain, the company have maintained the following characteristics:

- **Long term view** – The company has always taken a long term view taken into consideration that there have been a declining number of growers and planted hectares over the last 50 years but yields have compensate production (although they have been stable in the last 5 years).

- **Predominantly forward contract based** – As it buys specialised varieties, the company has used forward contracts to ensure enough supply of potatoes to keep their factory running non-stop.
- **UK sourced**
- **First class food safety and traceability**
- **Managing volatility** – As they contract their potatoes in November-December for planting the following spring and delivering during the following 12 months, the issue of volatility is very important. Management volatility (e.g., spikes in energy, tractor diesel, fertilisers) is important but the key thing is to maintain the stability of supply.
- **Driving economic and environmental sustainability -** This is very important and there has to be value for all the partners. It takes several aspects: their growers have to make money; environmental sustainability (e.g., increasing pressure on water) comes as part of the social corporate responsibility of the company.

As mentioned by McCain CEO, Mr. Nick Vermont, 5 or 6 years ago they were struggling to contract all the potatoes they needed. They felt that they needed to change their contract model. They make their growers change their mind about who their competitor were (i.e., not their neighbour but the European one) and to make the growers to work together.

The company organised McCain grower groups, which are close to a cooperative. This was due to the difficulties in managing 300 individual growers each operating individually. McCain did not force the growers into specific groups, i.e., it did not tell them who to partner with but made clear that if the growers wanted to grow their tonnage, access to new varieties, and access to new investment then they needed to be in grower group. Then you can get the economies of scale that would allow providing the product for McCain at a competitive rate.

The grower groups started in 2003 and they do 20-60 thousand tonnes a year between the 10-25 members self selected. The groups are limited companies. All the farmers are directors and they have one full time coordinator.

An interesting aspect of the chain is the management of price volatility (inputs and outputs) which is based on an indexation model introduced to measure movement of potato growing costs.

5 Discussion

The purpose of this section is to start presenting elements that are important for the functioning of a collaborative supply chain for the development of innovations and ultimately for the sustainability of the chain. Next, we compare the characteristics observed in the above case studies with the framework, in order to extract lessons.

5.1 Elements of a collaborative supply chain

Before discussing the characteristics of the supply chain and their influence on innovation in all the presented case studies, it is important start from a framework that serves as a standard for comparing the cases. The selected framework corresponds to one of the development of collaborative supply chain relationships within which decision making and it is taken from Leat and Revoredo-Giha (2008). This framework is presented in Figure 7.

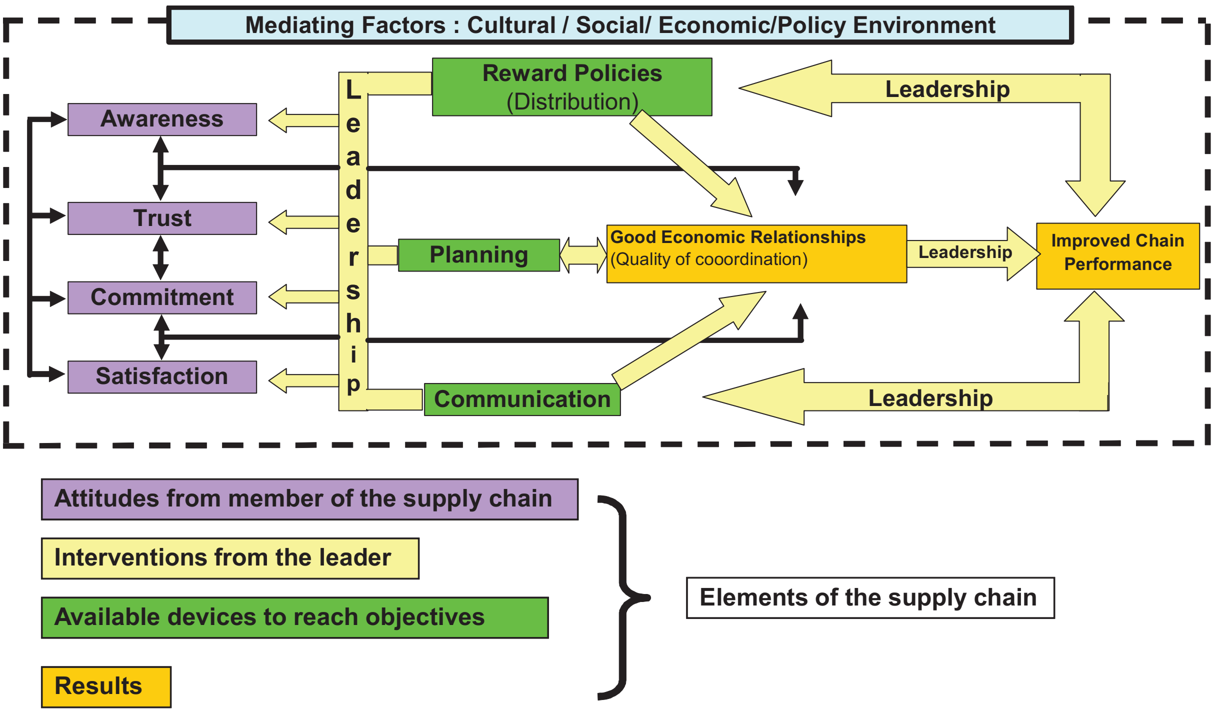

Figure 7. Organisation of a collaborative supply chain

Source: Leat and Revoredo-Giha, 2008.

As shown in the Figure this type of integrated supply chains, invariably involves the development of inter-organisational relationships. Such relationships, if they are to be sustainable, should be stable and mutually beneficial for all the member of the chain and a source source of competitive advantage (e.g. Dyer and Singh, 1998; Sahay, 2003; Power, 2005).

As shown in the Figure, the supply chains are not in vacuum but their relationships take place within a **social, cultural, political and economic environment**. In the wider scope of economic activity - be it production, exchange or consumption - such activity is regarded as “embedded” in patterns of social organisation, relationships and cultural characteristics (Granovetter, 1985). The notion of social embeddedness encapsulates the idea that economic behaviour is embedded in, and mediated by, a complex and extensive web of social relations. In the case of food supply networks or chains, both economic relations (as reflected in prices, costs and markets) and social ones (such as local ties, trust and friendship) are seen as being vital for success (Hinrichs, 2000; Winter, 2003).

A fundamental pre-requisite of good marketing performance is that of **awareness of the customer**, and their needs. Harmsen et al. (2000) note that market orientation involves a focus on, and responsiveness to, customers and competitors, as part of an external orientation. Within the context of supply chains and their performance, this awareness should be extended to embrace the needs of other chain participants as well. Such awareness invariably involves information sharing (Peterson et al., 2000).

Assessing the quality of inter-firm relationships has been the focus of many recent studies. Roberts et al. (2003) reviewed several of them, which along with other studies have illustrated the importance of “soft” factors as indicators of relationship quality. These factors are satisfaction, commitment and trust. **Satisfaction** (cognitive and affective evaluation based on the personal experience across all episodes within a relationship (Storbacka et al., 1994, p. 25); **commitmen**t (an enduring desire to maintain a valued relationship - Moorman et al. 1992, p. 316), and **trust** (“willingness to rely on an exchange partner in whom one has confidence”, Lewin and Johnston, 1997, p.28). It has been suggested that the outcome of trust is “the firm's belief that a partner’s company will perform actions that will result in positive outcomes for the firm as well as not take unexpected actions that result in negative outcomes” (Anderson and Narus, 1990, p.45).

Moving away from the attributes of supply chain participants to the mechanisms which can further enhance supply chain relationships and performance, we have communication, sharing rewards and penalties and whole chain planning. **Communication** has emerged as an important factor in achieving successful inter-firm co-operation (e.g. Bleeke and Ernst, 1999; Mohr et al., 1996; Tuten and Urban, 2001). Since communication allows chain participants to learn about and react to changes in the requirements and expectations of other chain participants, superior chain performance, enabled by modern information technologies, is of prime importance to the continued development of inter-firm relationships. The concept of **sharing rewards and penalties** within the chain is a mechanism for driving chain efficiency and unity (Peterson et al., 2000). This might be regarded as particularly important within agri-food chains where the overall supply chain margin is under pressure such as in agrifood. O’Keeffe (1998), in presenting lessons from supply chain partnerships in Australian agribusiness, identifies the importance of rewards being shared equitably for partnership success. Peterson et al., (2000) stress that **whole chain planning** is necessary for whole chain success and all chain members should be involved in the planning process if a chain's potential is to be realised.

An important aspect for the performance of supply chains, and in our view for the success of innovations, is the value of leadership to successful supply chain relationship has been summarised by (Peterson et al., 2000): … “leaderless chains lack vision, direction and unity and are characterised by a high failure rate. The leader’s role is to provide the focus and coordination, and to ensure that all participants know, and are committed to, the customer's objectives.” (p. 10). Lambert and Cooper (2000), identify the importance of management effort by the focal company, regarding this as a key requirement for supply chain relationships involving managed and monitored supply process links. Furthermore, the quality of leadership within supply chain firms is an important driver of development and improvement as this helps to shape the culture of the firm as well as managing the perceptions held by staff of “us and them” in their alliances (Kidd et al., 2003).

5.2 Fresh potato supply chains

Figure 8 represents the stylised facts of the studied fresh potato supply chains. The focal company is the processor (i.e., the packer), which is the one that coordinates the relationship between retailers and the rest of the chain.

The processor has the role of preferred supplier of the retailer. In the studied cases, the retailers exercise strong power since they could easily replace the processor as a supplier. In addition, the processor does not have a diversified customer base as one retailer is their main client (i.e., Asda in the case of Taypack and Tesco for the Romney Marsh Potato Company). The effect of this structure is that the returns of any innovation, and in general the margins of production, depend on the negotiation with the retailers, which would take the lion’s share.

The described situation limits one of the tools that the captain of the chain has to maintain commitment on the chain and trust, which is the possibility of administering rewards. With tight margins, growers do not necessarily commit their production or they do not necessarily commit to improvement in the chain.

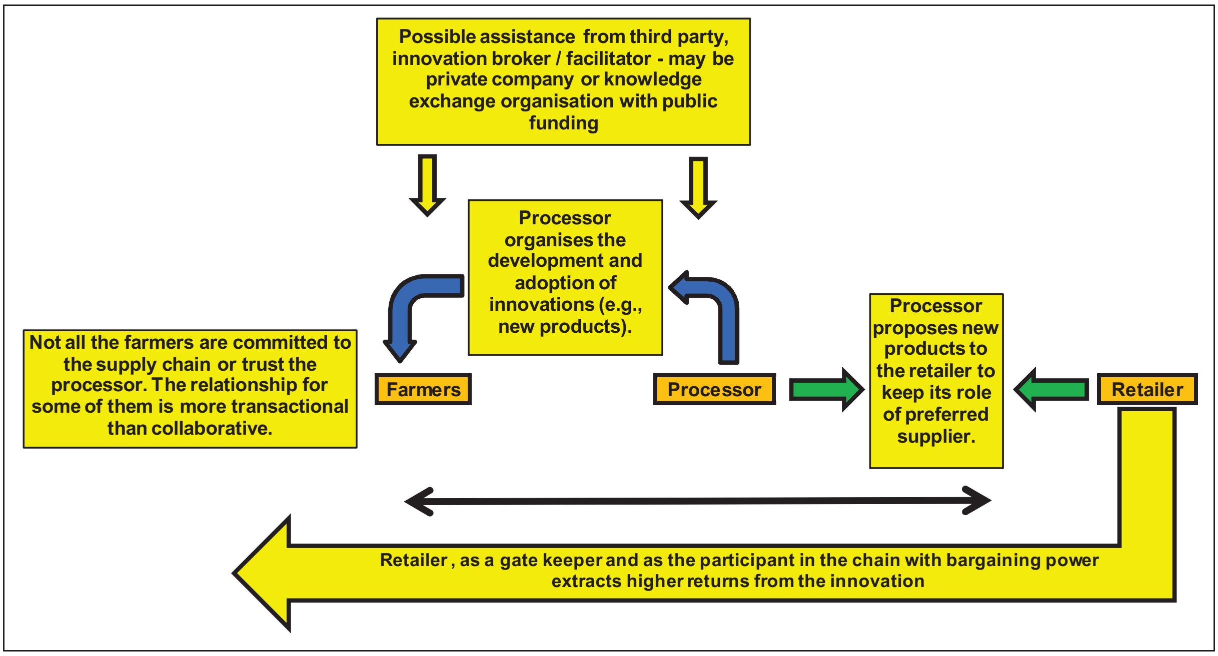

Figure 8: Innovation in a supply chain where retailer has bargaining power

5.3 Processed potato supply chain

Figure 9 portraits the main characteristics of processed potato supply chain. As in the fresh potato chain, it is the processor. The processor is the focal company and captain of the chain. It organizes the innovations and all the improvement along the chain.

An important difference with respect to the fresh potato supply chain is that in this case the processor diversifies customers. This allows it to increase the power and particularly to be able to extract higher returns from retailers. Nevertheless, the competition from products from abroad keeps tight the margins. An important aspect that helps into the cohesion of the chain is the incorporation of a cost index for growers, which allows contracts to be adjusted by changes in the different inputs. Not considering this risk-management factor brought the supply chain Taypack-Asda to an end.

A key aspect is that, in contrast with the fresh potato case, the processor has power within the supply chain. This power, in their relationship with the growers, derives not only that it offers economic conditions that allow every member of the chain to profit of the relationship but also from the fact that the processors oversight the entire supply chain. It collects information from consumers or retailers and passes it to the rest of the supply chain.

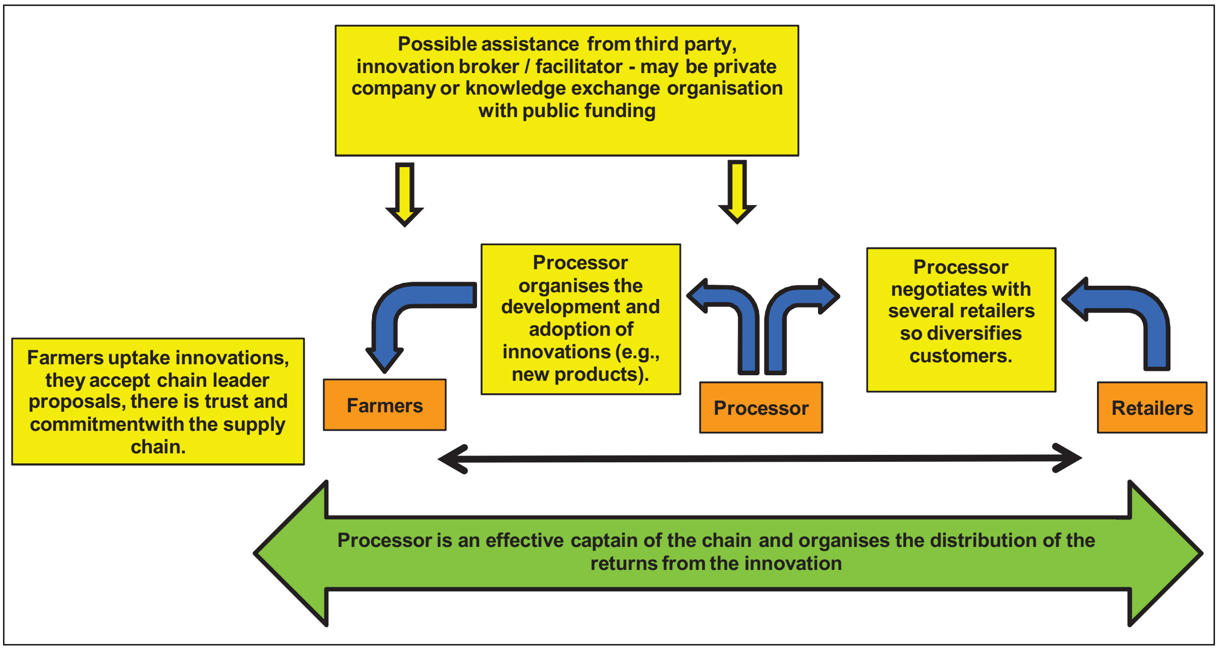

Figure 9: Innovation in a supply chain with an effective leader

6 Conclusions

The main conclusions from the analysis of the case studies are as follows:

- The distribution of power is important for both innovation and sustainability of the supply chain:
    - As regards of the distribution of returns from the innovations as these have effects on the uptake of new technology by different member of the chain.
    - This has implications in terms of trust and commitment to the supply chain leader and to operating within the supply chain.
    - Because the exercise of the power has implications for innovation, it has also effects on the sustainability of the supply chain.
- It is clear from the case studies that for the so called captain of the supply chain to have an active role in promoting innovation, it needs to have power enough to ensure the fair distribution of returns and this might be achieved through diversification of customers (particularly when retailers have so much economic power).
- What about farmers? Because the position they are in the supply chain, operating individually they have little chance to start potentially successful innovations of their own and their best chance is to operate within a supply chain where the chain leader organises growers and proposes innovations that take into consideration what customers and consumers want.
- Furthermore, operating within a supply chain of collaborative characteristics, farmers have the possibility to build in the relationship risk management (like cost adjusted contracts) elements that protect them in times of price volatility.

There are certainly several areas of further research to be considered:

- One is focusing on the relationship between the characteristics of the supply chain and innovation within the agricultural sector. We believe that the food supply chain has peculiar characteristics that make lessons from other sectors of limited interest. One of these is the fact that food supply chain moves from commodities to consumer level products.

- Another is how to create incentives for the creation of collaborative supply chains that bring increasing welfare and sustainability to the farming sector.

Acknowledgements

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STRUCTURAL CHANGE AND TECHNICAL CHANGE IN POLISH AGRICULTURE: AN ADJUSTMENT COST APPROACH WITH TECHNICAL AND ALLOCATIVE EFFICIENCY

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Abstract

This paper aims to understand the state of adjustment process and dynamic structure in Polish agriculture. A dynamic cost frontier model using the shadow cost approach is formulated to decompose cost efficiency into allocative and technical efficiencies. The dynamic cost efficiency model is developed into a more general context with a multiple quasi-fixed factor case. The model is implemented empirically using a panel data set of 1,143 Polish farms over the period 2004 to 2007. Due to the regional disparities and a wide variety of farm specialization, farms are categorized into two regions and five types of farm production specialization. The estimation results confirm our observation that adjustment is rather sluggish implying that adjustment cost are considerably high. It takes up to 30 years until Polish farmers reach their optimal level of capital and land input. Allocative and technical efficiency differ widely across regions. Moreover, efficiency is rather stable over time and among farm specialisations. However, their results indicate that the regions characterized by the larger farms perform slightly better.

Keywords: Polish agriculture, dynamic efficiency, adjustment cost, shadow cost approach

JEL codes: D21, D61, Q12

1. INTRODUCTION

The main purpose of the paper is to understand the influences of technical change on Polish Agriculture after the accession to the EU in 2004. EU membership offered several opportunities for Polish farmers. First the benefited stronger from monetary transfers provided by EU agricultural market and rural policies. This released probably existing credit constraints und increased investment possibilities of farmers. Furthermore, more intense integration into the EU market fostered competition with other EU members on the domestic as well the internal market. In turn, a higher competitive threat requires a restructuring of production and factor inputs. Moreover, since 2000 Polish economy experienced significant economic growth leading to higher pull factors regarding structural change. In sum, all these developments imply structural adjustment process including investment and changes in the production program to meet the requirements set by the changing economic and institutional environment. Moreover, it can expected that these restructuring processes will be accompanied by significant technical change, since technical improvement are usually implemented in new inputs, especially investment in new machinery and other equipment which in turn also require the use of appropriate and improved material inputs.

However, structural adjustment requires significant modifications of the production programs. This process usually occurs over several production periods. This implies that the estimation of a comparative static production frontier is inappropriate, instead, the representation of the technology has to take account of multiperiod decisions making processes. This feature is explicitly considered in the dynamic duality model of intertemporal decision making (Epstein and Denny 1983). The paper extends the adjustment costs model with allocative and technical efficiency of Rungsuriyawiboon and Stefanou (2007) into a more general context with a multiple quasi-fixed factor case. The model is implemented empirically using a panel data set of 1,143 Polish farms over the period 2004 to 2007. The study period allows examining the post-accession performance of Polish farms. Due to a large difference across regions and a wide variety of farm specializations, the study focuses on two regions (i.e. North and South) and five types of farm production specialization (i.e. field crops, dairy cattle, grazing livestock, granivores and mixed farms). The production technology of Polish farm is presented by one output variable (the aggregate of crop and livestock), four variable inputs (labour, overhead, fertilizer, livestock) and two quasi-fixed factors (land and capital).

Rungsuriyawiboon and Stefanou (2007) built on the work of Epstein and Denny (1983); Vasavada and Chambers (1986); Howard and Shumway (1988); Luh and Stefanou (1991, 1993); Fernandez-Cornejo et al. (1992); Manera (1994) and Pietola and Myers (2000) and formalize the theoretical and econometric models of dynamic efficiency in the presence of intertemporal cost minimizing firm behaviour. The dynamic efficiency model is developed by integrating the static production efficiency model and the dynamic duality model of intertemporal decision making. Basically, technical and allocative inefficiencies are considered following by the shadow coast approach developed by Kumbhakar and Lovel (2000). The dynamic efficiency model defines the relationship between the actual and behavioural value function of the dynamic programming equation (DPE) for a firm's intertemporal cost minimization behaviour. Therefore, the dynamic efficiency model provides the system of equations which allows measuring both technical and allocative inefficiency of firms. Recently, Huettel, Narayana and Odening (2011) extend the Rungsuriyawiboon and Stefanou (2007) model by developing a theoretical framework of a dynamic efficiency measurement and optimal investment under uncertainty.

The remainder of the paper is organized as follows. The next section presents the theoretical framework and mathematical derivations of the dynamic efficiency model for the multiple quasi-fixed factor case. The following section discusses the data set and the definitions of the variables used in this study. The next section elaborates the econometric model of the dynamic efficiency model with the two-quasi-fixed factor case. The results of empirical analysis are presented and discussed in the next section and the final section concludes and summarizes.

2. THEORETICAL FRAMEWORK AND MODEL SPECIFICATION

2.1. Dynamic Intertemporal Cost Minimizing Firm

Dynamic economic problem facing a cost minimizing firm behaviour can be addressed by characterizing firm investment behaviour as the firm seeking to minimize the present value of production costs over an infinite horizon. This framework allows one to analyze the transition path of quasi-fixed factors to their desired long-run levels. The underlying idea is that the adjustment process of quasi-fixed factors generates additional transition costs and the optimal intertemporal behaviour of the firm can be solved by using the notion of adjustment costs as a means to solve the firm's optimization problem. With the presence of adjustment costs for the quasi-fixed factors, a firm faces additional transition costs of quasi-fixed factors beyond acquisition costs in the decision making process. This dynamic intertemporal cost minimizing firm model is dealt with two sets of control variables, variable input and dynamic factors (i.e. net investment of quasi-fixed factors), and it can be solved by the appropriate static optimization problem as expressed in the DPE or Hamilton-Jacobi-Bellman equation (Epstein and Denny 1983). The dynamic duality model of intertemporal cost minimizing firm behaviour provides readily implemental systems of dynamic factor demands consisting of optimal net investment demand for quasi-fixed factors and optimal variable input demand.

Let x and q denote a nonnegative vector of variable inputs and quasi-fixed factors, $\mathbf{x} \in \Re_+^N$ and $\mathbf{q} \in \Re_+^Q$, respectively, where w and p denote a strictly nonnegative vector of variable input price and quasi-fixed factor price, $\mathbf{w} \in \Re_+^N$ and $\mathbf{p} \in \Re_+^Q$, respectively.

The value function of the DPE for the intertemporal cost minimizing firm behaviour can be expressed as

$$(1) \qquad rJ(\mathbf{w}',\mathbf{p}',\mathbf{q}',y,t) = \min_{\mathbf{x},\dot{\mathbf{q}}>0} \{\mathbf{w}'\mathbf{x} + \mathbf{p}'\mathbf{q} + \nabla_{\mathbf{q}} J'\dot{\mathbf{q}} + \gamma(y - F(\mathbf{x}',\mathbf{q}',\dot{\mathbf{q}}',t)) + \nabla_t J\}$$

where r is the constant discount rate; y is a sequence of production targets over the planning horizon; t is time trend variable; $\nabla_{\mathbf{q}} J$ is a $(Q\times1)$ strictly nonnegative vector of the marginal valuation of the quasi-fixed factors; $\dot{\mathbf{q}}$ is a $(Q\times1)$ nonnegative vector of net investment in quasi-fixed factors; γ is the Lagrangian multiplier associated with the production target; $F(\mathbf{x}',\mathbf{q}',\dot{\mathbf{q}}',t)$ is the single output production function; $\nabla_t J$ is the shift of the value function due to technical change.

Equation (1) can be viewed as the dynamic intertemporal model of firm's cost minimization problem in the presence of the perfect efficiency. When a firm does not minimize its variable and dynamic factors given its output and does not use the variable and dynamic factors in optimal proportions given their respective prices and the production technology, the firm is operating both technically and allocatively inefficient. Measure of firm's inefficiency can be done by adopting a shadow price approach as described in Kumbhakar and Lovell (2000).

Figure 1: The dynamic intertemporal cost model in the presence of the inefficiency

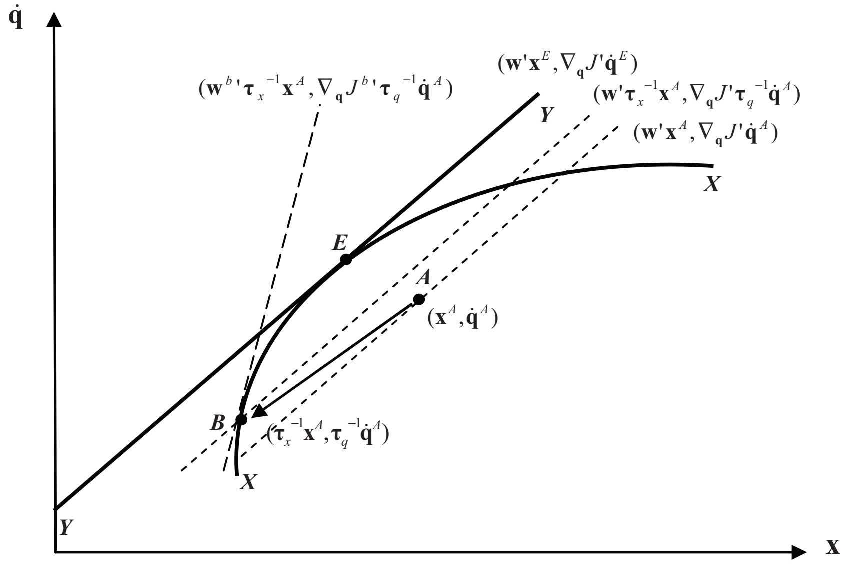


Figure 1 shows the bundle of variable and dynamic factors $(\mathbf{x},\dot{\mathbf{q}})$. The curve XX represents the isoquant. All curves to the southeast of XX represent higher output levels. Since $\nabla_{\mathbf{x}}F > 0$ and $\nabla_{\dot{\mathbf{q}}}F < 0$, it is downward sloping, moreover, $\nabla_{\mathbf{xx}}F < 0$ and $\nabla_{\dot{\mathbf{q}}\dot{\mathbf{q}}}F < 0$ implies that the function is concave. The line YY represents the isocost curve derived from the long-run shadow cost function in equation (1). According to the definition of costs, they are increasing in variable inputs and higher net investments. Point E represents the point that the firm will choose to minimum long-run costs occurred at the contact point of the isoquant and isocost curves such that $\nabla_{\mathbf{x}}\dot{\mathbf{q}} = -(\mathbf{w}/\nabla_{\mathbf{q}}J) = -(\nabla_{\mathbf{x}}F/\nabla_{\dot{\mathbf{q}}}F)$;; $\nabla_{\mathbf{q}}J < 0$.

Consider Point A in Figure 1 where a firm uses the bundle of inputs $(\mathbf{x}^A,\dot{\mathbf{q}}^A)$ available at price $(\mathbf{w},\nabla_{\mathbf{q}}J)$ to produce output y measured using the XX curve. Given the input price $(\mathbf{w},\nabla_{\mathbf{q}}J)$, a minimum cost will occur at point E with the cost of $(\mathbf{w}'\mathbf{x}^E,\nabla_{\mathbf{q}}J'\dot{\mathbf{q}}^E)$. The firm is technically inefficient, because the operation is not on the XX curve. Thus both, the variable input use as well as dynamic factor can be reduced, and thus, costs can be saved without an adjustment of production (e.g. moving from point A to point B in figure 1). Let $\boldsymbol{\tau}_x^{-1}$ and $\boldsymbol{\tau}_q^{-1}$ denote an input-oriented measure of the technical efficiency of the producer for variable and dynamic factors, respectively. The firm will be technically efficient at point B under the input uses of $(\boldsymbol{\tau}_x^{-1}\mathbf{x}^A,\boldsymbol{\tau}_q^{-1}\dot{\mathbf{q}}^A)$ with the cost of $(\mathbf{w}'\boldsymbol{\tau}_x^{-1}\mathbf{x}^A,\nabla_{\mathbf{q}}J'\boldsymbol{\tau}_q^{-1}\dot{\mathbf{q}}^A)$. At point B the firm is still allocatively inefficient, because the marginal rate of substitution at $(\boldsymbol{\tau}_x^{-1}\mathbf{x}^A,\boldsymbol{\tau}_q^{-1}\dot{\mathbf{q}}^A)$ diverges from the actual input price $(\mathbf{w},\nabla_{\mathbf{q}}J)$. However, the firm is allocatively efficient relative to the shadow input price $(\mathbf{w}^b,\nabla_{\mathbf{q}}J^b)$. The shadow prices (internal to the firm) are defined as input prices forcing the technically efficient input vector to be the cost minimizing solution for producing a given output. Shadow prices will differ from market (actual) prices in the presence of inefficiency. Figure 1 illustrates the presence of the technical and allocative inefficiency in the dynamic intertemporal model of this cost minimizing firm behaviour.

2.2. Derivation of Dynamic Efficiency Model

In the presence of inefficiency, the dynamic efficiency model with intertemporal cost minimizing firm behaviour can be formulated using the shadow price approach. A basic idea underlying the construction of the dynamic efficiency model is to define the relationship between actual and shadow (behavioural) value functions of the DPE for the firms' intertemporal cost minimization behaviour. The behavioural value function of the DPE is expressed in terms of shadow input prices, quasi-fixed factor and output whereas the actual value function can be viewed as the perfectly efficient condition. The shadow input prices are constructed to guarantee optimality relationship and they will differ from market (actual) prices in the presence of inefficiency. The inefficiency of firm can be measured and evaluated as a deviation between the behavioural and actual value function.

Let $\mathbf{x}^b$ and $\dot{\mathbf{q}}^b$ denote a nonnegative vector of behavioural variable inputs and behavioural dynamic factors, $\mathbf{x}^b \in \Re_+^N$ and $\dot{\mathbf{q}}^b \in \Re_+^Q$, respectively. Following the shadow price approach, $\mathbf{x}^b$ and $\dot{\mathbf{q}}^b$ can be expressed in terms of actual variable and dynamic factors as $\mathbf{x}^b = \boldsymbol{\tau}_x^{-1}\mathbf{x}$ and $\dot{\mathbf{q}}^b = \boldsymbol{\tau}_q^{-1}\dot{\mathbf{q}}$, respectively where $\boldsymbol{\tau}_x$ and $\boldsymbol{\tau}_q$ are the inverse of producer-specific scalars providing input-oriented measures of the technical efficiency in variable input use and dynamic factor use, respectively. Let $\mathbf{w}^b$ and $\nabla_{\mathbf{q}} J^b$ denote a strictly nonnegative vector of behavioural variable input price and behavioural dynamic factors, $\mathbf{w}^b \in \Re_+^N$ and $\nabla_{\mathbf{q}} J^b \in \Re_+^Q$, respectively. Similarly, $\mathbf{w}^b$ and $\nabla_{\mathbf{q}} J^b$ can be expressed in terms of actual price of variable and dynamic factors as $\mathbf{w}^b = \boldsymbol{\Lambda}_n \mathbf{w}$ $(n = 1,...,N)$ and $\nabla_{\mathbf{q}} J^b = \boldsymbol{\Sigma}_q \nabla_{\mathbf{q}} J^a$ $(q = 1,...,Q)$, respectively where $\boldsymbol{\Lambda}_n$ and $\boldsymbol{\Sigma}_q$ are allocative inefficiency parameters for the nth variable input and the qth dynamic factor, respectively.

Consider the behavioural input prices and quantity, the DPE for the firms' intertemporal cost minimization behaviour can be expressed as

$$(2) \qquad rJ^b(\mathbf{w}^{b}{}', \mathbf{p}', \mathbf{q}', y, t) = \mathbf{w}^{b}{}'\mathbf{x}^b + \mathbf{p}'\mathbf{q} + \nabla_{\mathbf{q}} J^{b}{}'\dot{\mathbf{q}}^b + \gamma^b(y - F(\mathbf{x}^{b}{}', \mathbf{q}', \dot{\mathbf{q}}^{b}{}', t)) + \nabla_t J^b$$

where γ^b is the behavioural Lagrangian multiplier defined as the short-run, instantaneous marginal cost; $\nabla_t J^b$ is the shift of the behavioural value function.

Differentiating (2) with respect to $\mathbf{p}$ and $\mathbf{w}^b$ yields the behavioural conditional demand for the dynamic and variable factors, respectively. Using $\dot{\mathbf{q}}^b = \boldsymbol{\tau}_q^{-1}\dot{\mathbf{q}}$ and $\mathbf{x}^b = \boldsymbol{\tau}_x^{-1}\mathbf{x}$, the optimized demand for the dynamic and variable factors yield

$$(3) \qquad \dot{\mathbf{q}}^{\circ} = \boldsymbol{\tau}_q \dot{\mathbf{q}}^b = \boldsymbol{\tau}_q (\nabla_{\mathbf{qp}} J^b)^{-1} \cdot (r\nabla_{\mathbf{p}} J^b - \mathbf{q} - \nabla_{\mathbf{p}t} J^b)$$

$$(4) \qquad \mathbf{x}^{\circ} = \boldsymbol{\tau}_{\mathbf{x}} \mathbf{x}^b = \boldsymbol{\tau}_{\mathbf{x}} \boldsymbol{\Lambda}_n^{-1}(r\nabla_{\mathbf{w}} J^b - \nabla_{\mathbf{wq}} J^{b}{}'\dot{\mathbf{q}}^b - \nabla_{\mathbf{w}t} J^b)$$

where $\nabla_{\mathbf{w}^b} J^b = \boldsymbol{\Lambda}_w^{-1} \nabla_{\mathbf{w}} J^b$

The value function in actual prices and quantities as the optimal level can be defined as

$$(5) \qquad rJ^a(\cdot) = \mathbf{w}'\mathbf{x}^{\circ} + \mathbf{p}'\mathbf{q} + \nabla_{\mathbf{q}} J^{a}{}'\dot{\mathbf{q}}^{\circ} + \nabla_t J^a$$

Differentiating (5) with respect to $\mathbf{p}$ and $\mathbf{w}$, and applying the same step as for the behavioural value function yield

(6) $$\dot{\mathbf{q}}^{\circ} = (\nabla_{\mathbf{qp}} J^{a}{}')^{-1}(r\nabla_{\mathbf{p}} J^{a} - \mathbf{q} - \nabla_{\mathbf{p}t} J^{a})$$

(7) $$\mathbf{x}^{\circ} = (r\nabla_{\mathbf{w}} J^{a} - \nabla_{\mathbf{qw}} J^{a}{}'\dot{\mathbf{q}} - \nabla_{\mathbf{w}t} J^{a})$$

Using the behavioural demand function in (6) and (7), the value function in actual prices and quantities (5) can be written as

(8) $$\begin{aligned} rJ^{a}(\cdot) \;=\; & \mathbf{w}'\boldsymbol{\tau}_{x}\boldsymbol{\Lambda}_{n}^{-1}(r\nabla_{\mathbf{w}} J^{b} - \nabla_{\mathbf{qw}} J^{b}{}'((\nabla_{\mathbf{qp}} J^{b}{}')^{-1}(r\nabla_{\mathbf{p}} J^{b} - \mathbf{q} - \nabla_{\mathbf{p}t} J^{b})) - \nabla_{tw} J^{b}) \\ & + \mathbf{p}'\mathbf{q} + \boldsymbol{\Sigma}_{q}^{-1}\nabla_{\mathbf{q}} J^{b}{}'\boldsymbol{\tau}_{q}(\nabla_{\mathbf{qp}} J^{b}{}')^{-1}(r\nabla_{\mathbf{p}} J^{b} - \mathbf{q} - \nabla_{\mathbf{p}t} J^{b}) + \nabla_{t} J^{b} \end{aligned}$$

where $\nabla_{t} J^{a} = \nabla_{t} J^{b}$ implying a shift in the behavioural value function is the same proportion as that in the actual value function.

Differentiating (8) with respect to $\mathbf{p}$, $\mathbf{q}$ and t (neglecting third derivative) and substituting into (6) yields

(9) $$\begin{aligned} & \dot{\mathbf{q}}^{\circ}\left[\mathbf{I}/r + \boldsymbol{\tau}_{q}\boldsymbol{\Sigma}_{q}^{-1}(\nabla_{\mathbf{qp}} J^{b} + \nabla_{\mathbf{qq}} J^{b}{}'(\nabla_{\mathbf{qp}} J^{b}{}')^{-1}\nabla_{\mathbf{pp}} J^{b} - \mathbf{I}/r) - \boldsymbol{\Sigma}_{q}^{-1}\nabla_{\mathbf{qp}} J^{b}\right] = \\ & \left[r\mathbf{w}'\boldsymbol{\tau}_{x}\boldsymbol{\Lambda}_{n}^{-1}(\nabla_{\mathbf{wp}} J^{b} - \nabla_{\mathbf{qw}} J^{b}{}'(\nabla_{\mathbf{qp}} J^{b}{}')^{-1}\nabla_{\mathbf{pp}} J^{b}) + \right. \\ & + \boldsymbol{\tau}_{q}\boldsymbol{\Sigma}_{q}^{-1}\left[r\nabla_{\mathbf{q}} J^{b}{}'(\nabla_{\mathbf{qp}} J^{b}{}')^{-1}\nabla_{\mathbf{pp}} J^{b} - \nabla_{\mathbf{q}t} J^{b}{}'(\nabla_{\mathbf{qp}} J^{b}{}')^{-1}\nabla_{\mathbf{pp}} J^{b}\right] \\ & \left. + (\mathbf{I} - \boldsymbol{\tau}_{q}\boldsymbol{\Sigma}_{q}^{-1})\nabla_{\mathbf{p}t} J^{b}\right] \end{aligned}$$

Similarly, differentiating (8) with respect to $\mathbf{w}$, $\mathbf{q}$ and t (neglecting third derivatives) and substituting into (7) yields

(10) $$\begin{aligned} \mathbf{x}^{\circ} = \; & \boldsymbol{\tau}_{w}\boldsymbol{\Lambda}_{n}^{-1}\begin{bmatrix} r\mathbf{w}'(\nabla_{\mathbf{ww}} J^{b} - \nabla_{\mathbf{qw}} J^{b}{}'(\nabla_{\mathbf{qp}} J^{b}{}')^{-1}\nabla_{\mathbf{wp}} J^{b}) + r\nabla_{\mathbf{w}} J^{b} \\ -\nabla_{\mathbf{w}t} J^{b} + \nabla_{\mathbf{qw}} J^{b}{}'(\nabla_{\mathbf{qp}} J^{b}{}')^{-1}\nabla_{\mathbf{p}t} J^{b} \end{bmatrix} \\ & + \boldsymbol{\tau}_{q}\boldsymbol{\Sigma}_{q}^{-1}\left[r\nabla_{\mathbf{q}} J^{b}{}'(\nabla_{\mathbf{qp}} J^{b}{}')^{-1}\nabla_{\mathbf{wp}} J^{b} - \nabla_{\mathbf{q}t} J^{b}{}'(\nabla_{\mathbf{qp}} J^{b}{}')^{-1}\nabla_{\mathbf{wp}} J^{b}\right] \\ & - \dot{\mathbf{q}}^{\circ}\boldsymbol{\tau}_{w}\boldsymbol{\Lambda}_{n}^{-1}(\nabla_{\mathbf{qw}} J^{b} - \nabla_{\mathbf{qw}} J^{b}{}'(\nabla_{\mathbf{qp}} J^{b})^{-1}(\nabla_{\mathbf{qp}} J^{b} - \mathbf{I}/r) + \boldsymbol{\tau}_{q}\nabla_{\mathbf{qw}} J^{b}) \\ & - \dot{\mathbf{q}}^{\circ}\boldsymbol{\tau}_{q}\boldsymbol{\Sigma}_{q}^{-1}(\nabla_{\mathbf{qq}} J^{b}{}'(\nabla_{\mathbf{qp}} J^{b}{}')^{-1}\nabla_{\mathbf{wp}} J^{b}) \end{aligned}$$

The dynamic efficiency model in the presence of inefficiencies consists of the actual conditional demands for dynamic factors in equation (9) and variable inputs in equation (10).

3. DATA DISCUSSIONS

3.1. Definition of Variables

The empirical analysis focuses on agricultural production in Poland using a balanced subpanel of the Polish FADN dataset for the period 2004-2007[1]. In our analysis, the production technology of Polish farm is presented by one output variable, four variable inputs (i.e. labour, overhead, crop input, livestock input) and two quasi-fixed factors (i.e. land and capital). Labour and land were given in physical inputs, e.g. total labour input expressed in annual work units (= full-time person equivalent) and total utilized agricultural area in hectare, respectively. All other inputs and outputs were provided in nominal monetary values. Capital input comprises land improvement, permanent crops, farm buildings, machinery, equipment and the breeding livestock. Material input in crop production is the aggregate of

[1] The Farm Accountancy Data Network (FADN), Source: http://ec.europa.eu/agriculture/rica/

fertilizer, seed, pesticide and other inputs expenditure for crop production. Material input in livestock production comprises feed and other input expenditure for livestock production. Overheads include expenditures for energy, maintenance, purchased services and other not assignable inputs.

The volume of capital input was captured by dividing the capital input by the price index of fixed assets. This index was only available for the national level. Rental prices for capital were derived by calculating the product of the price index of fixed assets times the sum of the nominal interest rate and the depreciation rate (Jorgenson 1963). The latter two variables were calculated from the data set[2]. Price indices for variable inputs were only available at the national level[3]. Farm specific prices indices were derived using the following procedure: First we calculated the volume of the individual inputs by dividing the data in current prices by the corresponding price index at the national level. Second, for each of the three categories the corresponding inputs were aggregated. Third, the relations of input in current and constant prices constitute the farm specific price indices.

No reliable price information for land and labour are available from Polish statistics. However, the data set contains information on land rents and wages paid for some firms. Farm specific prices were calculated in the following manner. First the available information was regressed on several farm specific indicators.[4] We used this information in a stepwise procedure to find the best fit between prices and regressors. The estimation results were then used to determine the factor prices for each farm.

---

[2] Depreciation rate was by the relation of depreciation and fixed assets. The interest rate was the relation of interest paid and the amount of proportion of interest paid and long and medium-term loans.

[3] All price indices were taken form national statistics and the EUROSTAT website.

[4] These includes dummy variables on specialisation, farm size in European Size Units, location by Wojwodship (e.g. region), altitude of the farm, the existence of environmental limitations, the availability of structural funds and the education level of the farmer.

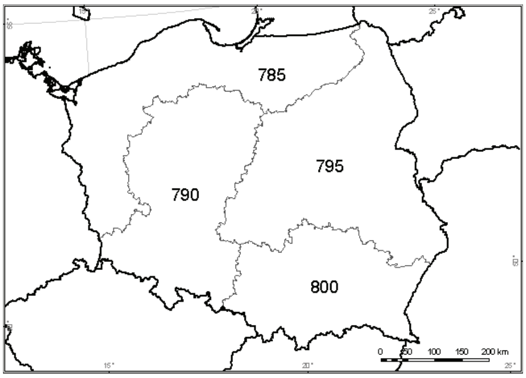
Table 1: Descriptive statistics of the variables, 2004-2007*

		Pomorze and Mazury				Malopolska and Pogórze			
	Variable	Mean	Std..	Min	Max	Mean	Std	Min	Max
p_c	P_CROP	1.003	0.200	0.749	1.477	1.037	0.200	0.731	1.488
p_a	P_ANIM	1.026	0.039	0.910	1.457	0.971	0.044	0.378	1.072
p_y	P_OUT	1.017	0.102	0.767	1.408	0.999	0.101	0.771	1.357
y_c	X_CROP	80,498	137,764	341	3,555,780	44,965	75,273	739	1,289,640
y_a	X_ANIM	123,552	274,984	40	5,539,070	68,915	129,130	521	2,256,540
y	X_OUT	204,050	339,487	10792	6,063,050	113,880	176,891	2,727	2,529,410
Share on crop production		42.2%	22.7%	0.2%	100.0%	43.3%	21.8%	0.4%	99.1%
w_l	P_LAB	13,966	813	12,010	17,739	14,195	937	12,010	19,140
w_2	P_CRP_I	1.002	0.056	0.927	1.173	1.002	0.061	0.929	1.186
w_3	P_ANI_I	1.003	0.074	0.925	1.083	1.003	0.074	0.925	1.083
w_4	P_OVER	0.988	0.035	0.915	1.082	0.987	0.036	0.916	1.242
p_l	P_LAN	225	41	116	340	227	51	113	374
p_k	P_CAP	0.924	0.521	0.006	4.370	1.093	0.611	0.033	3.607
x_1	X_LAB	2.075	1.148	0.510	16.900	1.916	1.048	0.250	18.420
x_2	X_CRP_I	31,279	50,165	228	1,080,980	15,130	27,013	105	442,185
x_3	X_ANI_I	69,638	183,282	88	3,450,370	33,569	66,487	264	823,026
x_4	X_OVER	21,217	29,872	849	733,522	11,395	17,707	647	316,292
l	X_LAN	48.9	58.3	2.0	699.1	21.2	25.2	0.4.2	253
k	X_CAP	764,458	745,718	28,719	1,0948,300	458,427	529,251	49,035	8,947,220

Total of 5,480 observations; 3,012 for the North region and 2,468 for the South region

For output we could resort to regional price information on farm products. We used this information to constructs multilateral consistent Törnquist Theil Indices for crop, animal and total output using the approach developed by Caves et al. (1982). The output volumes were given the relation of data in current prices and the output price indices.

Figure 2: Polish FADN regions



785 Pomorze and Mazury
790 Wielkopolska and Slask
795 Mazowsze and Podlasie
800 Malopolska and Pogórze

Source: http://ec.europa.eu/agriculture/rica/regioncodes_en.cfm?CodeCountry=POL

3.2. Selection of Regions

The data set covers all Polish FADN regions, however, due to the disparity across regions, this paper focuses on farms located in 2 regions, Pomorze and Mazury (785) in the northwest and Malopolska and Pogórze (800) in the southeast of Poland. A total number of 1,470 farms were extracted from the data, 763 in Pomorze and Mazury and 617 in Malopolska and Pogórze. Figure 2 illustrates the location of farms in each region. These regions were selected because of the pronounced differences in production structures (Table 1). Compared to the Malopolska and Pogórze, the Pomorze and Mazury exhibit higher levels of labour productivity (by 40%) and capital productivity (by 7%). They, however, have lower levels of land productivity (by 23%), crop productivity (by 13%), animal productivity (by 14%) and overhead productivity (by 4%). Moreover, the northwestern region is characterized by comparatively large enterprises, while the Southeast is dominated by rather small farms.

This structure finds its expression in the amount of production as well as in the intensity of input use. Farms in Pomorze and Mazury operate twice as much land as farms in the Southeast. The other inputs per farm are also considerable higher in the Northwest. However, since labour input is about the same in both regions, agriculture in Malopolska and Pogórze is more labour intensive than in Pomorze and Mazury. The regional diversity in input use results in corresponding differences in the amount of production. However, there is no pronounced regional specialization of production. In both regions, about 40% of total production results from crop production (table 1). Given the diversity of input use among the regions we expect pronounced regional differences in the exploitation of production possibilities (technical efficiency). In addition, we assume that considerable differences regarding allocative efficiencies exist.

Table 2: Farm specialization in each region, 2004-2007 (Percentage share)

	Year							
	2004		2005		2006		2007	
Specialization	Pomorze/ Mazury	Malo-polska/ Pogórze	Po-morze/ Mazury	Malo-polska/ Pogórze	Po-morze/ Mazury	Malo-polska/ Pogórze	Po-morze/ Mazury	Malo-polska/ Pogórze
Field crops	18.5	21.8	17.7	19.4	17.2	17.8	17.0	21.5
Dairy cattle	20.3	8.9	21.1	9.7	21.9	11.0	21.7	12.0
Grazing livestock	2.8	4.9	2.5	5.8	3.2	6.3	5.3	6.8
Granivores	8.8	7.6	10.2	8.3	10.6	8.9	10.9	9.1
Mixed farms	49.6	56.8	48.4	56.8	47.1	56.0	45.1	50.6

Table 2 shows types of farm production specialization varying in each region over the study period. Farms in both regions tend to specialize in raising dairy cattle, other grazing livestock, granivores, a variety of field crops, or mixed farms. Over the study period, mixed farms are a common specialization in these regions accounting for nearly 50% in the Pomorze and Mazury and more than 50% in the Malopolska and Pogórze. The dairy cattle farms are another specialization in the Pomorze and Mazury accounting for 20% followed by the field crop farms, granivroes and grazing livestock farms. In the Malopolska and Pogórze, the field crop farms are another specialization accounting for 20% followed by the dairy cattle farms, granivores and grazing livestock farms. In both regions, the mixed farms tend to decrease over the year while the dairy cattle farms and granivores tend to increase. It has been observed that 243 farms in the Pomorze and Mazury and 210 farms in the Malopolska and Pogórze had switched the specializations over the study period.

4. ECONOMETRIC MODEL

Equations (9) and (10) constitute a system of quasi-fixed and variable factor demands that can be estimated using appropriate econometric approaches. However, before presenting our estimation strategy, a few more ideas regarding the empirical implementation will be presented. Our empirical model distinguished between the two quasi-fixed factors, net investment and land. In order to ease the derivation and the empirical setup we assume that both net investment and land are independent. Under this simplifying assumption, $\nabla_{\mathbf{qp}} J^b$, $\nabla_{\mathbf{qq}} J^b$ and $\nabla_{\mathbf{pp}} J^b$ are diagonal matrices, e. g. the off-diagonal elements $J^b_{kp_l}$, $J^b_{lp_k}$, J^b_{kl} and $J^b_{p_k p_l}$ are each equal to zero. Therefore, the demand equation (9) becomes:

$$
\begin{aligned}
&\dot{k}^o (1/r + \boldsymbol{\tau}_q \boldsymbol{\Sigma}_k^{-1} (J^b_{kk} (J^b_{kp_k})^{-1} J^b_{p_k p_k} + J^b_{kp_k} - 1/r) - \boldsymbol{\Sigma}_k^{-1} J^b_{kp_k}) \\
&\qquad = r\boldsymbol{\tau}_x \boldsymbol{\Lambda}_n^{-1} \mathbf{w}' (J^b_{\mathbf{w}p_k} - J^b_{k\mathbf{w}} (J^b_{kp_k})^{-1} J^b_{p_k p_k}) \\
&\qquad + \boldsymbol{\tau}_q \boldsymbol{\Sigma}_k^{-1} (r J^b_k (J^b_{kp_k})^{-1} J^b_{p_k p_k} - J^b_{tk} (J^b_{kp_k})^{-1} J^b_{p_k p_k})
\end{aligned} \tag{11}
$$

$$
\begin{aligned}
&\dot{l}^o (1/r + \boldsymbol{\tau}_q \boldsymbol{\Sigma}_l^{-1} (J^b_{ll} (J^b_{lp_l})^{-1} J^b_{p_l p_l} + J^b_{lp_l} - 1/r) - \boldsymbol{\Sigma}_l^{-1} J^b_{lp_l}) \\
&\qquad = r\boldsymbol{\tau}_x \boldsymbol{\Lambda}_n^{-1} \mathbf{w}' (J^b_{\mathbf{w}p_l} - J^b_{l\mathbf{w}} (J^b_{lp_l})^{-1} J^b_{p_l p_l}) \\
&\qquad + \boldsymbol{\tau}_q \boldsymbol{\Sigma}_l^{-1} (r J^b_l (J^b_{lp_l})^{-1} J^b_{p_l p_l} - J^b_{tl} (J^b_{lp_l})^{-1} J^b_{p_l p_l})
\end{aligned} \tag{12}
$$

In addition, the demand for variable inputs (10) is given by:

$$
\begin{aligned}
x^o = \boldsymbol{\tau}_x \boldsymbol{\Lambda}_n^{-1} &\begin{bmatrix} \mathbf{w}' (r\nabla_{\mathbf{ww}} J^b - r\nabla_{k\mathbf{w}} J^b (\nabla_{kp_k} J^b)^{-1} \nabla_{\mathbf{w}p_k} J^b - r\nabla_{l\mathbf{w}} J^b (\nabla_{lp_l} J^b)^{-1} \nabla_{\mathbf{w}p_l} J^b) \\ + r\nabla_{\mathbf{w}} J^b - \nabla_{t\mathbf{w}} J^b + \nabla_{k\mathbf{w}} J^b (\nabla_{kp_k} J^b)^{-1} \nabla_{tp_k} J^b + \nabla_{l\mathbf{w}} J^b (\nabla_{lp_l} J^b)^{-1} \nabla_{tp_l} J^b \end{bmatrix} \\
&+ \boldsymbol{\tau}_q \boldsymbol{\Sigma}_k^{-1} (r J^b_k (J^b_{kp_k})^{-1} J^b_{\mathbf{w}p_k} - r J^b_{kt} (J^b_{kp_k})^{-1} J^b_{\mathbf{w}p_k}) \\
&+ \boldsymbol{\tau}_q \boldsymbol{\Sigma}_l^{-1} (r J^b_l (J^b_{lp_l})^{-1} J^b_{\mathbf{w}p_l} - J^b_{lt} (J^b_{lp_l})^{-1} J^b_{\mathbf{w}p_l}) + J^b_{t\mathbf{w}} \\
&- \dot{k}^o \begin{bmatrix} \boldsymbol{\tau}_x \boldsymbol{\Lambda}_n^{-1} (J^b_{k\mathbf{w}} - J^b_{k\mathbf{w}} (J^b_{kp_k})^{-1} (J^b_{kp_k} - 1/r) + \boldsymbol{\tau}_q^{-1} J^b_{k\mathbf{w}}) \\ + \boldsymbol{\tau}_q \boldsymbol{\Sigma}_k^{-1} (J^b_{kk} (J^b_{kp_k})^{-1} J^b_{\mathbf{w}p_k}) \end{bmatrix} \\
&- \dot{l}^o \begin{bmatrix} \boldsymbol{\tau}_x \boldsymbol{\Lambda}_n^{-1} (J^b_{l\mathbf{w}} - J^b_{l\mathbf{w}} (J^b_{lp_l})^{-1} (J^b_{lp_l} - 1/r) + \boldsymbol{\tau}_q^{-1} J^b_{l\mathbf{w}}) \\ + \boldsymbol{\tau}_q \boldsymbol{\Sigma}_l^{-1} (J^b_{ll} (J^b_{lp_l})^{-1} J^b_{\mathbf{w}p_l}) \end{bmatrix}
\end{aligned} \tag{13}
$$

Equations (11) to (13) form the system equation of the dynamic efficiency model in the presence of inefficiencies. To estimate the dynamic efficiency model, one must specify a functional form to the behavioural value function. In addition, all inefficiencies must be specified to implement the estimation of all coefficient parameters of the behavioural value function. A quadratic behavioural value function assuming symmetry of the parameters can be expressed as[5]

$$
J^b(\cdot) = \beta_0 + \mathbf{w}'\boldsymbol{\beta} + \frac{1}{2}\mathbf{w}'\mathbf{B}\mathbf{w}, \tag{14}
$$

where $\mathbf{w}' = (\mathbf{w}^b \; p_k \; p_l \; k \; l \; y \; t)$; $\boldsymbol{\beta}$ and $\mathbf{B}$ are a vector and a symmetric matrix of parameters, respectively.

The system (11) to (13) is recursive with the endogenous variables of net investment and land, serving as an explanatory variable in the variable input demand equations. Because of this structure, estimation can be accomplished in two stages. In the first stage, the optimized actual

[5] The behavioral value function in equation (25) must satisfy the following regularity conditions. $J^b(\cdot)$ is nonincreasing in (k, l); nondecreasing in $(\mathbf{w}^b, p_k, p_l, y)$; convex in (k, l) ; concave in $(\mathbf{w}^b, p_k, p_l)$ and linearly homogenous in $(\mathbf{w}^b, p_k, p_l)$.

investment demands in capital and land are estimated by using the maximum likelihood estimation (MLE). In the second stage, since the optimized actual variable input demand equations are overidentified, the system of variable input demand equations is estimated by using a generalized method of moments (GMM) estimation giving all parameter values that were obtained in the first stage. The consistency of the system GMM estimator relies upon the assumption of no serial correlation in the idiosyncratic error terms. Following the Newey and West (1994) procedure, a lag of two periods (one period) of autocorrelation terms is used to compute the covariance matrix of the orthogonality conditions for the GMM estimation in the northwest (southwest) model. Another essential assumption for the consistency of the system GMM estimator crucially depends on the assumption of exogeneity of the instruments. The validity of the instrument variables is tested by performing the Hansen's (1982) J-test of overidentifying restrictions. Under the null hypothesis of orthgonality of the instruments, the test statistic is asymptotically distributed as chi-square with as many degrees of freedom as overidentifying restrictions. The null hypothesis fails to reject implying that the additional instrumental variables are valid, given a subset of the instrument variables in valid and exactly identifies the coefficient.

5. Empirical Results

The dynamic efficiency model defined in section 4 can be viewed as the perfectly inefficient model. When all inefficiency parameters in dynamic and variable factors are equal to one, the model is reduced to the dynamic intertemporal cost minimizing firm as presented in Epstein and Denny (1983). In this section, the analysis begins by estimating two models; (a) a full model is based on the assumption that firms are perfectly inefficient in dynamic and variable factor demands. This model allows capturing all inefficient parameters in the dynamic efficiency model. Following Cornwell, Schmidt and Sickles (1990), all allocative and technical efficiencies of dynamic and variable factors are specified to vary across production specialization[6] and through time, and (b) a restricted model is based on the assumption that firms are perfectly efficient in dynamic and variable factor demands. The restricted model is estimated by setting all inefficient parameters of the full model equal to one.

A hypothesis test regarding the presence of the perfect efficiency in production is conducted using the likelihood ratio (LR) test. The LR test is approximately chi-square distributed with the degrees of freedom equal to the number of restrictions. Table 3 presents the estimated coefficients and standard errors for the structural parameters of the dynamic efficiency model in both models.[7] The estimation results from both models are similar and provide the same sign for all parameter estimates except for the estimated parameters, β_{w3w3}, β_{w2w4}, β_{w2l}, β_{w4t} and β_{lt}. Most coefficient estimates particularly the first-order coefficient are significant at the 95% confidence interval using a two-tailed test except for the estimated parameters β_{w2} and β_{w3} in the restricted model. The LR test of the null hypothesis that firms are perfectly efficient in dynamic and variable factor demands is rejected at the 95% confidence level.

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[6] Types of production specialization are classified into 5 categories: field crops, dairy cattle, grazing livestock, granivores and mixed farms as described in section 3.

[7] The full set of estimated coefficients including the dummy variables used to calculate all inefficiency parameters of dynamic and variable inputs are not reported.

Table 3: Estimated parameters of the dynamic efficiency for the full and restricted models

	Full Model		Restricted Model			Full Model		Restricted Model	
	Estimates	Std Err	Estimate	Std Err		Estimates	Std Err	Estimate	Std Err
β_o	-0.152***	0.022	-0.614***	0.082	β_{w2w3}	5.757**	2.864	2.883	1.780
β_t	0.015***	0.005	0.009**	0.003	β_{w2w4}	-3.059	2.615	3.361**	1.449
β_{tt}	0.018	0.04	0.055	0.033	β_{w2pk}	0.056	0.403	0.464**	0.236
β_{w2}	0.320**	0.212	0.248	0.209	β_{w2pl}	1.993*	1.107	0.480	0.539
β_{w3}	0.289***	0.025	0.197*	0.142	β_{w2k}	0.131	0.436	0.789***	0.234
β_{w4}	0.086***	0.021	0.187***	0.023	β_{w2l}	0.187	0.375	-0.704***	0.200
β_{pk}	0.209***	0.002	0.381***	0.002	β_{w2y}	-0.294	0.427	-0.169	0.222
β_{pl}	0.011***	0.004	0.081***	0.014	β_{w3w4}	1.013*	0.599	4.772	6.817
β_k	-0.800***	0.002	-0.180***	0.002	β_{w3pk}	-1.936	1.826	-0.989	1.337
β_l	-0.027***	0.001	-0.267***	0.015	β_{w3pl}	7.213	4.624	0.683	2.846
β_y	0.128***	0.002	0.430***	0.017	β_{w3k}	-8.368***	1.769	-4.940***	1.214
β_{w2t}	0.748	1.116	1.663***	0.475	β_{w3l}	4.776***	1.502	1.503	1.009
β_{w3t}	-1.151	3.835	-2.399	3.528	β_{w3y}	1.072	1.702	1.755	1.125
β_{w4t}	-0.346	0.262	0.086	0.219	β_{w4pk}	-0.961***	0.185	-1.188***	0.171
β_{pkt}	0.335	0.493	0.514	0.443	β_{w4pl}	-0.888*	0.528	-1.094**	0.534
β_{plt}	1.895*	1.149	0.997	0.932	β_{w4k}	-1.347***	0.218	-1.312***	0.22
β_{kt}	0.642	0.49	1.322***	0.402	β_{w4l}	0.139	0.201	0.091	0.202
β_{lt}	0.605	0.406	-0.02	0.331	β_{w4y}	0.709***	0.223	0.642***	0.224
β_{yt}	-0.852*	0.453	-0.733**	0.368	β_{pkk}	83.897***	2.011	43.628***	0.313
β_{w2w2}	23.002***	3.296	13.905***	3.236	β_{pky}	-9.681***	0.319	-9.714***	0.292
β_{w3w3}	1.280	14.762	-7.647	10.102	β_{pll}	36.798***	7.115	20.036***	0.78
β_{w4w4}	0.764***	0.185	0.728***	0.186	β_{ply}	-1.499*	0.866	-2.050**	0.858
β_{pkpk}	0.153***	0.004	0.152***	0.003	β_{ky}	-9.524***	0.379	-9.475***	0.379
β_{plpl}	0.047	0.032	0.040	0.032	β_{ly}	-1.791***	0.249	-1.908***	0.247
β_{kk}	-0.131***	0.005	-0.129***	0.005					
β_{ll}	-0.021***	0.003	-0.022***	0.003					
β_{yy}	0.120***	0.004	0.120***	0.004					

Note: Full model refers to the dynamic model in the presence of the perfect inefficiency while the restricted model refers to the dynamic model with assuming all inefficiency parameters equal to one.

[a] Price of labour (w_1) was normalized. Subscripts on β_{wn} coefficients refer to price of nth inputs: 2 = crop; 3 = livestock; 4 = overhead; 5 = capital; 6 = land. Under the assumption that the quasi-fixed factor, k and l, are independent, the estimated parameters, β_{kl}, β_{kpl}, β_{lpk} and β_{pkpl} are assumed to be zero.

* significant at 10%; ** significant at 5%; *** significant at 1%. The regressions that also include dummy variables used to calculate all efficiency parameters of dynamic and variable inputs are not reported.

Table 4: Estimated parameters of the dynamic efficiency for the North and South models

	Northwest Model (Pomorze and Mazury)		Southwest Model (Malopolska and Pogórze)	
	Estimates	Std Err	Estimate	Std Err
β_{o}	-0.202***	0.034	-0.103***	0.032
β_{t}	0.065	0.726	0.011	0.008
β_{tt}	0.052	0.062	-0.030	0.06
β_{w2}	0.154	0.329	0.243	0.319
β_{w3}	0.521***	0.213	0.410***	0.224
β_{w4}	0.069***	0.017	0.085***	0.017
β_{pk}	0.179***	0.003	0.201***	0.003
β_{pl}	0.103	0.224	0.016**	0.007
β_{k}	-0.579***	0.002	-0.789***	0.003
β_{l}	-0.125***	0.011	-0.326***	0.028
β_{y}	0.136***	0.003	0.137***	0.002
β_{w2t}	0.099	0.168	0.026	0.174
β_{w3t}	-0.069	0.572	-0.099	0.584
β_{w4t}	-0.056	0.039	-0.011	0.043
β_{pkt}	0.001	0.007	-0.002	0.008
β_{plt}	0.034**	0.017	-0.013	0.019
β_{kt}	0.009	0.007	-0.010	0.008
β_{lt}	0.021***	0.006	-0.009	0.006
β_{yt}	-0.021***	0.006	0.021***	0.007
β_{w2w2}	31.428***	5.152	10.493**	5.143
β_{w3w3}	4.591	4.136	5.259	7.622
β_{w4w4}	0.808***	0.275	1.284***	0.301
β_{pkpk}	0.163***	0.004	0.170***	0.005
β_{plpl}	0.080*	0.047	0.033	0.053
β_{kk}	-0.137***	0.007	-0.159***	0.006
β_{ll}	-0.039***	0.005	-0.020***	0.004
β_{yy}	0.138***	0.006	0.157***	0.006
β_{w2w3}	0.444*	0.143	9.059**	4.398
β_{w2w4}	-0.682*	0.385	0.477	0.422
β_{w2pk}	0.074	0.058	-0.113*	0.063
β_{w2pl}	0.269	0.165	0.098	0.177
β_{w2k}	0.068	0.066	-0.134*	0.069
β_{w2l}	0.195***	0.062	0.189***	0.053
β_{w2y}	-0.172***	0.064	0.234***	0.061
β_{w3w4}	2.891*	1.580	0.600	1.714
β_{w3pk}	-0.027	0.228	-0.789***	0.274
β_{w3pl}	0.331	0.703	1.063	0.738
β_{w3k}	-0.597***	0.261	1.137***	0.268
β_{w3l}	0.710***	0.251	-0.066	0.213
β_{w3y}	0.120**	0.024	0.673***	0.241
β_{w4pk}	-0.087***	0.026	-0.149***	0.031
β_{w4pl}	-0.153**	0.076	-0.110	0.093
β_{w4k}	-0.146***	0.032	-0.112***	0.036
β_{w4l}	-0.013	0.030	-0.008	0.031
β_{w4y}	0.093***	0.033	0.046	0.036
β_{pkk}	97.651***	2.256	75.465***	2.137
β_{pky}	-0.114***	0.004	-0.128***	0.004
β_{pll}	71.542**	17.382	61.018**	13.256
β_{ply}	-0.031**	0.013	-0.038***	0.014
β_{ky}	-0.098***	0.005	-0.123***	0.005
β_{ly}	-0.030***	0.004	-0.025***	0.003

Note: The northwest model refers to the full dynamic efficiency model using the data in the Pomorze and Mazury while the southwest model refers to the full dynamic efficiency model using the data in the Malopolska and Pogórze.

[a] Price of labour (w_1) was normalized. Subscripts on β_{wn} coefficients refer to price of nth inputs: 2 = crop; 3 = livestock; 4 = overhead; 5 = capital; 6 = land. Under the assumption that the quasi-fixed factor, k and l, are independent, the estimated parameters, β_{kl}, β_{kpl}, β_{lpk} and β_{pkpl} are assumed to be zero

* significant at 10%; ** significant at 5%; *** significant at 1%. The regressions that also include dummy variables used to calculate all efficiency parameters of dynamic and variable inputs are not reported.

We conduct another hypothesis test to investigate whether farms operated in different regions have identical production technologies. Therefore, the estimation of the full model using the data of all farms (table 3) is compared with the estimates using the data in each region separately. The estimated coefficients for each model using the data in the northwest (Pomorze and Mazury) and southwest (Malopolska and Pogórze) regions are presented in table 4. The estimation results from each model and all first-order coefficients have the similar sign except for the estimated parameters, β_{w2w4}, β_{w2pk}, β_{w2k}, β_{w2y}, β_{w3k}, β_{w3l}, β_{pkt}, β_{plt}, β_{kt}, β_{lt} and β_{yt}. Most coefficient estimates particularly the first-order coefficient are significant at the 99% confidence interval except for the estimated parameters β_{w2} and β_{pl}. The LR test of the null hypothesis that the group-specific technologies are identical is rejected at the 95%

confidence level, implying the group-specific technologies are not the same. Therefore, the following empirical results will be discussed using the estimates obtained from the northwest and southwest models. Consequently, the parameter estimates in table 4 are used for further discussion of results.

The partial adjustment coefficient of quasi-fixed factors is defined as $M_u = (r - (\beta_{qp_q})^{-1})$ where $q = k, l$ (Epstein and Denny 1983). Assuming a discount rate of 5%, the findings show that the estimated adjustment rate of the quasi-fixed factor to its long-run equilibrium level is relatively low in both regions. In the northwest farms, the estimated adjustment rate is 4.0% per annum by capital and 3.6% per annum by land, or it may take capital approximately 25 years and labour approximately 28 years to adjust fully to its long-run equilibrium level. The southeast farms, however, takes much longer time to adjust both capital and land to their long-run equilibrium. The results indicate that in the southeast farms the estimated adjustment rate of capital and land is 3.7% and 3.4% per annum, respectively, or it may take capital and labour approximately 27 and 30 years respectively to adjust fully to their optimal level. These results imply that the sluggish adjustment processes exist in Polish agriculture. The findings are consistent with former analysis of farm size development in Poland (Goraj and Hockmann 2010).

Table 5: Technical and allocative efficiency over time and by specialization

Efficiency scores	Northwest region (Pomorze and Mazury)				Southwest region (Malopolska and Pogórze)			
	By year							
	2004	2005	2006	2007	2004	2005	2006	2007
TE(q)	0.582	0.534	0.532	0.622	0.491	0.468	0.491	0.540
TE(x)	0.601	0.571	0.552	0.615	0.623	0.590	0.475	0.573
AE(k)	0.627	0.654	0.64	0.581	0.393	0.409	0.422	0.433
AE(l)	0.785	0.811	0.813	0.797	0.676	0.695	0.703	0.706
AE(w_2)	0.752	0.746	0.736	0.723	0.900	0.895	0.895	0.892
AE(w_3)	0.600	0.599	0.587	0.563	0.691	0.695	0.675	0.655
AE(w_4)	1.398	1.322	1.292	1.300	3.156	2.513	2.074	2.151

Efficiency scores	Northwest region (Pomorze and Mazury)					Southwest region (Malopolska and Pogórze)				
	By specialisation									
	Field crops	Dairy cattle	Grazing livestock	Grani-vores	Mixed farms	Field crops	Dairy cattle	Grazing livestock	Grani-vores	Mixed farms
TE(q)	0.555	0.563	0.568	0.616	0.564	0.470	0.459	0.447	0.443	0.508
TE(x)	0.572	0.583	0.603	0.636	0.580	0.606	0.578	0.563	0.548	0.540
AE(k)	0.633	0.636	0.649	0.576	0.626	0.392	0.401	0.394	0.413	0.423
AE(l)	0.817	0.803	0.778	0.781	0.801	0.684	0.684	0.685	0.700	0.703
AE(w2)	0.721	0.761	0.755	0.723	0.741	0.908	0.908	0.905	0.922	0.891
AE(w3)	0.624	0.602	0.623	0.512	0.581	0.723	0.735	0.766	0.714	0.667
AE(w4)	1.306	1.344	1.405	1.26	1.339	3.103	2.328	2.399	2.192	2.125

* TE(q) = technical efficiency of dynamic factors; TE(x) = technical efficiency of variable inputs; AE(k) = allocative efficiency of net investment in capital; AE(l) = allocative efficiency of net investment in land; AE(w_2) = allocative efficiency of crop input; AE(w_3) = allocative efficiency of livestock input; AE(w_4) = allocative efficiency of overhead input.

Table 5 presents average the estimated efficiency scores. An estimate of the technical efficiency of dynamic and variable factors is bounded between zero and unity. The value of technical efficiency scores equal to one implies that farm can minimize both dynamic and variable factors to produce a given level of output. The estimated technical efficiencies of net investment in quasi-fixed factors over time range from 0.468 to 0.622 with an average of 0.536 whereas those of variable inputs range from 0.45740 to 0.623 with an average of 0.576. These findings imply that the Polish farms in this study, on average, could have been reduced the dynamic and variable factors by 46% and 42%, respectively and still produce the same level of output. The average value of the northwest farm technical efficiency is 56.7% (for dynamic factors) and 58.5% (for variable inputs). Northwest farms achieved higher technical efficiencies than southeast farms (approximately 12% higher by dynamic factors and 3.5% higher by variable inputs). The estimates further show that technical efficiency is slightly improving over times. This holds for both regions. Moreover, the average differences between the specialisation within the regions are pronounced. What matters is the regional effect while the specialisation effect appears to be marginal.

In general, allocative efficiency scores are bounded between zero and unity. The value of one implies that farm can use the dynamic factors in optimal proportions given their respective prices and the production technology. Average farm allocative efficiencies of net investments in capital and land are 0.529 and 0.753, respectively. These results suggest that Polish farms could potentially reduce the net investment in capital and land demands by 47% and 25% to their cost-minimizing level of factors. The average value of the northwest farm allocative efficiencies of net investments in capital and land is 0.625 and 0.802, respectively. The findings indicate that the northwest farms have average farm allocative efficiency of dynamic factors both capital land higher than the southeast farms.

Following the shadow price approach, the price of labour input is arbitrarily specified as the numeraire. The value of allocative efficiency of variable input demands represents price distortions of the nth variable input relative to the labour input. An estimate of allocative efficiency of variable input demands less (greater) than one means that the ratio of the shadow price of the nth variable input relative to the labour input is considerably less (greater) that the corresponding ratio of actual prices. This implies that the firms are overusing (underusing) the nth variable input relative to the labour input. The average farm allocative efficiencies of crop, livestock and overhead input demands are 0.810, 0.629 and 1.848, respectively. These results imply that Polish farms are over-utilizing crops and livestock relative to the labour input while they are under-utilizing overhead relative to the labour input. The average value of the northwest farm allocative efficiencies of crop, livestock and overhead input demands is 0.739, 0.587 and 1.328, respectively. Compared to the southeast farms, the northwest farms show a higher degree of over-utilization in crops and livestock relative to labour while they indicate a lower degree of under-utilization in overhead relative to labour.

Table 6 gives information about the impact of technical change on total cost and individual input use. The figures are calculated using the parameter estimates of the behavioural value function (2) and the input demand equations given (3) and (4):

$$(15) \qquad \frac{\partial \dot{\mathbf{q}}^b}{\partial t} = r\nabla_{\mathbf{p}t} J^b (\nabla_{\mathbf{qp}} J^b)^{-1}$$

$$(16) \qquad \frac{\partial \mathbf{x}^b}{\partial t} = r\left[\nabla_{\mathbf{w}t} J^b - \nabla_{\mathbf{wp}} J^b (\nabla_{\mathbf{qp}} J^b)^{-1} \nabla_{\mathbf{p}t} J^b\right]$$

These expression provide the impact of technical change in absolute terms. The relative changes ae estimated by dividing (15) and (16) by (3) and (4), respectively. Besides the bias we are interested in the effect of technical change on total cost of production (in relative terms). This is estimated by $\partial \ln J^b / \partial t$ where J^b is given by (14).

Table 6: Impact of technical change

		Northwest Model (Pomorze and Mazury)	Southwest Model (Malopolska and Pogórze)
Total cost reduction	2004	0.01%	-0.07%
	2005	0.03%	-0.12%
	2006	0.05%	-0.17%
	2007	0.07%	-0.22%
Bias of technical change	Crop input	0.29%	0.08%
	Animal input	-0.22%	-0.28%
	Overheads	-0.17%	-0.03%
	Capital	0.01%	-0.02%
	Land	0.02%	-0.02%

The impact of technical change on production, the overall effect as well as its bias, are rather low in both regions. It appears that only the Southwest could benefit from technical change in the period under investigation. Farms in the Northwest experienced a (marginal) reduction of the production possibilities. The impact on variables inputs had a similar structure between the two regions: crop input using and animal and overhead input saving. However, the sign for the quasifixed inputs are opposite for the regions. In the northwest technical change was factor using while in the Southeast is had a factor saving characteristics.

On the one hand these results are consistent with the parameter estimates shown in Table 4 and the technical change indicators follow the parameter differences. Moreover, the estimates also provide that almost none of the parameters for technical change is significant, implying that that the impact of technical change on the production structures in the period under investigation can be disregarded. However, this result is rather astonishing, since other studies investigating a similar period report significant positive influences of technical change (Goraj and Hockmann 2010).

6. CONCLUSIONS

Over the past two decades, Polish agriculture has undergone profound transformations. This paper deals with the astonishing observation that farm restructuring in Poland is rather sluggish and there is no indication that this will change in the next few years. Contrarily, farm size appears to be rather small, even the agricultural sectors is facing significant internal and external threats like increasing competition in agriculture with other EU countries or increasing the demand for labour from other sectors of the overall economy.

This paper analyses this phenomenon by developing and estimating a dynamic frontier model using the shadow cost approach. The dynamic cost efficiency model allows considering the impact of allocative and technical efficiency, as well as adjustment costs resulting from the change of quasi-fixed input use. The model presented in this paper extends the theoretical literature insofar as not only one but multiple quasi-fixed factors are considered. In this paper, the model is analysed using two quasi-fixed inputs (i.e. land and capital). The data set used for estimation was provided by the Polish FADN agency. It includes detailed information on production and input use. However, the data has to be supplemented by information on product and factors prices. These were provided by national statistics and EUROSTAT. We estimated the dynamic cost efficiency model for two rather distinct FADN regions (i.e.

Northwest and Southeast). The first is characterized by, for the Polish situation, larger farms, while in the Southeast smaller farms are dominated.

The shadow cost approach does not given information for individual firms, however, it allows a detailed information of average technical and allocative efficiencies of the variable and quasi-fixed inputs. The results show that adjustment costs are a relevant phenomenon in Polish agriculture. Moreover, they have confirmed the observation already made from the data that adjustment processes are very sluggish. It takes up to 30 years until Polish farms moved to the optimal level of capital and land input. Furthermore, the estimates provide that technical efficiency is a relevant phenomenon in both regions for all inputs. Moreover, the efficiency scores for both variable and quasi-fixed inputs were rather similar, with slightly higher figures in the Northwest. In general, both inputs could possibly be reduced by about 50% while still producing the same level of output. Moreover, there is neither significant indication that technical efficiency varies over time nor largely differs among farm specialisations. The last two conclusions also hold for allocative efficiency. However, allocative efficiencies for land and capital are higher in the Northwest than in the Southeast, implying that those farms replying more intensively than the smaller farms in the Southeast. Furthermore, the estimates provide that labour is overused in relation to overheads, but underused in relation of crop and animal inputs. This holds for both regions, however, overuse is more pronounced in the Northwest, while overuse is prominent in the Southeast.

We estimate a rather low impact of technical change. Moreover, the effects differ between the regions not by size but only by direction. Given other studies on Polish agriculture, these results appear quite suspicious. This suggests that we have to improve the estimate procedures, probably by using different estimation techniques. This strategy is inevitable since the present estimates provide rather unexpected results the regarding allocative efficiencies. Since Polish agriculture belongs to the most labour intensive in the EU, an overuse instead of an underuse of labour is expected. Since allocative inefficiency is inter alia determined by the shape of the isoquants it has to be checked whether the curvature conditions regarding the behavioural value function are satisfied and whether restrictions have to be applied that guarantee that the value fnction behaves well.

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Cost Efficiency and Farm Self-selection in Precision Farming: The Case of Czech Wheat Production

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Annotation: This paper examines allocative and cost efficiency implications of adopting variable-rate fertiliser application using survey data from Czech wheat farms. Data Envelopment Analysis delivered higher efficiency scores for precision farming (PF) adopters. Correcting for selection bias using a one-step endogenous switching regression reveals that farms displaying a lower cost efficiency score are less likely to adopt PF technology. Non-adopters switching to PF technology would likely be affected by a significant decrease in cost efficiency given their production conditions and/or managerial and technical skills. In line with this, results indicate that human capital and farm size increase the likelihood of PF adoption. Cost (allocative efficiency) implications of PF-related changes in input structure only, on the other hand, are not found to have an impact on the choice of technology. A positive allocative efficiency effect of PF technology is brought about mainly by a farm's ability to better extrapolate the soil's productive potential, which is insufficiently reflected in the land rental prices. The allocative as well as cost efficiency implications of PF technology are further related to technology-specific responses to various farm characteristics and technological practices. PF technology makes farms' efficiency more responsive to production conditions, farm specialisation, legal form and other technological practices. The overall efficiency effect the PF practices is, therefore, conditioned on farm characteristics.

Key words: Precision farming, cost efficiency, technical efficiency, allocative efficiency, Czech agriculture, endogenous switching regression.

1 Introduction

Global efforts to improve the management of agricultural production to achieve higher economic performance and sustainability point to the importance of continuously investigating economic and environmental potentials of various production technologies claimed to bring about the more efficient use of farm resources. Precision agriculture adopters strive to produce along these lines, with economic incentives representing the dominant drivers of their technology selection (e.g., Roberts, English and Mahajanashetti, 2000), but positive environmental effects are still being realised (e.g., Khanna 2001). Despite the political interest in precision farming (PF) adoption and its potential for economic benefits, the PF adoption rate is still relatively low (Daberkow and McBride, 2003; Tey and Brindal, 2012). This relatively low rate, as well as the ambiguity of empirical results on PF technology's economic effects (English, Roberts and Mahajaneshetti, 1998; Batte, 1999) contribute to agricultural economists' continued interest in analysing the underlying factors that influence PF adoption and illustrate its economic effects.

Whelan and McBratney (2000: 265) offer the following definition of precision farming: "Matching resource application and agronomic practices with soil and crop requirements as they vary in space and time within a field." Replacing the widely-used uniform application of inputs, not considering within-field production potentials with a system that assesses within-

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field variability in soil and crops (e.g., through yield or soil nutrition monitoring) and responds with site-specific management practices (Paxton et al., 2011) can be expected to yield economic benefits. Precision farming has been projected (i) to increase revenues by increasing crop yields above the yields achieved with a uniform level of input application, and (ii) to reduce costs of production by reducing the level of inputs required to achieve a given yield (Roberts, English and Mahajanashetti, 2000).

Adopting PF technology can also be accompanied by cost increases due to new technical demands and input reallocation. Since PF substitutes information and knowledge for physical inputs (Bongiovanni and Lowenberg-Deboer, 2004: 359), implementing PF practices can introduce higher costs of information collection (e.g., soil and yield monitoring for the diagnostic stage), as well as costs related to variable input application. Physical inputs, mainly direct inputs such as fertilisers and other chemicals, are thus replaced by specialised machinery and human capital. This cost effect of PF-related input re-allocation has not received much scientific validation.

This paper examines the impact of PF adoption on economic returns measured by cost efficiency and aims to highlight the role of technology-related input re-allocation in the overall cost effect. This analysis must consider the possibility of self-selection bias, since farmers can be expected to endogenously self-select themselves into a sub-group through their adoption/non-adoption decision instead of being randomly selected from the survey respondents (Khanna, 2001: 36). The farms' self-selection into adopting the PF technology can result from the expectation of technology-related costs and benefits, which depend on the farm's information on the productive or cost-reducing potential of the new technology, as well as their assessment of their own capacity to realise this potential conditioned on their characteristics. More technically efficient farms can, therefore, be assumed to have a greater potential to extrapolate the benefits of new technologies such as PF, and hence to show a higher propensity to adopt the technology. To correct for the self-selection bias, we apply a one-step endogenous switching regression. This study analyses farm-level survey data on Czech wheat-producing farms and focuses on variable rate of fertiliser application as the PF practice of interest.

The paper is structured as follows: The following chapter discusses existing empirical studies on the economic implications of PF technologies and identifies the main added value of our analysis. The subsequent chapter introduces methods, data and variables applied in the analysis. Chapter four presents and discusses the empirical results, while Chapter five summarises the study and derives main conclusions.

2 Previous research

A review of theoretical models (see Feder and Umali, 1993) as well as empirical studies of PF technology's economic implications (see below) points to the thin line between the positive economic effects and PF-related costs and their dynamics, which makes the expectation of the net economic benefits less intuitive. For example, Anselin, Bongiovanni and Lowenberg-DeBoer (2004) identified a profitability-increasing effect of variable rate technology when applying a spatial econometric approach to strip trials data. Most studies have, however, found that the net economic implications of PF technology are conditional on a range of farm, field, market or institutional conditions. For instance, Bongiovanni and Lowenberg-Deboer (2004) find that PF is a modestly more profitable alternative than uniform field management for a wide range of restrictions on nitrogen application levels (e.g, government regulation on nitrogen use). Khanna (2001), by using a double selectivity model on a sequential adoption of PF technologies, came to the conclusion that adopting site-specific technologies leads to gains in nitrogen production on less productive soils. Experiments on cereals fields carried out by

Godwin et. al. (2002) showed that the benefits from PF systems outweigh the additional costs in some farm (size) categories, and depending on the sophistication of the PF system. Roberts, English and Mahajanashetti (2000) stress the importance of the quality of the diagnostic stage of the PF practice implementation for drawing benefits from PF technology adoption. They also point out that the economic outcomes of the PF technology are sensitive to input and output prices.

Numerous studies confirm the importance of the expected economic benefits for PF adoption, and thus farm self-selection into the technology. For instance, Khanna, Epouhe and Hornbaker (1999) concluded that uncertainty in returns due to adoption, high costs of adoption, and a lack of demonstrated effects of advanced site-specific technologies on yields and input use are some of the major reasons for low adoption rates. Considering various stages of technology adoption, Leathers and Smale (1991) found that under uncertain impact of the new technologies, it is rational for the farmers to adopt components of the technology sequentially rather than to adopt the complete technology all at once.

Our data does not allow us to consider sequential adoption. However, the data does include a large range of farm characteristics that allow us to effectively correct for a possible selection bias. Also, the detailed production and technological data permits a closer look at the cost-structural shifts due to technological changes than was possible in any of the previous studies. Most empirical studies use partial production outcome indicators such as profits (Fernandez-Cornejo, 1996) and input productivity such as nitrogen productivity (Khanna, 2001; Roberts, English and Mahajanashetti, 2000), land productivity (Fuglie and Bosh, 1995), or labour productivity (Fleisher and Liu, 1992). These partial (individual input) productivity indicators ignore the production multi-dimensionality with regard to input structure and hence the joint productivity of the input set. Estimating farm-level cost efficiency measures taking into account the multiple-input productivity effect and the possibility of decomposing this measure into its allocative and technical parts thus helps to obtain new insights on the economic effects of PF practices.

Also, previous studies analysing the determinants of PF adoption and its economic implications that controlled for self-selection mostly applied two-step methods developed by Heckman (1976) and Lee (1976). However, the two-step procedure can deliver inconsistent standard errors (Lokshin and Sajaya, 2004: 282). We apply a full-information ML (FIML) method that allows for a one-step (simultaneous) estimation of the efficiency equations and technology choice equation that provides more consistent standard errors.

3 Methodology

In the first step of the analysis, farm-level efficiency measures are obtained by means of a deterministic linear programming method, Data Envelopment Analysis (DEA). Because of the expected physical input and cost reducing effect of precision farming, the cost-minimising behavioural objective is assumed for the specification of the DEA model. It is of interest to derive not only input-oriented technical efficiency measures, but also allocative efficiency, as precision farming has an impact on the inputs' structure. Both efficiency measures represent components of overall cost efficiency, which will be analysed in connection to PF technology in the second step. A joint feasible production set will be assumed in the cost efficiency model for both production practices (PF and non-PF) to create a joint performance benchmark and thus a comparative basis for the efficiency measures.

In the second step of the analysis, determinants of the technology selection and efficiency level are analysed using endogenous switching regression. To illuminate the PF cost effect related to input allocation and the overall cost effect, this analysis is carried out for cost and allocative efficiency separately. The use of switching regression is motivated by the fact that the level of allocative and cost efficiency could differ between PF adopters and non-adopters as a result of the PF technology effect, as well as the fact that adopting PF is a non-random selection choice. As discussed in the introduction, to choose between the two production practices, the farm compares the expected net benefit of both technological alternatives and chooses a practice that delivers the highest returns on its set of characteristics.

Endogenous switching regression models can be estimated by either two-step least square or maximum likelihood (ML) estimation; however, methods estimating one equation at a time are inefficient and derive inconsistent standard errors (Lokshin and Sajaya, 2004: 282). More consistent standard errors can be derived by implementing a full-information ML (FIML) method that simultaneously fits the continuous (efficiency) and the probit (technology choice) equations of the model.

If there is no statistical indication of dependency between the two parts of the switching model, and hence no indication of a self-selection in the PF adoption choice, the efficiency effect of precision technology is estimated using a truncated regression.

3.1 Efficiency measures and Data Envelopment Analysis

For the aim of cost efficiency measurement, we analyse a farm production system with one output variable. We consider a situation where a farm produces output $y \in R_+$, using a vector of $k = 1,2,...,K$ inputs, $x \in R_+^K$. The feasible production set, T, is defined as:

$$T = \{ \langle y, x \rangle \in R_+^{M+K} \mid x \text{ can produce } y \}, \tag{1}$$

where the production technology is assumed to be convex and non-increasing in inputs, non-decreasing in outputs, and exhibits strong disposability in both inputs and output[2]. In the cost minimisation context, the output, y, is fixed. Given a vector of $k = 1,2,...,K$ input prices, $p \in R_+^K$, one can define the minimum cost associated with producing a particular output as:

$$E(y, p) = \min_x \{ p'x \mid \langle x, y \rangle \in T \}. \tag{2}$$

The cost-minimising input vector is denoted by x_c; where the minimum cost level equals $p'x_c$ and the cost at the observed input vector is equal to $p'x$. The cost efficiency measure of a firm then can be defined as the ratio of minimum cost over observed cost:

$$CE = p'x_c / p'x . \tag{3}$$

This will take a value between zero and one, where a value of one indicates full cost efficiency, implying that it is not technologically feasible to produce the given amount of output with a lower cost.

Cost efficiency, *CE*, can be further decomposed into two components - a part due to technical efficiency, *TE*, and a part due to allocative efficiency, *AE*. It is methodologically simpler to derive *TE* and calculate *AE* using the two already derived measures.

The Farrell (1957) technically efficient input vector[3] for the observed input vector that is not located on the boundary of the technology set, x_t, can be identified by proportionally shrinking the observed input vector, x, until it is projected onto the boundary of the technology set; i.e. by solving the optimisation problem:

$$TE(y, x) = \min_\theta \{ \theta \mid \langle \theta x, y \rangle \in T \}, \tag{4}$$

[2] See Coelli et al. (2005) for further discussion of these properties.
[3] This measure considers the production boundary for constant returns to scale technology.

where θ is a scalar that takes a value between zero and one. The technically efficient input vector is calculated as $x_t = \theta x$. The cost corresponding with the technically efficient input level is $p'x_t$. Expressed as a ratio, technical efficiency can be denoted as:

$$TE = p'x_t / p'x = p'(\theta x) / a'x = \theta . \quad (5)$$

Allocative efficiency, which relates to having the correct input mix given observed input price ratios, can then be derived as a ratio between cost efficiency and technical efficiency as follows:

$$AE = CE / TE, \quad (6)$$

which corresponds to the ratio of the cost related to the cost-minimising input vector and the cost related to the technically efficient input vector:

$$AE = p'x_c / p'x_t . \quad (7)$$

As mentioned in the introduction, to solve the presented optimisation problems, we apply input-oriented and cost-minimising DEA programs[4] to derive technical and cost efficiency measures, respectively. The purpose of DEA is to construct a frontier over the data points such that the observed output points lay within the production possibility set enveloped by the frontier. To obtain the presented ratio θ representing *TE*, one can solve following a (constant returns to scale) DEA program:

$$\begin{aligned} &\min_{\theta,\lambda} \theta , \\ &\text{st} \quad -y_i + Y\lambda \geq 0, \\ &\qquad \theta x_i - X\lambda \geq 0, \\ &\qquad \lambda \geq 0 , \end{aligned} \quad (8)$$

where the vectors x_i and y_i represent data on the *K* inputs and *M* outputs of the *i*-th farm; *X* is the $K \times I$ input matrix and *Y* the $M \times I$ output matrix; θ is a scalar and λ is a $I \times 1$ vector of constants.

The cost-minimising DEA program can be denoted as follows:

$$\begin{aligned} &\min_{\lambda,xic} (p_i'x_{ci}), \\ &\text{st} \quad -y_i + Y\lambda \geq 0, \\ &\qquad x_{ci} - X\lambda \geq 0, \\ &\qquad \lambda \geq 0 . \end{aligned} \quad (9)$$

The cost efficiency and allocative efficiency scores will be calculated as described in Coelli et al. (2005) and illustrated above in equations (3) and (6), respectively. To derive the efficiency measures, we apply the DEAP software (Version 2.1) developed by Coelli (1996).

The derived farm-level efficiency scores are then analysed using the endogenous switching regression in relation to the PF technology choice.

3.2 Endogenous switching regression model

Since the propensity to select PF technology can depend on the efficiency gains that might result from technology that are conditioned on the set of farm characteristics, we are interested in modelling the interdependence between the efficiency equation and the technology choice equation. We implement FIML to simultaneously estimate the two equations, which provides more efficient parameter estimates and consistent standard errors when compared to fitting

[4] See Coelli et al. (2005) for a detailed description of the programs.

one equation at a time by either two-step least squares or ML estimation (Lokshin and Sajaya, 2004).

Drawing from Maddala (1983) and Lokshin and Sajaia (2004), a model is considered which specifies an agent with two regression equations and a criterion function, I_i, that determines the agent's regime - in this case, the technology selection:

$$I_i = 1 \quad \text{if} \quad \gamma Z_i + u_i > 0,$$

$$I_i = 0 \quad \text{if} \quad \gamma Z_i + u_i \leq 0,$$

$$\text{Regime 1:} \quad y_{1i} = \beta_1 X_{1i} + \varepsilon_{1i} \quad \text{if} \quad I_i = 1, \tag{10}$$

$$\text{Regime 2:} \quad y_{2i} = \beta_2 X_{2i} + \varepsilon_{2i} \quad \text{if} \quad I_i = 0, \tag{11}$$

where y_{ji} are the dependent variables in the continuous (efficiency) equations, X_{1i} and X_{2i} are vectors of weakly exogenous variables, Zi is a vector of exogenous variables explaining the endogenous selection dummy I_i; β_1, β_2, and γ are vectors of parameters to be estimated. Error terms u, ε_1 and ε_2 are assumed to have a trivariate normal distribution with mean vector zero and covariance matrix:

$$\Omega = \begin{bmatrix} \sigma_u^2 & \sigma_{1u} & \sigma_{2u} \\ \sigma_{1u} & \sigma_1^2 & . \\ \sigma_{2u} & . & \sigma_2^2 \end{bmatrix}.$$

The covariance between ε_1 and ε_2 is not defined, as y_{1i} and y_{2i} are never observed simultaneously; σ_u^2 is assumed equal to one. Given the assumption on the error terms, the logarithmic likelihood function for the system of equations (10) and (11) is as follows:

$$\ln L = \sum_i \left(I_i w_i \left[\ln\{\Phi(\eta_{1i})\} + \ln\{\phi(\varepsilon_{1i}/\sigma_1)/\sigma_1\} \right] + (1 - I_i) w_i \left[\ln\{1 - \Phi(\eta_{2i})\} + \ln\{\phi(\varepsilon_{2i}/\sigma_2)/\sigma_2\} \right] \right),$$

where Φ is a cumulative normal distribution function, □ is a normal density distribution function, w_i is an optimal weight for observation i, and

$$\eta_{ji} = \left(\gamma Z_i + \rho_j \varepsilon_{ji} / \sigma_j \right) \Big/ \sqrt{1 - \rho_j^2} \quad \text{j=1, 2.}$$

In this expression, $\rho_1 = \sigma_{1u}^2 / \sigma_u \sigma_1$ is the correlation coefficient between ε_{1i} and u_i, and $\rho_2 = \sigma_{2u}^2 / \sigma_u \sigma_2$ is the correlation coefficient between ε_{2i} and u_i.

Lokshin and Sajaya (2004) developed a Stata module *movestay*, which allows an implementation of the presented FIML. This module is applied for estimating the switching efficiency-PF technology choice regression model in this paper.

3.3 Data and variables

The study utilises survey data on 93 wheat producing Czech farms during the production year 2007/08[5]. These farms cultivate wheat, on average, on 28% of their total area and achieved yields of 6.31 tons per hectare. This is slightly higher than the national average of 5.77 tons per hectare. This figure reflects the favourable production conditions of selected farms which are mostly situated in two of the best agronomical zones for cereal and sugar beet production, both of which have an average altitude of 260 m.

[5] The data collection was carried out in 2009 within the project 'Economic system of evaluating farm performance with respect to sustainable use of natural resources', No.: QH71016, financed by the Czech National Agency for Agricultural Research.

The economic data shows that average per hectare costs were 16.9 thousand CZK (676 €), with unit production costs of 2,700 CZK/ton of wheat (107 €). Direct inputs - fertilisers, chemicals and seed - account for 8,301 CZK per ha, while fuels account for 2,177 CZK per ha, capital costs are 3,108 CZK per ha, and labour inputs are 1,148 CZK per ha. Individual per hectare input items are as follows: 0.57 tons of fertilisers; 3.2 kg of chemicals; 240 kg of seeds; 12.3 hrs of labour; 95 litres of fuels. The most intensively used machinery in the crop production - tractors - generates about 164,000 CZK (6,561 €) of costs, which means about 453 CZK (18 €) per ha of wheat. About one-fourth of seeds are purchased and the remaining portion is self-produced. The total amount of all nutrients applied to wheat was 150.5 kg per ha. The larger farm sizes predetermines that field spatial distribution in the sample is relatively high. There are up to 53 wheat fields per farm, with an average of 18 fields. Wheat field size is slightly greater than 30 ha.

This section specifies variables for both models. To make the structure of variables simpler, they will be presented in a tabular form. Table 1 describes variables included in the cost efficiency DEA model and Table 2 presents variables used for the specification of the endogenous switching regression. Table 2 includes two dependent variables for the first (efficiency) part of the model. For each of the variables, the model is estimated separately; the remaining variables are the same for both models. Note that the number of observations to be used in the switching regression decreases due to missing values in some of the variables.

Table 1. Cost efficiency DEA model variables from farm-level 2007/08 survey data (93obs.)

Variable abbreviation	Variable description (unit)	Mean	Stand. dev./ frequency	Min	Max
Output	Wheat production (thousand tons)	2,373.08	1,806.02	263.70	9,580.62
k input variables	k = 1,2,..., *K*, *K* = 5				
Chemicals	Fertilisers, chemicals and seed applied in wheat production (stand. unit)	505.28	410.62	27.46	2533.23
Fuel	Fuel consumed in wheat production (thousand litres)	32.22	26.89	1.56	142.11
Capital	Tractors used in wheat production (motor hrs)	1,142.40	719.08	180.00	2,970.00
Land	Total land used for wheat production (ha)	361.55	247.94	30.00	1,237.69
Labor	Total labor used in wheat production, incl. share of overhead labor (hrs)	4,083.41	3,230.95	370.50	23,541.60
k input price variables					
Price_chem	Fixed price for standardized unit (nitrogen fertilizer) (CZK/ton)	5,934.16	-	-	-
Price_fuel	Fixed price for standardized unit of fuel (gas) (CZK/litre)	24.60	-	-	-
Price_capital	Annual and wheat production share of total value of tractors (CZK/motor hrs)	169.33	119.97	13.17	684.47
Price_land	Paid rent for arable land (CZK/ha)	1,662.63	722.40	250.00	3,530.00
Price_labor	Fixed (to sample average) labour cost (CZK/hr)	125.82	-	-	-

Table 2. Variables in the endogenous switching efficiency-PF selection model (84 obs.)

Variable abbreviation	Variable description (unit)	Mean/ frequency	Stand. dev.	Min	Max
I. Efficiency equations *(for both regimes)*					
Dependent variable					
CE_tr	log transformation of CE measures	0.442	0.499	-0.632	1.607
AE_tr	log transformation of AE measures	1.254	0.725	-.132	4.701
Explanatory variables					
JSC	Legal form - joint stock company (yes = 1)[D]	26%	n.a.	0	1
Nr. owners	Number of owners	122	197	1	750
Land_rent	Rent paid for land (CZK)	1 680	771	250	4500
Share_crop	Share of crop production in total revenues (%)	72	24	19	100
Share_grass	Share of grass land in total land (%)	3	6	0	51
Field_prep_sow	Field preparation jointly with sowing as an alternative to separate operations (yes = 1)[D]	11%	n.a.	0	1
Fert_b.sowing	Fertilisation before sowing (yes = 1)[D]	49%	n.a.	0	1
Adopt_innov	Farm assessment of its use of technological innovations (1 = very bad, 4 = very good)[K]	2.8	0.62	1	4
Care_machin	Farm assessment of its standards regarding the taking care of machinery (1 = very bad, 4 = very good)[K]	3.18	0.49	1	4
Revenues	Total revenues (mio. CZK)	44.894	36.750	6.500	165.121
II. Technology selection equation					
Dependent variable					
PF-selection	Choice of PF (in fertilization) technology (yes = 1)[D]	42%	n.a.	0	1
Explanatory variables (all explanatory variables from I. part of the model + following variables)					
Probl_qualific	Farm assessment of its problems with labor qualification (0 = no problem, 3 = very large problem)[K]	0.81	0.81	0	3
Field_size	Average field size (ha)	25.5	14.5	6.8	81.1
Share_yield.dam	Estimated share of yield damage (%)	6.8	9.8	0	50

Note: [D] stands for a dummy variable; [K] stands for a categorical (scale) variable.

4 Results

DEA analysis delivered results implying that farms in the sample have, on average, the potential to reduce costs by 37%[6] (Table 3). The lower levels of allocative efficiency compared to technical efficiency scores imply that there is a greater potential for decreasing costs through correcting for input combinations (allocation) through different production practices (technologies) than in the radial (proportional) adjustment of input levels as captured by technical efficiency. Differences in all three efficiency scores between PF adopters and non-adopters suggest higher economic returns from precision farming. A two-group mean-comparison test, however, implies that these differences are statistically significant (at a 10% significance level) only in the technical efficiency scores[7].

[6] Despite the intention of collecting data in similar production regions, it needs to be pointed out that a share of the measured inefficiency is attributable to differences in production conditions among farms, which is mainly reflected in the technical efficiency scores. This is due to the deterministic nature of the DEA approach.

[7] This test is not indicative of the causality between efficiency and precision farming practices, nor of the fact that this relationship could not be significant when controlling for other efficiency-determining farm characteristics.

Table 3. Summary of technical, allocative and cost efficiency scores

Type of producers	Nr. Obs.	Mean	Stnd. dev.	Min	Max
TE - total farm sample	93	0.835	0.123	0.578	1.000
AE - total farm sample	93	0.758	0.112	0.467	1.000
CE - total farm sample	93	0.634	0.137	0.349	1.000
TE - PF non-adopters	55	0.818	0.128	0.578	1.000
AE - PF non-adopters	55	0.755	0.115	0.467	0.991
CE - PF non-adopters	55	0.619	0.143	0.361	0.991
TE - PF adopters	38	0.860	0.111	0.628	1.000
AE - PF adopters	38	0.763	0.109	0.531	1.000
CE - PF adopters	38	0.657	0.125	0.349	1.000

Deriving the cost-minimising level of inputs for each observation in the process of cost efficiency measurement also facilitates a closer look at the farm-level use of individual input categories. Table 4 illustrates ratios of actually observed to cost-minimising levels of inputs in given input categories for the sample average, as well as for the two farm groups - farms both adopting and not adopting PF. The table suggests that the most overused input categories are fertilisers and chemicals, and fuel. PF adopters overuse these inputs slightly less than PF non-adopters, which is in line with the more precise and thus reducing practice in fertiliser application. However, this difference is not statistically significant. A similar trend is found in the use of fuel. Compared to PF non-adopters, PF adopters consume fuel in wheat production that is significantly closer to the fuel cost optimum. This could relate to the fact that PF adopters use significantly newer[8] and more fuel-efficient machinery than PF non-adopters.

Interestingly, Table 4 further shows that both groups of farms use less than an optimal amount of capital, which could be given by the relatively low price of capital due to a high degree of machinery depreciation and the frequent (transition-specific) complimentary transfer of machinery from predecessor farms. This result could also relate to the approximation of capital used in this study, which is derived from the amount of tractor hours used in wheat production, and the annual value of these tractors derived from the value at purchase, while the volume of all machinery necessary for wheat production is markedly higher. The last statistically significant difference in the overuse of inputs can be found in land. The ratios in Table 4 suggest that farms applying PF techniques use lesser land for a given level of output than do PF non-adopters (achieve higher land productivity), and thus can be assumed to use land more intensively and. In line with the expectation regarding higher labour intensity of PF technology, PF adopters are, on average, found to use more labour than PF non-adopters. However, this difference is statistically insignificant. Overall, the input structure analysis suggests a positive effect of PF-technology on allocative efficiency given the input prices, which calls for a deeper analysis that will follow.

[8] The average age of tractors in the group of farms adopting PF practices is 9.3 years, while it is 11.7 years in the case of farms not adopting PF practices. The two-group mean comparison-test finds the difference significant at the 5% significance level.

Table 4. Mean statistics for the ratio of real to cost-minimising input levels

Input category	Sample total	PF non-adopters	PF adopters	p-value*
Nr. Obs.	93	55	38	
Chemicals (stand. unit)	1.996	2.055	1.911	0.273
Fuel (stand. unit)	1.742	1.887	1.534	0.047
Capital (motor hours)	0.917	0.929	0.899	0.851
Land (hectares)	1.303	1.349	1.238	0.013
Labor (hours)	1.468	1.388	1.583	0.203

Note: * p-value of the two-group (PF adopters and non-adopters) mean-comparison test.

The relationships between PF adoption and allocative and cost efficiency are further analysed by means of an endogenous switching regression model, the estimates of which are presented in Tables 5 and 7, respectively. Each table includes two models - a complete model, in which the first and second efficiency equations (for the two regimes - PF adoption and non-adoption) contain the same variables, and a more parsimonious model in which some of the most insignificant variables are eliminated to increase the overall fit of the model.

Table 5 presents estimates of the switching regression of the determinants of the PF selection and allocative efficiency. As indicated by the Wald test, both models - i.e. complete and more parsimonious - are overall well-fitted (at the 5% significance level). Since the more parsimonious model is more significant, we interpret the parameters of this model. Parameters of the first equation indicate that among farms adopting PF technology, the chosen legal form, particularly Joint Stock Company, has a positive impact on the level of allocative efficiency. This could relate to the specific capital and ownership structure of legal forms in agriculture related to the form of capital transformation. Joint Stock Companies often acquired more productive capital compared to cooperatives, and progressively invested in new technologies (see Curtiss et al. 2012). Furthermore, the number of owners increases allocative efficiency. This effect can also be observed in the second regime (group of non-adopters), as it is also statistically significant in equation 2. Therefore, the cost efficiency effect of the number of owners is independent of the adoption of PF technology. It is likely that the more owners a farm has, the higher is the share of employees who are simultaneously owners. In this case, the positive impact of the number of owners could approximate the positive incentive structure related to employee ownership. Land rental price, which is included in the model to mainly capture soil quality differences, is also found to have a positive impact on allocative efficiency. The positive effect could suggest that the price does not fully cover the productive potential of the soil. In other words, the increase in productive potential is not sufficiently reflected in the increase of land rental price. The fact that the effect of land rental is significant in the first equation could only suggest that the PF adopters are better at utilising the productive potential of the soil.

An unexpected estimation result is that, among PF adopters, the degree of specialisation in crop production has negative implications for allocative efficiency. A detailed data analysis revealed that farms specialising in crop production have a significantly higher capital value[9] than do farms with more diversified production. The higher value of tractors suggests better technical parameters and specialisation of machinery, which has a negative allocative efficiency effect within the group of farms adopting PF. This result could suggest that farms have difficulties to utilise the productive potential of more advanced machinery in relation to its price (the price productivity ratio increases faster for PF adopters that for PF non-adopters), which could relate to the issue of a longer learning curve.

[9] Note that only capital (tractors) applied in wheat production is (are) considered.

Total revenues also have a negative effect on allocative efficiency, in this case in both equations (thus, this is not a technology-specific effect). Further data analysis discloses that total revenues are highly correlated with farm arable land size. Most importantly, land rental prices increase with total revenues, which would suggest that for farms to achieve higher revenues, they had to acquire more land for which they had to offer competitive farm land prices. These farms were thus willing to pay higher prices for a comparatively similar quality of land (which significantly reduces allocative efficiency) to achieve economies of size. In line with this argument is the finding that the effect of revenues is insignificant in the cost efficiency model (economies of size do not outweigh the cost effect of higher land rental prices).

The efficiency model also delivers significance of parameters of two technological variables. The first variable, *Field_prep_sow* depicts an operation in which soil preparation and sowing is performed in one-step when compared to other methods of soil preparation and sowing (mainly as separate sequential operations). This variable's parameter is statistically significant (at the 10% significance level) only in the second allocative efficiency equation, which implies that among farms not applying PF technology, this one-step operation improves allocative efficiency. It is reasonable to expect that those who apply this management in soil preparation are more oriented on advanced practices also in other operations. On the contrary, the second variable *Fert_b.sowing*, representing fertilisation before sowing reduces allocative efficiency in both models. This suggests that this type of fertilisation results in excessive costs, and this cost-increasing effect due to input allocation is not specific for either PF adopters or non-adopters. The size of the negative effect of the fertilisation before sowing is smaller for PF adopters.

The third part of the allocative efficiency-PF switching regression model in Table 5 will be interpreted together with this part of the cost efficiency-PF switching regression model in Table 6.

Important for the interpretation of the allocative efficiency-PF switching regression in Table 6 is the likelihood ratio test of independent equations, which estimates whether the selection bias adjustment is significant. The statistical insignificance of the test suggests that the allocative efficiency and PF adoption models are not jointly determined, and that the allocative efficiency effects of the PF technology themselves do not determine the selection of PF adoption.

Estimates presented in Table 6, however, suggest that the results are different for the cost efficiency-PF relationship. The Wald test of equations' independence is significant at the 10% and 5% significance levels in the complete and more parsimonious models, respectively. Note that this significance is related to the relationship between the PF-adoption equation and the (second) cost efficiency equation for PF non-adopters as depicted by the statistically significant correlation coefficient ρ_2. This suggests that farms choosing not to adopt PF fertilising methods would achieve lower cost efficiency than a random farm from the same sample would have achieved with the non-PF technology. Farms adopting PF fertilisation do statistically no better or worse than a random farm would have.

Table 5. ML estimates of endogenous switching regression model of allocative efficiency and precision farming (84 observations)

	Complete model						**More parsimonious model**					
	Allocative eff. eqn. 1 (PF adopters)*		Allocative eff. eqn. 2 (PF non-adopters)*		PF choice equation		Allocative eff. eqn. 1 (PF adopters)*		Allocative eff. eqn. 2 (PF non-adopters)*		PF choice equation	
	Par. Est.	P-value	Par. Est.	P-value	Par. Est.	P-value	Par. Est.	P-value	Par. Est.	P-value	Par. Est.	P-value
JSC	0.439	0.053	0.090	0.663	0.109	0.762	0.461	0.028	-	-	0.176	0.622
Nr. owners	0.061	0.113	0.076	0.096	0.008	0.927	0.064	0.093	0.086	0.029	0.014	0.870
Land_rent	0.310	0.090	0.235	0.099	-0.139	0.506	0.340	0.074	0.215	0.156	-0.150	0.490
Share_crop	-0.912	0.038	-0.326	0.446	0.386	0.597	-0.939	0.019	-	-	0.612	0.428
Share_grass	-0.564	0.901	-1.421	0.114	-3.527	0.456	-	-	-1.132	0.136	-4.429	0.337
Field_prep_sow	0.250	0.461	0.718	0.079	-0.539	0.474	0.319	0.238	0.718	0.082	-0.474	0.504
Fert_b.sowing	-0.419	0.111	-0.486	0.125	0.573	0.117	-0.450	0.072	-0.574	0.059	0.471	0.163
Adopt_innov	-0.105	0.594	0.132	0.451	0.399	0.205	-	-	0.145	0.454	0.412	0.201
Care_machin	0.029	0.892	0.225	0.387	0.408	0.276	-	-	-	-	-	-
Revenues	-0.010	0.016	-0.006	0.043	0.010	0.077	-0.011	0.004	-0.006	0.088	0.011	0.071
Probl_qualific	-	-	-	-	-0.335	0.272	-	-	-	-	-0.408	0.105
Field_size	-	-	-	-	0.022	0.062	-	-	-	-	0.022	0.060
Share_yield.dam	-	-	-	-	0.056	0.003	-	-	-	-	0.057	0.003
Constant	2.423	0.001	0.472	0.623	-4.071	0.007	2.173	0.000	0.938	0.054	-2.870	0.007
Wald test of fit			19.23	0.037					17.49	0.015		
Wald test of indep. equations			0.63	0.426					0.75	0.385		
ρ_1 (stnd. dev.)			-0.611	0.678					-0.557	0.529		
ρ_2 (stnd. dev.)			0.337	0.709					0.243	0.802		

Note: Values of cost efficiency are log transformed to gain a more normal distribution. The robust Huber/White/sandwich estimator of the variance is used in place of the conventional MLE variance estimator; *AE_lt is the dependent variable.

Table 6. ML estimates of endogenous switching regression model of cost efficiency and precision farming (84 observations)

	Complete model						More parsimonious model					
	Cost efficiency eqn. 1 (PF adopters)*		Cost efficiency eqn. 2 (PF non-adopters)*		PF choice equation		Cost efficiency eqn. 1 (PF adopters)*		Cost efficiency eqn. 2 (PF non-adopters)*		PF choice equation	
	Par. Est.	P-value	Par. Est.	P-value	Par. Est.	P-value	Par. Est.	P-value	Par. Est.	P-value	Par. Est.	P-value
JSC	0.604	0.004	0.300	0.203	0.165	0.640	0.567	0.011	0.245	0.314	0.131	0.700
Nr. owners	0.069	0.142	0.127	0.009	0.031	0.696	0.062	0.192	0.142	0.006	0.034	0.671
Land_rent	0.170	0.018	0.227	0.114	-0.130	0.608	0.160	0.010	0.237	0.178	-0.123	0.616
Share_crop	-0.754	0.065	-0.386	0.377	0.385	0.627	-0.789	0.017	-	-	0.566	0.399
Share_grass	-5.520	0.024	-1.469	0.063	-4.337	0.332	-5.040	0.048	-1.447	0.062	-3.830	0.363
Field_prep_sow	0.466	0.046	0.559	0.294	-0.462	0.575	0.442	0.077	-	-	-0.787	0.349
Fert_b.sowing	-0.356	0.196	-0.265	0.236	0.571	0.093	-0.289	0.175	-	-	0.684	0.029
Adopt_innov	0.224	0.226	0.316	0.074	0.382	0.259	0.212	0.224	0.214	0.138	0.303	0.369
Care_machin	-0.115	0.619	0.233	0.320	0.332	0.358	-	-	0.317	0.217	0.384	0.277
Revenues	-	-	-	-	0.012	0.090	-	-	-	-	0.012	0.033
Probl_qualific	-	-	-	-	-0.502	0.029	-	-	-	-	-0.526	0.017
Field_size	-	-	-	-	0.021	0.230	-	-	-	-	0.023	0.162
Share_yield.dam	-	-	-	-	0.057	0.023	-	-	-	-	0.058	0.016
Constant	0.588	0.624	-0.971	0.267	-3.713	0.016	0.237	0.718	-1.232	0.151	-3.862	0.010
Wald test of fit			34.41	0.000					32.30	0.000		
Wald test of indep. equations			2.85	0.091					4.72	0.030		
ρ_1 (stnd. dev.)			0.164	(0.971)					0.247	(0.771)		
ρ_2 (stnd. dev.)			0.560	(0.290)					0.657	(0.234)		

Note: Values of cost efficiency are log transformed to gain a more normal distribution. The robust Huber/White/sandwich estimator of the variance is used in place of the conventional MLE variance estimator; *CE_lt is the dependent variable.

In this context, switching regression allows us to use the parameters for the PF adopters equation to predict the cost efficiency values for the PF non-adopters, were they to adopt the PF practice, and vice versa. This results in four sets of predicted values for cost efficiency that are summarised in Table 7. The hypothetical predictions assume that the coefficients obtained in the switching regression for PF adopters would apply to PF non-adopters were they to apply the PF technology, and analogically, the coefficients obtained for PF non-adopters would apply to PF adopters were they to revert.

Table 7. Summary of predicted values for cost efficiency

	Type of producers	Mean	Stnd. dev.	Min.	Max.
1.	PF adopters (in PF mode)[1)]	0.651	0.069	0.495	0.797
2.	PF adopters (in non-PF mode)[2)]	0.805	0.060	0.680	0.917
3.	PF non-adopters (in PF mode)[2)]	0.603	0.118	0.156	0.802
4.	PF non-adopters (in non-PF mode)[1)]	0.640	0.086	0.438	0.840

Note: [1)] predictions of real state, [2)] predictions of hypothetical state.

The results in Table 7 show that the average predicted cost efficiency for the PF non-adopters in their real regime (line 4) is higher than their level of cost efficiency for the hypothetical situation, i.e. were they to apply PF (line 3). Adopters of PF would do much better were they to return to non-PF technology (line 2), however, their predicted cost efficiency values (line 1) still accede the cost efficiency of PF-non adopters (line 4). This could imply that only more cost efficient farms are willing to undergo losses of new-technology adoption as they expected to do better than a random farm and improve in the course of the learning curve. These results support the expected self-selection into the technology. However, only the proof of self-selection of less efficient farms into conventional (non-PF) technology is statistically significant.

The differences in the parameters of the first two equations in Tables 5 and 6 are related to the technology-specific effects of the selected variables on technical efficiency, the second component of cost efficiency. One of the differences refers to the effect of revenues. Total farm revenues as a proxy for farm size were found to have a highly insignificant effect on cost efficiency in both equations[10]. This suggests that the negative effect of revenues on overall cost due to related allocative inefficiencies is eliminated by their positive effect on technical efficiency, likely due to associated economies of scale. Analogous to the allocative efficiency model, the legal form of Joint Stock Company and land rent continue to have a significant positive effect on overall cost efficiency among PF-adopters. The parameter for the number of owners lost its significance in the first equation; however, it is still significant in the second equation. Among PF adopters, specialisation in crop production also has a negative implication for overall cost efficiency. Contrary to the allocative efficiency model, the share of grass land in total cultivated land has a significant negative effect for total cost efficiency in both equations. Land has been turned into grass land mainly in less favourable areas for agricultural production, which suggests that the share of grass land could proxy for the farm producing in worse production conditions. In contrast to previous results, the negative effect of the technological operation of applying fertilisers before sowing is not significant for cost efficiency, and carrying out sowing jointly with field preparation has a positive effect for cost efficiency only within the PF regime.

[10] In combination with the variable Land_rent, the variable Revenues caused a collapse of the model. The model with Revenues, without the variable Land_rent, provides good estimates; however, the parameter for Revenues is highly insignificant. On the other hand, the model with Land_rent without Revenues is overall better fitted, and the parameter for Land_rent is statistically significant, as shown in Table 6.

Finally, we interpret the parameters of the PF adoption model. We focus on the estimates presented in Table 6, since the overall fit of the cost efficiency-PF switching regression, when compared to the allocative efficiency-PF switching regression, is greater (see the Wald test statistics). Similar to Khanna (2001) or Khanna, Epouhe and Hornbaker (1999), we find that farm size (revenues) and human capital[11] positively increase the farms' likelihood of adopting PF technology. The propensity of PF adoption also increases with the estimated yield damage due to seasonal weather conditions, which could indicate that farms experiencing greater yield volatility are more likely to adopt PF technology, or they are more likely to adopt the technology because they have a greater capacity to estimate yield responses to changing weather conditions. The last significant parameter in the PF choice model is the parameter for the variable fertilisation before sowing. This result suggests that farms that are more concerned with soil nutrition sufficiency are more likely to adopt PF in fertilisation, since the results of some of the steps in fertilisation (incl. the first productive fertilisation) are known to be sensitive to the application method.

5 Conclusion

This paper examines the economic implications of adopting the variable-rate application of fertilisers and the determinants of adopting this PF technology utilising data from Czech wheat farms during the 2007/08 production year. Economic indicators are represented by cost efficiency and its two components - technical and allocative efficiency - which allows for a separation of the PF technology-related allocative cost effect due to changes in input structure with regard to price relations, and the technical efficiency effect that embodies the cost differences due to technology-specific ratios of the real to technically optimal input levels. The relationship between PF adoption and efficiency scores is analysed by means of a one-step endogenous switching regression.

The efficiency analysis revealed that there are marked potentials for cost efficiency improvements among the analysed farms. The greatest inefficiencies are found in the use of variable inputs (fertilisers and chemicals) and fuel. Significant differences in input use optimality (input productivity) between PF technology adopters and non-adopters are found in the use of fuel and land, with PF adopters showing higher partial productivities. Results on overall efficiency scores also show that PF adopters can be characterised as more efficient. However, as estimates of the switching regressions suggest, the causal relation is not straightforward.

The results of the first endogenous switching regression disclose statistical independence between the determination of allocative efficiency and the PF technology choice. The results thus do not confirm the self-selection hypothesis with regard to the expected efficiency influencing the PF technology choice when only allocative efficiency (effect of technology-related input structure change) is considered. Despite the expected negative impact of PF technology on allocative efficiency due to the intensification of information/knowledge and machinery innovation, the PF technology is found to have overall rather a positive effect on allocative efficiency given the input prices in the Czech market during the analysed period. The allocative efficiency increases relate mainly to the fact that the PF technology significantly increases the farms' ability to abstract the soil's productive potential, while land prices remain the same for PF adopters and non-adopters.

Contrary to the relationship between allocative efficiency and PF technology choice, total cost efficiency and the technology-choice regressions are found to be significantly dependent. The estimates show that farms not adopting PF practices do significantly better without the

[11] In our case, human capital is approximated by problems with workers' qualification, for which the parameter estimate is negative.

technology switch than if they were to adopt the PF technology. Similarly, farms adopting the PF technology are found to display lower cost efficiency in reality when compared to a hypothetical situation of non-adopting the technology. However, these differences are found to be insignificant. Also, the PF adopters' predicted cost efficiency values in the PF adoption regime are still higher than the predicted cost efficiency values for PF non-adopters in their real non-adoption regime. In general, the results suggest that less efficient farms are less likely to adopt PF technology, as they expect increases in overall costs given their production conditions and/or managerial and technical skills. In line with this argument, it was found that a farm's problems with workers' qualifications, which represents lower human capital, significantly decreases the likelihood of PF adoption. On the other hand, a farm size generating economies of scale is a factor that increases the farm's propensity of choosing PF technology.

The impact of PF technology is mainly observed through changes in the allocative and total cost efficiency effects of some farm characteristics and accompanying technological practices. Precision Farming technology makes the farm cost efficiency more responsive to land quality and more sensitive to production conditions, farm specialisation, as well as legal form and other technological practices such as one-step field preparation and sowing.

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The assessment of the effects of investment support measures of the Rural Development Programmes: the case of the Czech Republic

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Abstract

The investment support has been considered as a principal vehicle for enhancing competitiveness of the Czech agriculture since the early days of the economic transition. However so far, little attention has been paid to the evaluation of actual effects of the corresponding support programmes. The objective of this paper is to assess economic and other effects of the measure 121 "Modernisation of Agricultural Holdings" of the RDP 2007-2013 on the Czech farms. The counterfactual approach is adopted investigating what would have happened if the supported producers did not participate in the programme and then comparing the result indicators. The quantitative analysis of programme effects is complemented by a qualitative survey on 20 farms which received the investment support between 2008 and 2010. The quantitative assessment showed significant benefits of the investment support in terms of business expansion (GVA) and productivity (GVA/labour costs) improvements. These results were confirmed by the qualitative survey. It showed that production expansion and productivity increase were primary objectives of the investment strategies on most of the farms. The public support enabled farms to achieve these strategic objectives. The respondents of the survey declared that the supported investment was important for their prosperity however, we could not prove it in the quantitative assessment in terms of profit and cost/revenue ratio. Finally, the issue of deadweight of the investment support is discussed: the figures on very low net investment relatively to the provided public support at the sector level and answers of respondents indicate possible significant deadweight, however, the insight is incomplete, since it does not take into account post accession restructuring of the sector and multiannual and multi-enterprise character of investment at the farm level.

Keywords: Investment support, counterfactual analysis, propensity score matching, direct and indirect effects
JEL Classification: Q10, Q18

1. INTRODUCTION

The objective of the paper is to assess economic and other effects of the measure 121 "Modernisation of Agricultural Holdings" of the Rural Development Programme (RDP) 2007-2013 and the similar one of the Operational Program - Agriculture (OP), 2004-2006 on the Czech farms.

The investment support has been considered as a principal vehicle for enhancing competitiveness of the Czech agriculture since the early days of the economic transition. However so far, little attention has been paid to the evaluation of actual effects of the corresponding support programmes. In the 1990s, the success of the interest subsidies for investment credits was justified practically only by the high participation rate and the "improved" level of the sector gross fixed capital formation (Trzeciak-Duval 2003, Janda 2006, Čechura 2008). The need for a more rigorous assessment arrived with EU development programmes: SAPARD, OP Agriculture and RDP 2007-2013. The considered quantitative indicators for the programme assessment are stated in the Common Evaluation a Monitoring Framework (CMEF, EC 2006). They are structured according to the Intervention Logic concept in input, output, result and impact indicators.

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There are two serious problems of CMEF and the EU evaluation guidelines which eventually might lead to wrong conclusions on the success of the programme: i) it is impossible to associate the result and impact indicators (as GVA/GDP) only with policy intervention, since there are number of other factors and circumstances affecting the results; ii) usually, policy measures either target or are exploited by only some groups of producers/regions, etc., which makes simple comparisons between supported and non-supported groups methodologically problematic (Michalek, 2007). To deal with these shortcomings we adopted the counterfactual approach investigating what would have happened if the supported producers did not participate in the programme and then comparing the result indicators (Khandaker et al. 2010). Since it is principally impossible to observe on the same farm the effects of participation and non-participation in the measure, one has to choose or to construct a control farm with identical characteristics from the pool of non-participating producers. To do this we follow propensity score matching approach (PSM, Caliendo and Kopeinig, 2005).

The paper is structured in six paragraphs: In the next paragraph we will review the investment support policy of the Czech Republic. Paragraph 3 is devoted to the adopted methodology and in Paragraph 4 we are presenting the quantitative assessment results. To get better notion of the actual investment projects and to learn about their effects on farmers and about problems with their implementation we conducted 20 case studies; these are described in paragraph 5. Afterwards, both results are compared and conclusions are drawn (paragraph 6).

2. INVESTMENT SUPPORT

From the beginning of agricultural transition it was clear that there were not sufficient funds on farms to assure a prompt recovery of the sector. In the early 1990s, the Czech government provided generous investment grants mainly to the emerging family farms. Later, the policy concentrated on improving access of farms to credits by providing interest subsidies and guarantees. The latter referred to a problem of lack of collateral; most of the assets was of doubtful value if the sector declined, while land was owned by external restituents or by the state (Janda and Ratinger 1997). The interest rate subsidy was a principal investment support measure until the EU accession, but even after that it has continued until now.

Gross fixed capital formation (GFCF) is a basic indicator of the investment activity in the Economic Accounts for Agriculture. GFCF of the agricultural sector varied substantially in absolute and relative[2] terms over last decade (**Chyba! Chybný odkaz na záložku.**). It can also be seen from **Chyba! Chybný odkaz na záložku.** that agricultural GFCF is correlated with the credit support of the Support and Guarantee Fund for Farms and Forestry (SGFFF) at least until the EU accession. It is also worth to note that the amplitudes of agricultural GFCF are larger than those of the SGFFF support. It can have two explanations: first, the public support (SGFFF) encouraged also private investment activity; and second, the investment activity also reflects the sector and overall economic situation: post-privatisation stabilisation in in the late 1990s, accession expectations[3] in 2001-2003 and the recent financial crisis of 2008-2009.

The new impulses for investment activity have gradually come with the EU accession: new market opportunities resulting from joining the common market, financial stabilisation of farms given by increasing direct payments and finally the investment grants provided by the rural development programme.

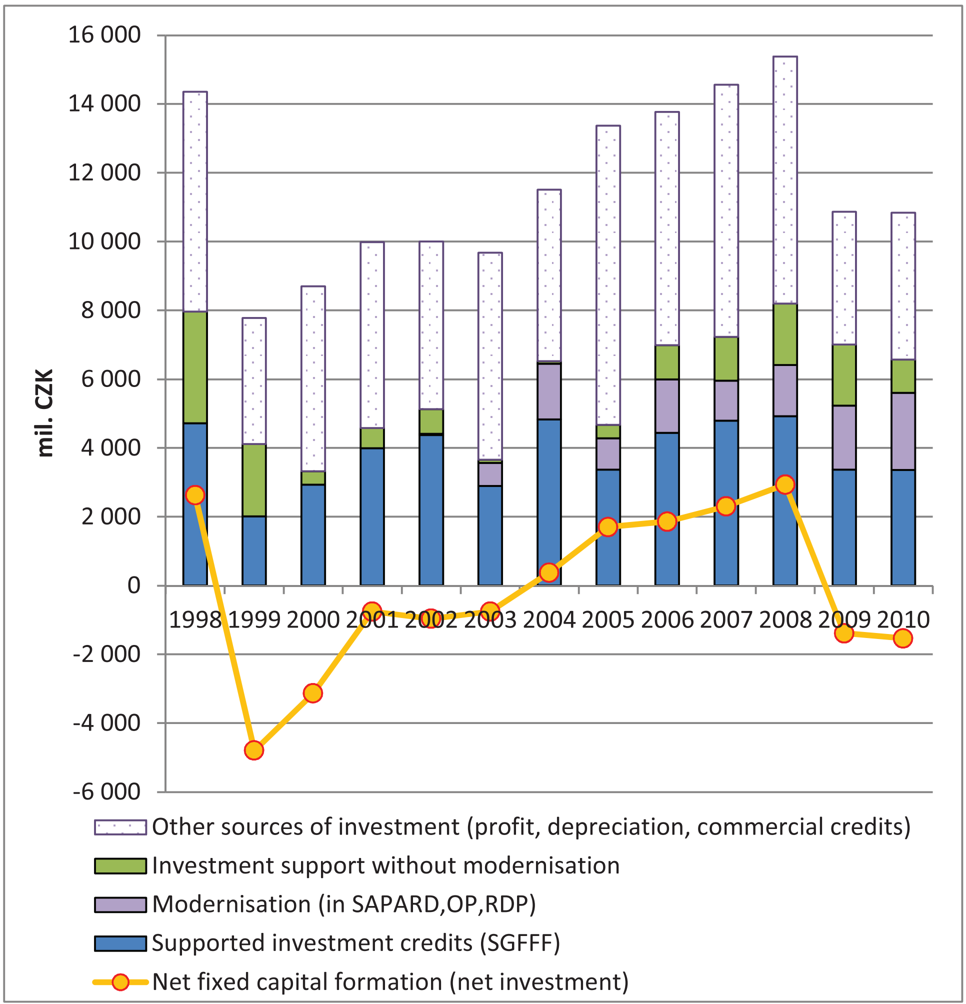
According to Bašek et al. (2010) integration in the common market can be seen as a driving factor of markedly increasing specialisation of farms: Growing specialisation in filed crops can be observed in good soil and climatic conditions. Growing concentration of dairy cow herds can also be noticed - not

[2] In respect to the total GFCF.

[3] Including the need to comply with "acquis", production expansion for creating a solid reference base, etc. One should also note that these years farmers got generous compensations for bad harvests caused by disastrous weather.

necessarily in specialised dairy farm, it usually mixed production system, however the dairy units are big and usually one of the main enterprises on the farm. Pig production has left common farms and nowadays it is concentrated in big specialised pig production companies; overall pork meet production declined continuously and dramatically over the last decade. In contrast beef cattle emerged on mountain and sub-mountain grasslands, however, these are truly product of the policy; market opportunities just determine the intensity. This specialisation trend has been also reflected in the investment activity.

Figure 1 Investment activity in agriculture 1998-2010



Source: CzSO (EAA), PGRLF, SZIF

Direct payments have stabilised farm income. In a consequence, it enabled corporate farms to pay off their restitution liabilities. They improved financial credibility of family and corporate farms vis-à-vis banks and input suppliers. Thus, they are likely behind the increasing investment activity between 2004 and 2008 (see

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Figure 1). We can see that during this period, farms invested above the reproduction (net investment – yellow line in

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Figure 1) while in most other years capital stocks declined.

Investment grants returned in the policy with SAPARD[4], but funds were rather limited. Since the EU accession they have become the main form of the investment support; in 2004-2006 the investment support was included in the Operational Programme for Agriculture, in the current period, it is the main tool of the Axis 1 of the Rural Development Programme (measures 121, 123, 124). While the measure 121 (Modernisation of agricultural holdings) has attracted farmers to the extent that its budget was increased already twice; the other two measures (123 - Adding value to agricultural and forestry products and 124 Cooperation for development of new products, processes and technologies in the agriculture and food sector and the forestry sector) have been considered as too demanding, their potential has been somehow hidden for farmers.

Returning to

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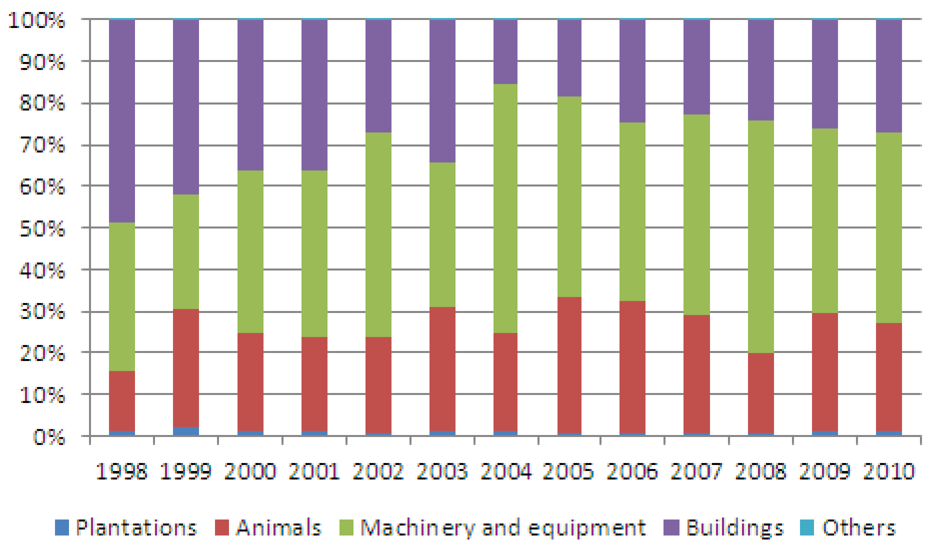
Figure 1 it is evident that the investment support might stimulate investment over the reproduction of capital only in 1998, and in the period shortly after accession (2004-2008). Given the fact that in best years, net investment might constitute only about a third of supported investments (thus the rate of public co-financing) we can conclude there was no or only very little additionality achieved by the policy. In the 1990, the policy declared as its objective to assure reproduction of agricultural capital, however, since the EU accession additionality has deemed to be achieved.

Most of the investment (more than 40%) goes to machinery and equipment (post-harvest processing, milking cooling equipment etc.). Investment in buildings dropped from almost 50% in 1998 to less than 30% in the recent years. Farmers' investment in breeding animals account for 20 to 30 per cent (Figure 2). The emphasis on machinery and equipment in the investment structure might indicate that farmers are more concerned of labour productivity than of the other possible effects of modernisation through investment. Nevertheless, it would be hard to assert that the other two main directions of

[4] Special Accession Programme for Rural Development

investment activity are undervalued; rather we can stress that the sector might have become saturated in terms of agricultural buildings (storages, sheds) and that breeding animals are regularly replaced.

Figure 2 Investment structure

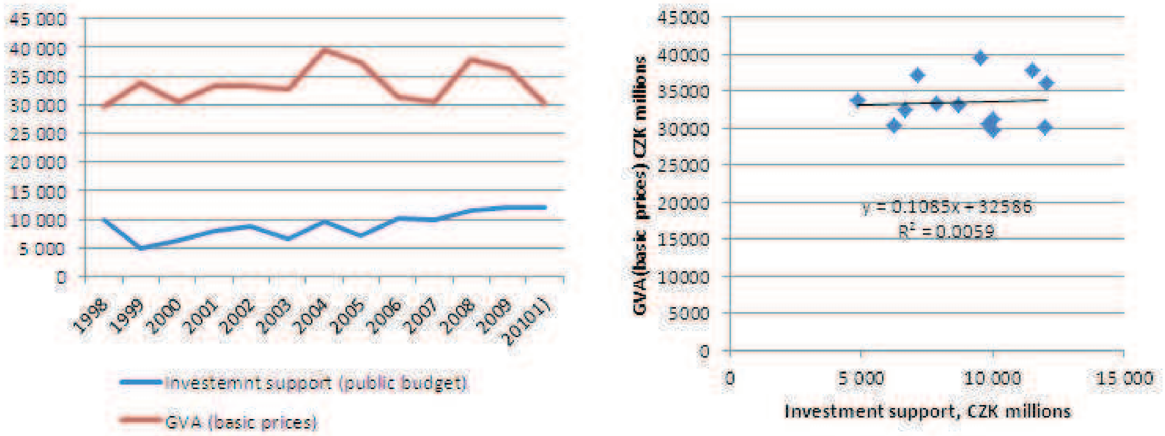


Source: CzSO (EAA)

In spite of the contraction of the Czech livestock production, most of the modernisation support went in the livestock sectors, particularly in the dairy enterprises (2008-2010) – see Table 2. It is because there were essential needs (welfare, manure storage and treatment) and because there are significant immediate and tangible benefits from modernisation (higher yields, higher quality, reduction of (hired) labour, improved health of animals – thus lower variable costs).

Linking the investment support (of all kind) to the performance of the agricultural sectors will provide a preliminary notion about the effect of the support. Such a brief analysis is illustrated in Figure 3.

Figure 3 Investment support and sectoral GVA



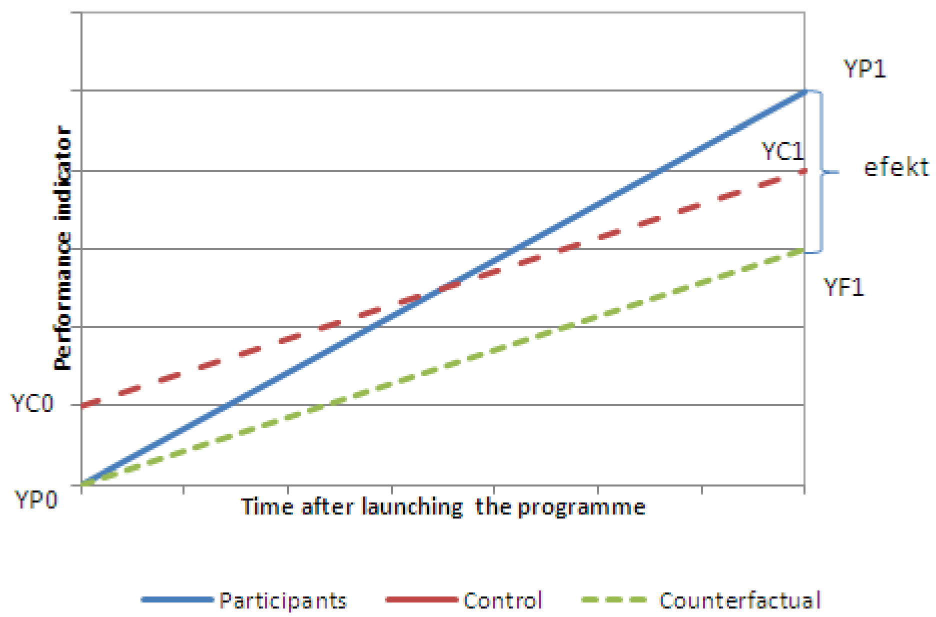
Source: CzSO (EAA)

From the first look (on the left chart), there is no evident effect of the support programme on the sectoral GVA. The simple statistical analysis (linear regression in the right chart) indicates that there might be about 10% of the investment support projected immediately in the agricultural GVA. However, the model is not statistically significant. Also, one should consider a delay of an investment effect. A simple shift of the effect of two or three years, however; does not lead to a significant relationship. It is evident that the sector approach is insufficient for the investment programme assessment.

3. METHODOLOGY

The above figures on the support programmes and the sectoral GVA indicate the difficulties (the ambiguity) of the judgement of the policy effectiveness and efficiency. There is therefore a need for methods and approaches which enable the evaluator to assess precisely the mechanisms by which beneficiaries are responding to the intervention. These mechanisms can include links through markets or improved social networks as well as tie-ins with other existing policies (Khandker, et al. 2010). To prove that changes in targets are due only to the specific policies undertaken the counterfactual approach is needed. It is illustrated in Figure 4. The performance of farms participating in an investment support programme (treated) improved from YP0 to YP1. The simple "before and after" comparison (YP1 – YP0) can hardly be accounted only to the programme, if there are changes in the performance independent of the programme as it is witnessed by the performance of non-participating (control) farms which also changed from YC0 to YC1 over the same period. However, neither the difference YP1-YC1 necessary represents a correct judgement of the effect of the programme, because it is likely that participating and non-participating groups differ in their structures and pre-programme situations (Khandeker, et al. 2010). The real effect can only be obtained if we know the counterfactual outcome YF1 i.e. what would happen if there was no programme. However, this is principally impossible, hence one has to find an estimate.

Figure 4 The idea of the counterfactual



Source: Khandker et al. (2010)

The standard framework in evaluation analysis to formalise the above problem provides Roy-Rubin-model (Caliendo, Kopeinig, 2005). Let D_i denotes a treatment indicator which equals one if individual i receives treatment and zero otherwise. The potential outcomes are then defined as $Y_i(D_i)$ for each individual i, where i = 1…N and N denotes the total population. The average treatment on treated (ATT) effect is defined as follows

$$\tau_{ATT} = E[\tau|D=1] = E[Y(1)|D=1] - E[Y(0)|D=1] \qquad (1)$$

The second term on the right hand side of Equation (1) is the counterfactual, however, unobservable. Instead we have to use E[Y(0)|D=0]. The effect τ_{ATT} is truly identified if and only if

$$0 = E[Y(0)|D=1] - E[Y(0)|D=0]; \qquad (2)$$

The right hand term of Equation (2) is called self-selection bias. In non/experimental data, the condition of zero self-selection bias is usually not achievable, statistical methods have to be used to estimate the average treatment effect on treated (τ_{ATT}). In this paper we adopted propensity score matching (PSM).

Assume that there is a set of observable variables X which are not affected by treatment and that potential outcomes are independent of treatment assignment, i.e.

$$Y(0), Y(1) \perp D|X, \forall X; \qquad (3)$$

This condition is known a "unconfoundedness" or conditional independence assumption. Let us defime the propensity score P(D = 1|X) = P(X), i.e. the probability for an individual to participate in a treatment given his observed variables X. The unconfoundedness condition can be rewritten as

$$Y(0), Y(1) \perp D|P(X), \forall X; \qquad (4)$$

As it was showed by Rosenbaum and Rubin (1983). A further requirement besides independence is the common support or overlap condition:

$$0 < P(D_i = 1|X_i) < 1, \text{ for some } i; \qquad (5)$$

which ensures that there are persons with which have positive probabilities to participate as well as to stay outside. The PSM estimator of the treatment effect on treated is then defined as

$$\tau_{ATT}^{PSM} = E_{P(X)|D=1}\{E(Y(1)|D = 1, P(X)) - E(Y(0)|D = 0, P(X))\}; \qquad (6)$$

We can understand the PSM estimator of τ_{ATT} as a mean difference in outcomes over the common support, appropriately weighted by the propensity score distribution of participants (Caliendo, Kopeinig, 2005). From the number of methods available for construing the PSM estimator we have chosen nearest neighbor (NN) matching and kernel matching.(KM) Nearest neighbor matching. Is the most straightforward approach; the individual from the comparison group is chosen as a matching partner for a treated individual that is closest in terms of propensity score. One of the disadvantages of NN matching is that only a few observations from the comparison group are used to construct the counterfactual outcome of a treated individual. Kernel matching (KM) is a non-parametric matching estimator that uses weighted averages of all individuals in the control group to construct the counterfactual outcome. Following Smith and Todd (2005), ATT effect estimator (6) can be rewritten

$$\tau_{ATT}^{PSM} = \frac{1}{N_T}\left[\sum_{Di=1} Y_i(1) - \sum_{Dj=0} w(i,j) Y_j(0)\right] \quad (7)$$

where N_T denotes the number of treated (participating in the programme). In the case of KM the weights w(i.j) are defined as follows

$$w(i,j) = \frac{K\left(\frac{P(X_j)-P(X_i)}{a}\right)}{\sum_{D_k=0} K\left(\frac{P(X_k)-P(X_i)}{a}\right)}; \qquad (8)$$

Where *K* is a kernel function and *a* is a bandwidth parameter. Note that kernel matching is analogous to regression on a constant term (Khandker et al. (2010)). The main advantage of this approach is the lower variance due to more information used. A drawback of it is that possibly observations are used that are bad matches. Therefore, good overlap is of major importance for KM.

The quantitative analysis of effects is completed by 20 case studies. The qualitative survey (interviews with the farm manager) concentrated not only on the manager's subjective assessment of economic benefits from the investment support but also on the non-economic effects as improved animal welfare or working conditions, the farm business development strategy and how the supported investment fits in it, motivations and information gathering for the given investment project, the use of advisory services and the cooperation with research.

We used several sources of data on farm characteristics and performance - CreditInfo database, LPIS, data on agricultural supports published by SZIF[5]. CreditInfo is main source, it is a database built on annual reports of companies (large legal entities) which are oblige by the Commercial Code to publish their economic and book keeping figures. CreditInfo includes only large farms and only financial indicators. From LPIS we linked information on utilised agricultural area and on land use.
All calculations are done in STATA 11.

[5] State Intervention Fund for Agriculture, the paying agency.

To get a deeper insight in the process and effects of investment support we selected 20 representative projects in respect to investment size, legal form of investor farm, type and direction of supported investment. On this small sample we conducted qualitative research aimed at business and investment strategies, the importance of the support for implementing the strategy, business environment and effects of the investment for modernisation. For this purpose we elaborated a questionnaire which included 28 questions structured in 7 blocks (Table 1). The respondents were asked to state their qualitative judgement on the investigated issue either on the 3 or 5 point scale[6] or by ordering pre-defined judgments or reasoning.

Beside filling the questionnaire the interview included free discussion on the implementation process, and lessons learned, and the excursion to the investigated investment. While the questionnaire was usually filled by the top manager, during the excursion we met also other management staff and workers associated with the given investment.

Table 1 Structure of the questionnaire for a qualitative survey.

Block	Questions	Content
I	A	Characteristics of the project holder
II	B-G	Current and past investment strategy
III	H-L, P	Project description including motivations
IV	M-N	Preparation of the project and of the application for a support
V	O, Q-Z	The assessment of project benefits, of fulfilments of expectations, …
VI	AA	Future investment strategy
VII	BB-CC	Business environment for investment

4. RESULTS OF THE QUANTITATIVE ASSESSMENT

The analysis concentrated on measure 121 of the current Rural Development Programme[7]. The modernisation targets (investment directions) are summarised in Table 2 below. Most of the support was directed in the livestock sector in terms of numbers (57%) as well as in terms of funds (72%). This bias against the livestock sector results from needs of applicants (see section 2) as well as from policy preferences – projects for modernization of the livestock production got additional points in the evaluation score. The structure of applicants follows the structure of farming and its geographical distribution; livestock production is concentrated more in less favoured areas and in a similar proportion are the applicants. Surprisingly, there is higher share of young farmer applicants for crop production projects than in the case of livestock production.

Table 2 Investment objects of measure 121 "Modernisation of agricultural holdings" 2008-2010

[6] 1-poor, 3 or 5 – excellent.

[7] i. e. RDP for period 2007-2013.

Investment object	Completed p #	Support budget CZK million	Individual	Corporate	in LFA	Young
Livestock	972	2149	32%	68%	69%	20%
Buildings	593	1363	33%	67%	67%	22%
of it dairy cow sheds	122	410	40%	60%	64%	11%
Technique and technology	126	195	27%	73%	63%	14%
Storages for secondary products	105	212	21%	79%	70%	12%
Crop prodution	392	779	39%	61%	27%	32%
Buildings	266	582	43%	57%	23%	37%
Machinery and equipment	126	197	29%	71%	33%	24%
Other	21	52	38%	62%	62%	10%
Total	1385	2980	34%	66%	57%	24%

Source: SZIF

In the CreditInfo database we identified 844 agricultural businesses which were included there with all economic figures for all four years of the period 2007-2010. About a third of them (291) were awarded an investment grant of the Czech RDP (measure 121) within this period; actually between 2008 and 2010, because no project was completed in 2007[8]. We lack the details about the investment directions of 291 supported farms included in the database CreditInfo, however it is very likely that their supported modernisation follows the same pattern as the population of farms participating in Measure 121 (Table 2).

There are significant differences between participating and non-participating farms in the CreditInfo sample: the average utilised agricultural area of participating farms is substantially greater (1826 ha) than the one of non-participants (1084 ha)[9]. I terms of assets[10] the difference is even deeper: the average value of assets is more than twice higher in the sample of participants than in the sample of nonparticipants, and the figures per hectare are CZK 83,882 and CZK 58,518 on participating and non-participating farms respectively. It indicates that participating farms are on average not only substantially larger but also much more capital and labour intensive than non-participating ones (see Table 3 for details). On the other hand, we can show that variation in both sub-samples is quite high and among non-participants significantly higher (for example the coefficient of UAA variation[11] is 0.71 for participants and 0.82 for non-participants). In fact high variation is positive for matching, since we likely find similar farms in the both sub-samples.

Table 3 Characteristics of participating and non-participating farms in the CreditInfo sample

Indicator	Unit	2007 Participating	2007 Non-particip.	2010 Participating	2010 Non-particip.	Index 2010/2007 Participating	Index 2010/2007 Non-particip.
Total assets	CZK '000/farm	146 633	63 082	153 188	63 405	104.5	100.5
UAA	ha/farm	1 831	1 100	1 826	1 084	99.8	98.5
The share of grasslands	%	21.2	23.7	21.8	24.2	102.8	102.0
Total assets/UAA	CZK '000/ha	80.1	57.4	83.9	58.5	104.7	102.0
Gross cash flow	CZK '000/farm	16 419	7 631	13 851	5 757	84.4	75.4
Cash Flow/UAA*	CZK '000/ha	9.0	6.9	7.6	5.3	84.6	76.6
Labour cost/UAA*	CZK '000/ha	12.0	8.9	11.2	8.5	93.9	95.5
Bank credits/total assets*	%	13.0	11.7	16.2	12.2	123.9	103.9

*weihgted average

UAA - Utilised Agricultural Area

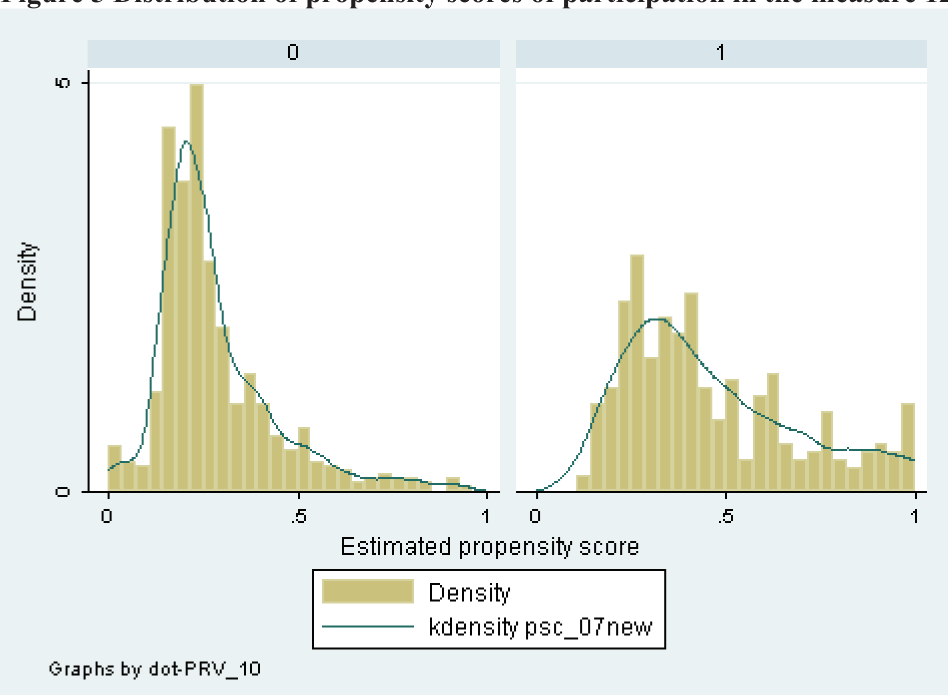
Source: CreditInfo (2011), LPIS (2011), SZIF(2011)

[8] We consider only completed projects
[9] The both figures for 2010
[10] Of the balance sheet
[11] Coefficient of variation = standard error/mean

For calculating propensity scores we applied probit regressions (Gujarati, 1988) on a set of structural variables (UAA, revenue, the share of grasslands, cash flow, depreciation and credits to total assets ratio). These structural variables are commonly considered as factors affecting investment and thus they are deemed as possible determinants of farm participation in the modernisation programme. The first two variables represent size of the business; the share of grasslands indicates if a farm is in the less favoured area (LFA); and the rest are variables referring to financial sources for investment. The probit regression showed that size variables are poor insignificant determinants of participation (Table 6 in Appendix). Note however, that multicoliearity of structural variables might be behind that. The distribution of estimated propensity scores is illustrated in Figure 5; a good overlap is evident.

In the research we tested two matching algorithms: nearest neighbour matching (in Stata attnd) and kernel matching (attk and psmatch2). In this paper we are presenting kernel matching with the standard Gaussian kernel ($K(u) = \exp(-u^2 / 2)$) and with the standard and Mahalanobis metric (Rubin, 1980, Stata – psmatch2), i.e. in equation (8) $P_j - P_i$ is replaced by the metric $d(i,j)= (P_j - P_i)\, S^{-1}(P_j - P_i)$, where P refers to the 2x1 vector of propensity scores and S is the pooled within-sample (2×2) covariance matrix of P based on the sub-samples of the participating and non-participating farms. Standard errors of the average treatment effects are calculated using bootstrapping.
We have chosen 6 performance variables (Table 4) on which we measure results of the investment support programme. Four of these variables relate to value added and productivity in both terms: their state and dynamics. In addition we look at profit and cost revenue ratio.

Figure 5 Distribution of propensity scores of participation in the measure 121 of the Czech RDP



Source: own calculations using STATA procedure pscore (probit regression)

Table 4 List of performance (result) variables

Acronym	Description	Applied by
GVA_	Gross Value Added	Božik et al. (2011)
GVA/LC	Productivity measured by the ratio of GVA over labour costs	
dGVA_	Change of GVA over 2007-2010	
d (GVA/LC)	Change of producivity over 2007-2010	
Profit	Profit	Michalek (2009)
Cost/rev	Cost Revenue ratio	

The assessment of the effect of measure 121 “Modernisation of agricultural holdings” based on kernel matching is summarised in Table 5. Both metric approaches provide very similar results; the main difference is in the significance levels. The average treatment effect differs substantially only in the case of productivity change.

Table 5 Results of matching (attk and psmatch2 in Stata).

	Total	Treated	Controls
Farms	837	290	547

attk (standard metric)

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat	P	sig.
GVA_10	Unmatched	21051	7173	13877				
Gross Value Added	ATT	21051	15035	6016	1275	4.717	0.000	***
GVA/LC_10	Unmatched	0.859	0.952	-0.093				
Productivity	ATT	0.859	0.636	0.223	0.066	3.403	0.001	***
dGVA_07_10	Unmatched	-5624	-3792	-1832				
Change of GVA	ATT	-5624	-7080	1457	773	1.884	0.068	*
d (GVA/LC)_07_10	Unmatched	-0.211	0.474	-0.685				
Change o productivity	ATT	-0.211	-0.273	0.062	0.086	0.714	0.309	
Profit_10	Unmatched	3060	1425	1635				
	ATT	3060	2126	934	1439	0.649	0.323	
Cost/Revenue_10	Unmatched	0.953	0.975	-0.023				
	ATT	0.953	0.984	-0.031	0.015	-2.072	0.047	*

psmatch2 (Mahalanobis metric), 837 observations

Variable	Sample	Treated	Controls	Differ.	S.E.	T-stat	P	sig.
GVA_10	Unmatched	21051	7173	13877	1218	11.39	*2E-24*	
Gross Value Added	ATT	21051	14491	6560	1788	3.670	0.001	***
GVA/LC_10	Unmatched	0.859	0.952	-0.093	0.787	-0.120	*0.396*	
Productivity	ATT	0.859	0.644	0.215	0.114	1.880	0.068	*
dGVA_10_07	Unmatched	-5624	-3792	-1832	634	-2.890	*0.006*	
Change of GVA	ATT	-5624	-7063	1439	948	1.520	0.126	
d (GVA/LC)_10_07	Unmatched	-0.211	0.474	-0.685	1.318	-0.520	*0.348*	
Change o productivity	ATT	-0.211	-0.443	0.232	0.096	2.410	0.022	**
Profit_10	Unmatched	3060	1425	1635	889	1.84	*0.0736*	
	0 ATT	3060	1941	1119	1258	0.890	0.268	
Cost/Revenue_10	Unmatched	0.953	0.975	-0.023	0.019	-1.170	*0.201*	
	0 ATT	0.953	0.965	-0.012	0.011	-1.100	0.217	

Treated = participating in mesure 121 of RDP
Controls= non-participating
Source: own calculation (Stata 11)

With exception of profit, all variables exhibit a significant effect of the investment support to modernisation in one or the other matching model; creation of GVA and labour productivity are significant in both models. In the case of profit, it is extremely high variation of this variable that the huge difference of averages between participants and constructed controls (CZK 1.1 million) is not statistically significant.

5. CASE STUDIES

The sample includes 7 individual and 13 corporate farms. All surveyed farms got support from the present Rural development plan (2007-2013) – measures 121 and 123; 7 investment projects were oriented on crop production, 10 projects on animal production and 3 projects on food processing products on farms. The average size of total investment expenditures of studied projects reached 15.7 mil. CZK with the average amount of the support 4.2 mil. CZK i.e. the rate of the support was on average 39%. All projects were already realised at least a year before the interview and mostly run under full operation.

In terms of farm strategies and objectives of investment, 75% of projects[12] were qualified by respondents as development (grow through) investments i.e. investments for the purpose of increasing farm ability to produce and to sell products or services; 25% of projects indicated rather replacement investment even if with higher operational efficiency; 15% of all projects were bounded with needs to comply with the legislative (environmental) requirements on production and 30% were realised in animal production in order improve animal welfare above current standards.

The investments in last 5 years which were realised in the context of farm development strategies aimed at growth (in 60% of cases), improving the quality (55%); 10% of respondents purely and further 15% of respondents additionally invested to advance specialisation of a farm.

These strategies obviously result not only from market opportunities and opportunities to provide public services, but also from internal conditions. Market opportunities were referred as the most significant factor by a half of respondents and the average score in this case was 4.5 on the 5 point scale. On the other hand, factors indicating surplus or absence of capacity were assigned as less important (only 1/5 of the respondents indicated lack of land for usage (average score 2.0) or shortage of qualified employees (average score 1.0) as the most important factors,.

The most information on possible innovations is acquired by supported investors from farmers' organisations and from internet sources. Both these knowledge sources are considered in the present conception of the knowledge transfer (KT) in agriculture as two basic levels[13]. Specialised advisory services (the most upper level of KT system) indeed were not included among the predefined answers, but it was not mentioned as other source of information in any case study. Also, from the other questions and informal interviews it was clear that use of publicly supported farm advisory is restricted only to a preparation of the investment support application and that the cooperation with research institutions is very low - almost absenting. This is in conformity with findings from other sources that the knowledge transfer from research to farm practices is weak. The actual decision on investment is made on the advice of input suppliers and often on the experience of other farmers who have already invested in the new technology[14].

From the perspective of motivation to participate in the programme, the measure oriented on farm modernisation and on increasing value added is seen first of all as opportunity to get a support for realisation of own innovation plans by 80% of respondents (45% respondents only with this type of motivation). For approximately one third of the investigated supported farms, their participation in the programme was also an exclusive opportunity to get additional financial means for investment. For another 1/3 of the respondents one of the motivation to participate was a need to meet legislative requirements on farm operations.

[12] There was possibility to label more possibilities therefore sum gives more than 100%.

[13] So called "introductory advice" provided by farmers' organisations was co/financed from public funds between 2005 and 2009, the reason for stopping co/financing were budget cuts of the Czech government.

[14] Thus it depends on farmer's network.

The importance of the investment support is possible to evaluate also with an assessment of implications in the cases when the support would not be received by a farm so called “deadweight effect” of investment support. The results of interviews show that in 35% of cases the investment project would not be realised without the support any more. Thirty per cent of respondents would make the investment in a reduced size, on average by 42% (the range 30-60%) of the financial framework of the actually realised supported investment. On the other hand, 35% of projects would be fully launched also without the investment support. But 2/3 of respondents in this group would realise investment in time-delay or at the expense of other investments in the farm that would not be realised under these circumstances. The average economic size of farms in the second group that would realise investment without support but in reduced size, is the highest (155 thousands CZK of total assets), received more endorsed projects by ten per cent compared to others two and the average size of investment costs per project is about 20 million CZK. Farms that would not realised project at all are in average by quarter smaller (measured by total asset value) compared to second group and the average size of project is 16 million CZK. The third group farms that would realise project even without support has economic size in between two mentioned groups, but the average size of authorised projects is the smallest – 12 million CZK. For these farms the supported investment projects have higher importance so that they would realise them also without support at the expense of other investments. It is possible to conclude that the deadweight effect of the RDP is not so high because only 12% of respondents would realise investment project without any restrictions and moreover the average size of realised projects of these farms was only halfway.

When we try to evaluate effects of the investment support it is necessary to know how important the supported investment was for the farm. For 47% of respondents this supported investment stand for a strategic project influencing in the prosperity of the farm. This importance is underlined also by the fact that the realised investment caused an increase of farm revenue (production) on average by 90% and the share of revenues from this supported activity makes on average more than third share. These projects are oriented especially on animal production and storage capacities. Middle-important and less important projects accounted for 42% resp. 11% of surveyed farms. These are projects with primarily noneconomic objectives, e.g. improving animal welfare, or smaller investment projects of all kind. They do not induce a dramatic production increase (with exception of one project).

Average pay-off period of supported projects is estimated at seven years, but the variability is considerable from 4 to 15 years. Mostly the supported projects contributed to improvement of total farm revenues in average by 18% and/or total cost reduction in average by 12%. The most often and the most significant cost reduction was write down in the case of labour costs followed by cost for repairs and maintenance, cost for energy, medicaments and feedstuffs. More than half of respondents agree herein that supported projects help them to increase in principal stability of their income and for other quarter of farms this benefit is less important. From the noneconomic effects were often mentioned first of all quality improvement and production security followed by improvement of animal welfare and animal production efficiency.

6. CONCLUSISONS: A COMPARISON OF QUANTITATIVE ASSESSMENT RESULTS WITH CASE STUDIES

The quantitative assessment showed significant benefits of the investment support in terms of business expansion (GVA) and productivity (GVA/labour costs) improvements. These results were confirmed by the qualitative survey. The qualitative survey showed that production expansion and productivity increase were primary objectives of the investment (and investment strategies) on most of the farms. The public support enabled farms to achieve these strategic objectives.

The respondents of the survey of 20 supported farms declared that the supported investment was important for their prosperity, however, we could not prove it in the quantitative assessment in terms of profit and cost/revenue ratio; ATT are in favour of participating (treated farms), but the variances are too high that there is no statistical significance of them.

We learned that most of the investigated farms have their business development strategy and that the investment support enabled the farmers to accomplish it more timely and in greater extent than it would be without it. It can be learn from Table 3 that the ratio of bank credits to total assets increased dramatically on participating farms over the investigated period while on non-participating farms it stayed almost the same in 2010 as in 2007. It indicates that the policy (measure 121 of RDP) encouraged farms to take credits as well as that there are some credit constrains for farms which might prevent them to participate in the investment support programme.

From the case studies results, that supported investment expose into income increasing of farms. This improvement flows from increasing of animal production efficiency, in general from revenue increasing and also relatively important reduction of operational costs and especially labour costs. Moreover respondents indicated range of other qualitative non-economic benefits such as quality and security improving of products, decreasing losses and animal welfare improving.
Finally, the issue of deadweight of the investment support is discussed: the figures on very low net investment relatively to the provided public support at the sector level indicate possible significant deadweight, however, the insight is incomplete, since it does not take into account post accession restructuring of the sector and multiannual and multi-enterprise character of investment at the farm level. According to answers of respondents from the case studies follows that the deadweight effect of the RDP does not seem to be so high because only twelve per cent of respondents would realise investment project without any restrictions and moreover the average size of realised projects of these farms was only halfway.

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Appendix:

Table 6 Results of probit regression

dotprv_10	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
UAA_07	-8.7E-05	8.38E-05	-1.04	0.298	-0.00025	0.000077
Grasslands_07	0.36373	0.195535	1.86	0.063	-0.01951	0.746971
cash_flow_07	2.23E-05	1.14E-05	1.95	0.051	-8.76E-08	4.47E-05
revenue_07	2.18E-06	2.63E-06	0.83	0.407	-2.97E-06	7.34E-06
depreciation_07	7.06E-05	2.21E-05	3.19	0.001	2.72E-05	0.000114
cf/LC_07	-0.10456	0.047989	-2.18	0.029	-0.19862	-0.0105
credits/TA_07	0.203832	0.481414	0.42	0.672	-0.73972	1.147386
_cons	-1.04485	0.128012	-8.16	0	-1.29575	-0.79395

Source: own calculation (STATA)

Contribution of Supports to Modernisation for Enhancing Competitiveness of the Czech Agricultural and Forestry Holdings

Marie Pechrová

Annotation: Specific weaknesses of the Czech agriculture are "longstanding under-capitalization and credit burden on business, low level of support and market protection in comparison with other European countries prior accession to the EU and low level of financial means in the agricultural sector during the transformation process." (Ministry of Agriculture, 2010) These factors are limiting the competitiveness of Czech farms. One of the ways how to combat these disadvantages is to invest to the modernisation of the agricultural sector, support innovations and their transmission into practice. Czech Republic can benefit from the European Agricultural Fund for Rural Development (EAFRD) under established Rural Development Programme (RDP). First priority axis of this program is devoted to increasing of competitiveness of agriculture and forestry. Measure *I.1.1 Modernisation of agricultural holdings* is aimed on investment promoting and improving the overall performance of the farm to increase its competitiveness. *Measure I.1.2 Increasing of the economic value of forests* has the same objective, but aims on forestry companies. The mid-term evaluation of the RDP evoked the question if the subsidised investments had contributed to the introduction of new products or services and technologies by the enterprises.

The aim of this article is to answer the question if the subsidies on modernisation from the EU's funds have statistically significant impact on the introduction of new technologies or products by agricultural holdings and thus enhancing their competitiveness. On the basis of performed statistical hypothesis testing, the author came to the conclusion that subsidies into modernisation of the agricultural and forestry holdings statistically significantly contributed to the introduction of new technologies and innovations.

Key words: Rural Development Program, agricultural and forestry holdings, modernisation, competitiveness, innovation

1 Introduction

The term competitiveness was originally used for economical subjects only, but the meaning has broadened overtime and is currently applied on states, regions and other territories. "International competitiveness refers to the ability of a country to produce goods which would be able to face foreign competition, and has the potential to maintain or (and) to increase held quotas on foreign markets." (Hagiu, 2011) Competitiveness in the EU is defined as "the ability to resist the market pressure." (Tomšík, 2009) In the case of a particular farm, its ability to compete is affected by the level of technology modernisation and innovation of technological approaches used in the production process. "Companies are trying to achieve competitive advantage in order to help them obtain a better and a stable position in the marketplace. The best way for companies to achieve a competitive advantage is through innovation." (Ramadani, Gerguri, 2011)

"Innovation is widely held to be a key driver of economic growth at the heart of the knowledge economy." (OECD, 1996 in Dargan, Shucksmith, 2008). Supporting of the knowledge transfer, modernisation and innovation throughout food chain is one of the main objectives of Czech RDP. "Restructuring of the agriculture, enhancing the competitiveness of the agricultural subjects and stabilization of the jobs in rural areas" (Ministry of Agriculture, 2010) are understood by the policymakers as the contribution of the Axis I to the achieving of Lisbon's strategy targets. This is in line with Steiner et al's (2011) conclusion that "stimulating innovation is a major route to reaching the Lisbon targets." "To implement the

Lisbon Strategy, the agricultural production must be continually developed (to increase competitiveness).” (Ramanauskas et al., 2010).

Competitiveness in the 21st century is closely related with the research and implementation of its results into practice. In the agrarian-food processing sector, the competitiveness lays on the speed of transferring innovations into practice. In the strategic document Vision of the Czech agriculture after 2010 (Ministry of Agriculture, 2010) there is declared that "from the internal factors to enhance competitiveness of the Czech agriculture are in particular important: raising of the work productivity, maintain high level of investment and increased emphasis on investment in advanced technology.“

Ramanauskas et al (2010) recommend “stimulating innovation in the proposed investment projects that require support from the EU to establish the level of innovation and giving priority to the projects with a large level of innovations.”

Axis I of the Rural Development Programme is concentrating on the support of competitiveness of agriculture, forestry and food processing industry. Allocation of financial means on the axis I is 22.53 % of the financial means available in the European Agricultural Fund for Rural Development (EAFRD). The majority of subsidies (85.5 %) are granted to the priority *I.1 Modernisation, innovation and quality*. This measure was included in the previous subsidy programme and has integrity since 2004. The aim of the measure is to help farmers to renew, reconstruct, modernise, finish or rebuild agricultural and non-agricultural buildings and innovate, modernise, acquire and improve their technologies.

Measure *I.1.1 Modernisation of agricultural holdings* is aimed on investment promoting and improvement of the farm overall performance to increase its competitiveness. Measure *I.1.2 Increasing of the economic value of forests* has the same objective, but aims on forestry companies. The question is if the supports for modernisation of agricultural and forestry holdings make significantly easier to implement the innovations which could help to enhance entrepreneurs’ competitiveness.

2 Methods

The primary research was not needed as the relevant data have been already available from the secondary sources. Particularly mid-term review of the RDP (Association of DHV and TIMO, 2010) contains the answers on the evaluation question: Have the subsidised investments contributed to the implementation of new technologies and/or products? Not only supported agricultural holdings, but also these who did not benefit from the EUs’ grand, were questioned. Therefore the counterfactual analyses are possible. For assessing the statistical significance of the contribution of the subsidies, $\chi2$ square test of independence was used.

Firstly, the data must be displayed in the association table, where particular cells were marked with letters (see Fig. 1.).

New products and/or technologies			
Subsidies	Yes	No	Sum
Yes	a	b	(a + b)
No	c	d	(c + d)
Sum	(a + c)	(b + d)	n

Fig. 1. Association table, **Source**: Wisniewski, 2002

This test is based on the chi-squared ($\chi 2$) probability distribution. The format of testing is following: defining of null and alternative hypotheses, calculating of the test statistics according to Fig. 2 and its comparison with critical table value.

$$\chi^2 = \frac{n(ad-bc)^2}{(a+b)(a+c)(b+d)(c+d)}$$

Fig. 2. $\chi 2$ square test statistics, **Source**: Wisniewski, 2002

As it is non-parametric tests, if the calculated value is smaller than the tabled one, null hypothesis has to be rejected. I performed $\chi 2$ square test to test the association between the answers of two groups of farmers to the given question. The strength of association was measured by Yule coefficient of association according to Fig. 3.

$$Q = \frac{ad-bc}{ad+bc}$$

Fig. 3. Yule coefficient of association, **Source**: Wisniewski, 2002

3 Results and Discussion

3.1 Assessment of the success in introducing new technologies and/or products

3.2 Measure I.1.1.1 Modernisation of agricultural holdings

Success of the first axis's measure *I.1.1 Modernisation of agricultural holdings* is assessed by prior defined evaluation questions which are asked to the farmers who were successful in application for support and who were not. Both groups were asked the same question, if they managed to introduce new technologies and/or products or not. Analysis was performed on a selected sample of respondents from both groups.

The data are available in the evaluation mid-term report (Association of DHV and TIMA, 2010). Fig. 4. shows the results. 287 of 367 farmers who were granted the financial means were able to introduce new technologies or products, while 80, despite obtaining the support, were not. Comparison group consisted of agricultural firms who were not subsidized, but despite that fact, 46.3 % of them were able to achieve innovation. The percentage of the farmers who were able to introduce new technologies and/or products is higher (78.2 %) in the group of subsidised farms.

It might be clear that the subsidies had positive impact on modernisation of the enterprises and its capability to deliver new products and/or technologies. However, the statistical verification must be performed to verify this hypothesis. Usage of $\chi 2$ square test for testing reveal the fact if the subsidies statistically significantly influence introducing of new products and/or technologies. Null hypothesis expects nonexistence of the interdependence. (H_0: there is not association between subsidies and introducing of new products and/or technologies).

New products and/or technologies			
Subsidies	Yes	No	Sum
Yes	a = 287	b = 80	(a + b) = 367
No	c = 170	d = 197	(c + d) = 367
Sum	(a + c) = 457	(b + d) = 277	n = 734

$$\chi^2 = \frac{n(ad-bc)^2}{(a+b)(a+c)(b+d)(c+d)} = 79.37 > \chi^2_{0,05(1)} = 3.841$$

Fig. 4. Answers on the evaluation question, **Source**: Association of DHV and Timo, 2010, own calculations

Calculated test criterion is higher than tabular value of χ2 – square test on the level of significance 0.05, therefore we reject null hypothesis. Subsidies with 95 % probability significantly influenced introduction of new products and/or technologies in the agricultural companies.

Association coefficient measuring the strength of association between variables is positive and points out to relatively strong dependency (Q = 0.76).

3.3 Measure I.1.2.1 Increasing of economic value of forests

Another measure from Axis I which desirable results are introducing of a new product or service or technology is *I.1.2.1 Increasing of economic value of forests*. The output indicator is number of holdings which are introducing new products or new approaches. The data collected shows that thanks to this support 58 % of the questioned enterprises were able to introduce new products or technologies. 30 firms from sample of 70 were unable to do so. In the comparison group, there were only 17 % of respondents able to introduce new products or technologies. The positive impact of subsidies is clearly visible.

Null hypothesis of the χ2 square test states that there is no association between subsidies to the forestry firm and its introducing of new products and/or technologies.

New products and/or technologies			
Subsidies	Yes	No	Sum
Yes	a = 40	b = 30	(a + b) = 70
No	c = 12	d = 58	(c + d) = 70
Sum	(a + c) = 52	(b + d) = 88	n = 140

$$\chi^2 = \frac{n(ad-bc)^2}{(a+b)(a+c)(b+d)(c+d)} = 23.99 > \chi^2_{0,05(1)} = 3.841$$

Fig. 5. Answers on evaluation question, **Source**: Association of DHV and Timo, 2010, own calculations

Calculated criterion is higher than critical value on the level of significance 0.05, therefore we have to reject null hypothesis and conclude that with probability of 95.0 % the support from EAFRD under measure I.1.2.1 has positive impact on introducing of new products or technologies by forestry enterprises. The association of introducing of the new products and/or technologies and subsidies is lower in case of this measure, as the coefficient of association is 0.73.

4 Conclusion

Introducing new technologies and products to the food production process is one of the important features to enhance agricultural and forestry companies' competitiveness. Or in other words, the best way how to achieve competitiveness is through innovation. The modernisation of the farms in the Czech Republic had been neglected for a long time due to the under-capitalization during previous political regime. To speed up the process of modernisation, financial means from the EU can be used.

Under Rural Development program, axis I, priority *I.1 Modernisation, innovation and quality* are implemented measures aimed on innovations in agricultural sector in the Czech Republic. The statistical analyses of the efficiency of these grand revealed that they are significantly supporting farms' (or forestry companies') ability to introduce new technology or place a new product on the market. The association between subsidies and introduction of the new technology and/or product is positive and relatively high, however, in case of forestry companies, it is slightly smaller.

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Improving Farm Competitiveness through Farm-Investment Support: a Propensity Score Matching Approach

Stefan Kirchweger and Jochen Kantelhardt[1]

Annotation: The heterogeneity of farms and the problem of self-selection are challenging the evaluation of treatments in agriculture. This is particularly the case for rural development measures whit voluntary participation and heterogeneous outcomes. But knowledge about the selection mechanisms for a certain treatment, in combination with econometric methods, can help to overcome these problems. One of these promising methods is the Propensity Score Matching (PSM) approach. In this paper we apply PSM in order to obtain treatment effects from the agricultural investment support programme in Austria on the farm income. We also test the robustness of the results to hidden bias with sensitivity analysis. Furthermore we split the sample in more homogenous subsamples in order to increase the robustness of the results. The results show that treatment effects differ by a large amount for the subsamples and that splitting leads to slightly more robust results.

Key words: Rural Development programmes, heterogeneity, causal effects, Propensity-Score Matching, sensitivity analysis

1 Introduction

There are about 187,000 farms located in Austria for the year 2007 (BMLFUW, 2011). Even though there have been structural changes and adaptations in the last few decades, the farms differ in farm structure and production systems. The heterogeneity is mainly due to the fact of different site conditions, i.e. mountainous or non-mountainous regions, as well as being the result of farm-manager characteristics or strategies. Furthermore, analyses in agriculture have to take into account that a farm is always built upon a unique relationship between the farm household and the farm enterprise. The heterogeneity of farm units and the unique relationship between farm and farm households leads to heterogeneous responses to support programmes (Pufahl and Weiss, 2009). This results in methodological challenges for researchers in carrying out quantitative analyses in the framework of Rural Development evaluation.

Quantitative evaluation asks for the causal effect. Therefore the Neyman-Rubin-Holland model has been developed .[2] In this model the causal effect (Δ_A) for one individual (A) is computed by comparing the outcome in the state of participation (Y_A^1) and the outcome in the state without participation (Y_A^0). This can be formulated as $\Delta_A = Y_A^1 - Y_A^0$. But a fundamental challenge arises, as one of these outcomes is counterfactual because one unit can either be participant or non-participant. When we look for counterfactual for treated units, one solution to this problem is the use of observable non-participants. The treatment effect can then be computed by simply comparing treated and non-treated units. But to follow causal claims, treatment must be independent of the potential outcome and treated and non-treated must be

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[2] This model is also known as the counterfactual model (Morgan and Winship, 2009), the Neyman-Rubin model (Sekhon, 2009) or Roy-Rubin model (Caliendo and Hujer, 2006) and was originally introduced by Neyman (1923) but is nowadays used in a wide range of topics for microeconomic evaluation (Sekhon, 2009).

homogenous, only differing by the analysed variable. If these are not fulfilled, the results are biased and/or have high variability. This is not a major issue in randomised experiments, as randomisation of treatment insures the independence of treatment and outcome. To reduce variability, the pairing of treated and untreated units can be used and number of observations can be increased (Rosenbaum, 2005a).

As experiments can hardly been used in agricultural treatment evaluation, we have to rely on observational data (Henning und Michalek, 2008). Observational studies differ from experiments, as the researcher cannot control the assignment of treatment to individuals (Rosenbaum, 2010, 65). Therefore, participants select themselves voluntarily for a certain treatment, which leads to a selection bias in the results. This bias is mainly due to variables (Z) disturbing the causal inference of the treatment (T) on the outcome (Y) and therefore violates the independence assumption. Figure 1 illustrates a causal relationship between the treatment T and the outcome Y, but Y is biased through the mutual dependence of T and Y on Z.

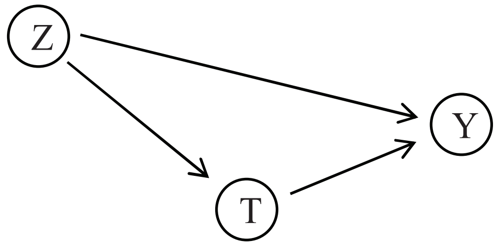

Figure 1: A causal diagram in which the effect of T on Y is disturbed through the back-door path, a mutual dependence on Z. (Source: Morgan and Winship, 2009)

As in heterogeneous observational studies, the increase in observations cannot reduce variability; more homogenous samples are needed (Rosenbaum, 2005a). Therefore the pairing of treated and untreated is needed to reduce both, bias and variability. One approach of pairing is *Propensity Score Matching* where treated and untreated are paired on similar propensity scores. Rubin and Rosenbaum (1983) prove that *matching* on the propensity score is sufficient. As with *Matching*, we only check for observable covariates; there always might be hidden bias caused by unmeasured variables.

The basic objective of this paper is to apply a *Propensity Score Matching* approach to analyse their ability to scope with heterogeneity in agricultural studies. This is exemplified on the agricultural investment support programme in Austria and its effects on the farm income of farms using the time period 2005-09. Therefore further analysis is implemented to reduce, on the one hand, the bias from unobservable variables and, on the other, to measure the robustness of the results regarding hidden biases. Furthermore we stratify the sample in dairy and granivore farms in order to obtain more homogenous samples and reduce variability as well as increase the robustness of the result. The following specific questions are asked:

- Can Propensity Score Matching be a supportive tool to derive causal effects from a farm investment support programme in empirical studies?
- How does Propensity Score Matching cope with heterogeneity in agriculture?
- Can bias be reduced by using smaller, more homogenous samples?

In Section 2 we give a brief introduction in farm investment and in the farm-investment support programme of Austria. Section 3 explains the methodological procedure and the database used in this paper. The results of this three-step approach are then displayed in Section 4. This section also includes the application of sensitivity analysis in order to judge on the causality of the different results. The results are discussed in Section 5.

2 Farm investment and the farm-investment support programme in Austria

The farm-investment programme is part of the second pillar of the Common Agriculture Policy and basically concerns improving competitiveness, work conditions, animal welfare and environmental conditions. To achieve these goals, 576 million Euros have been spent in Austria in the period from 2000 to 2009 (Dantler et al., 2010). The number of fostered farms during this period is slightly above 37,000, all mainly located in mountainous regions (see Figure 3). Consequently, forage farms (including mainly dairy and suckler-cow farms) are the main beneficiary of farm-investment payments, with a share of more than 56%. In contrast, in the distribution of farm type of all farms in Austria, forage farms have only a share of 37% (BMLFUW, 2011). In addition, there is an over-representation of granivore farms in contrast to field-crop farms. It is therefore not surprising that more than 50% of these funds foster the construction of barns mainly for dairy farming. Even though participants are mainly mountainous farms, it illustrates a low share of participants in the western federal states of Tyrol and Vorarlberg. This might be due to specific achievements by the federal states.

Furthermore, on average the share of participating farms increases for bigger farms. Hence the means of participants and non-participants differ, especially for the utilised agricultural area (UAA), total livestock units (LU) and milk quota (Dantler et al., 2010). As farm-investment support payments can only be obtained with an investment, and there is hardly any farm investment without support, we have to consider them jointly when evaluation is carried out (see Dirksmeyer et al., 2006 and Dantler et al., 2010). Therefore we also have to consider investment decisions in our analysis. A study done for German farms also points out that investing farmers have a lower share of equity and are older than non-investing farmers (Läpple, 2007). It is evident, therefore, that there has been a selection for participation based on structural and regional variables such as region, farm type, farm size and financial variables.

3 Methodological Approach

For the application of *matching* we use a three-step approach, where we first define the *matching* covariates and estimate the propensity score for the whole sample as well as for the subsamples of dairy, cash crop and granivore farms. Secondly, we match treated and controls based on the propensity score using a suitable Greedy algorithm with calliper *Matching*. As a last step, we calculate the average treatment effect on the treated with a difference-in-difference estimator for all samples. Afterwards sensitivity analysis is applied to judge on the quality of M*atching*.

3.1 The Propensity Score Matching approach

Matching follows the Conditional Independence Assumption (CIA) in order to find an adequate control group. Based on the work of Rubin (1977) and Rubin and Rosenbaum (1983), the CIA assumes that under a given vector of observable covariates (Z), the outcome (Y) of one individual is independent of treatment: $\{Y0, Y1 \perp T\} |Z$, where $\perp$ denotes independence. The *matching* procedure is based on conditioning on all covariates influencing T and/or Y (Z_1, Z_2, Z_3,….Z_k). This conditioning on Z should, on the one hand, lead to a reduction in selection bias in the form of a reduced correlation (r) between the errorterm of the treatment T (u) and the errorterm of the outcome Y (e) (see Figure 2).

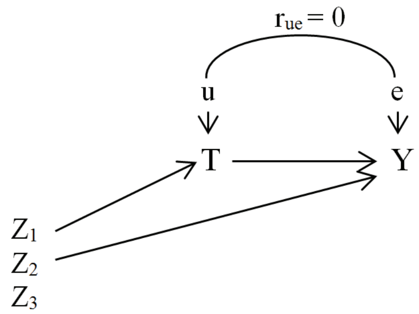

Figure 2: Identification of causal effects through conditioning on observed variables. (Source: Gangl, 2006)

Thus, through *matching* the income of farms are independent of whether the farm participated in the farm-investment programme or not. However, this requires the identification of all those covariates which influence the outcome and the probability of participation but are not influenced by programme participation. The selection of covariates is the most important task in the *matching* procedure. Guidance can be gained from statistical, economical and also practical background in order to choose the appropriate covariates. The influence of the participation on the covariates can be avoided by *matching* on farm variables before the start of treatment.

Another major assumption which needs to be fulfilled is the so-called Common Support Assumption. This basically requires the existence of non-participants having similar Z to all participants. Violation arises especially when covariates are used which predict too well the probability of treatment, but this is simply detected by visual control (Lechner, 2001). Losing observations because of missing common support is not usually a problem when these are not too numerous but might change the quantity of the results.

In order to identify similar controls, PSM use the propensity score (p(Z)) of each individual instead of each single covariate. The propensity score is defined as the probability of participation (Pr(T=1)) for one individual given the observed covariates Z, independent of observed participation: $p(Z) = Pr(T_i=1 \mid Z_1, Z_2, Z_3, \ldots Z_k)$. Rubin and Rosenbaum (1983) prove that *matching* on the propensity score is sufficient. *Propensity-Score Matching* (PSM) differentiates from exact *matching* as the values of covariates are usually different within the pairs with the same propensity score but are balanced in the treated and control group (Rosenbaum, 2010, 166). The estimation of the propensity score (PS) is commonly based on the fitted values of a binary logit or probit model, using observed treatment assignment (yes/no) as the explained and Z as the explanatory variable. The model must not be linear but may include interactions, polynomials and transformations of the covariates.

There are several algorithms available to pair controls and treated units. In our paper we use a *Greedy algorithm* with calliper pair *matching* without replacement approach. Similarity is therefore established by using a self-defined calliper. A non-participant which is found within the calliper serves as control for one treated and cannot be used as another control. The treated unit is dropped when there is no control available within the calliper. Through this the quality of *matching* rises, as the controls are much more similar in contrast to simple *Nearest Neighbour Matching (*Caliendo and Kopeinig, 2008) and the condition of common support can be fulfilled. Augurzky und Kluve (2004) argue that callipers which are not too narrow are preferable when the heterogeneous effects of treatment are expected (Augurzky und Kluve, 2004). Therefore we set the calliper to 0.2 for our application.

Through the two steps, the estimation of the propensity score and the actual *matching* using a radius algorithm, pairs consisting of participants and controls are built, and a control group which is similar to the participant group is generated. This results in a reduction of systematic mean differences between these groups. Furthermore, *matching* on p(Z) does not touch the Y variable until the estimation of the treatment effects in order to prevent it from new biases (Ho et al., 2007). Thus, the average treatment effect on the treated ($\tau | (T=1)$) can be computed, as the difference of the mean outcome of participants (Y_A^1) and controls (Y_B^0):

$$\tau | (T=1) = \sum_{A=1}^{n} Y_A^1 | p(Z)/n_A - \sum_{B=1}^{n} Y_B^0 | p(Z)/n_B \quad (1)$$

Matching can then be considered successful when the mean of the covariates between treated and control group is balanced. Balance is judged by conventional testing; alternatively, Ho et al. (2007) recommend using QQ-plots which plot the quantiles of a variable of the treatment group against that of the control group in a square plot (Ho et al., 2007). The *matching* algorithm in our analysis is run with the R-package "*Matching*" by J.S. Sekhon (see Sekhon, 2011).

As the independent assumption in *matching* is built on observable covariates, it is often criticised that there might still be hidden bias in the outcome, coming from unobserved variables. Therefore we implement a *difference-in-difference (DiD)* followed by sensitivity analysis considering the amount of hidden bias in the result.

3.2 Estimation of treatment effects

Smith and Todd (2005) recommend for controlling for unobservable covariates the implementation of a *DiD* estimator. The *DiD* relies on the assumption that the differences of participants and non-participants are similar at every time. It is computed as the difference of the progress of the participant and the non-participant from one point before (t') to one point after (t) the time of treatment (t_T) (Heckmann et al., 1998). By implementing the factor time and the before- and after-estimation in the analyses, we can monitor for unobservable, linear and time-invariant effects such as price fluctuations (Gensler et al., 2005). The combination of *matching* and *DiD* results in the *Conditional difference-in*-difference (CDiD) estimation and the used formula can be written as

$$\tau | (T = 1) = \sum_{A=1}^{n} (Y_{A,t}^1 - Y_{A,t'}^1) | Z/n_A - \sum_{B=1}^{n} (Y_{B,t}^0 - Y_{B,t'}^0) | Z/n_B \quad (2)$$

$$t' < t_T < t \quad (3)$$

For our analysis, the pre-treatment situation is in 2003, post-treatment is 2010 and the treatment itself took place between 2005 and 2009. The two-year gap before treatment is necessary, since the year of treatment is the year of payment and the investment usually happens a year or two before payment.

3.3 Sensitivity analysis

In order to investigate the reliability of the results we implement a sensitivity analysis in our model. Therefore we use the so called Rosenbaum bounds (see Rosenbaum 2002, 2005b and 2010). Basically this sensitivity analysis tests for the robustness of results and models. Rosenbaum's approach in particular focuses on the hidden biases from unobservable variables and therefore on the violation of the assumption of independence of treatment and outcome or random assignment of treatment after *matching*. There is hidden bias, when pairs look comparable in their observable characteristics but differ in their actual probability (π) of receiving the treatment.

To measure the departure from random assignment of treatment the parameter Γ is implemented in the odds ratio of the pairs. There is no departure if the odds ($\pi/1-\pi$) of each unit do not differ within the pair and the Γ=1. When the units k and j have the same probability, the odds ratio was at most:

$$\frac{1}{\Gamma} \leq \frac{\pi j/(1-\pi j)}{\pi k/(1-\pi k)} \leq \Gamma \qquad (4)$$

The parameter of one is given in randomised experiment, but in observational studies this hardly ever appears. If the parameter happens to be 2, this indicates that one of these units is twice as likely to receive the treatment as the other.

It is not possible to compute the parameter; therefore we assume a perfect situation, with a positive treatment and no hidden bias, but we are ignorant of these facts, and perform a sensitivity analysis (Rosenbaum, 2010, 259). In order to start, one selects a series of values for Γ. Then we can either judge the robustness on the p-values and see how the p-value changes for increasing values of Γ or how the magnitude of the treatment effects changes with an higher Γ. High sensitivity to hidden bias appears if the conclusions change for values of Γ just slightly higher than one and low sensitivity is given if the conclusions change at large values of Γ (Rosenbaum, 2005b). The sensitivity analysis in our paper is based on the Wilcoxon sign rank test and the Hodges-Lehmann (HL) point estimate for the sign rank test with an upper and lower bound.[3] The values and estimates of these tests might differ to our results as they deal differently with outliners. We use the R-package "rbounds" by L. Keele (see Keele, 2010).

3.4 Data

We use data from 2000 to 2010 of 1,636 voluntary bookkeeping farms in Austria, where we find 239 farms who only participated in the farm-investment support programme at least once between 2005 and 2009 and 845 farms who did not participate between 2000 and 2010. Farms which did not attend in the years 2000-2004 and 2010, as well as those which received less than 5000 Euros in payments, were dropped from the analysis. Participants and non-participants are matched with data based on the year 2003.

In observational studies, better results can be achieved, when samples are more homogenous (Rosenbaum, 2005a). In order to gain more homogenous samples we split the sample in three subsamples, for dairy and granivore farms. Whereas dairy farms are characterised as farms keeping dairy cows and granivore farms are farms whose sales are mainly due to fattening pigs and steers as well as breeding and fattening hens. We then apply the three-step approach for all three subsamples individually.

[3] A detailed derivation is given in Peel and Makepeace (2009).

4 Empirical Results

The results for the three-step estimation of the average treatment effect on the treated applied in the case of farm-investment support in Austria are displayed in this chapter. Furthermore we show the results of sensitivity analysis and stratification.

4.1 Estimation of the Propensity Score

In order to get the propensity scores of each unit we apply a binary logit model. In our model we include a multinomial variable for the farm type and whether the farm is located in the region west, south and north, a dummy variable for organic farming and metric variables for the age of the farm manager, the labour, the utilised agricultural area (UAA), the share of rented UAA, the livestock density, the share of equity and the non-farm income. The estimates for the coefficients are displayed in Table 1. The results indicate that dairy farms, farms with higher labour and livestock density, as well as more UAA and non-farm income, are more likely to invest and receive farm-investment support but cash-crop farms and farms with older managers are less likely. The model correctly predicts about 78% of the farms attending the programme and is statistically significant at the 0.1% level or better, as measured by the likelihood ratio test.

Table 1: Covariates estimates of logit-models explaining programme participation for the whole sample.

	Estimate	Std. Error	z value	
Intercept	-5.928	1.075	-5.514	***
Dummy permanent crop farms	0.708	0.458	1.546	
Dummy forage farms (exclusive dairy)	-0.030	0.485	-0.061	
Dummy cash-crop farms	-0.639	0.334	-1.911	.
Dummy dairy farms	0.453	0.237	1.910	.
Dummy granivore farms	0.403	0.314	1.284	
Dummy region south	-0.130	0.207	-0.628	
Dummy region west	-0.319	0.291	-1.096	
Dummy konv farming	-0.080	0.215	-0.373	
Age	-0.022	0.009	-2.453	*
Labour	0.565	0.126	4.487	***
Utilised agricultural area (log)	0.713	0.153	4.644	***
Share of rented land	0.587	0.372	1.579	
Livestock density	0.586	0.179	3.270	**
Share of equity	0.801	0.508	1.577	
Non-farm income (log)	0.140	0.039	3.548	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Using this model we estimate the bounded propensity score for each farm, which is the basis for the following *matching* step. The distribution of the propensity scores is quite similar in the treated and the control group (see Figure 3). This is necessary in order to find good matches.

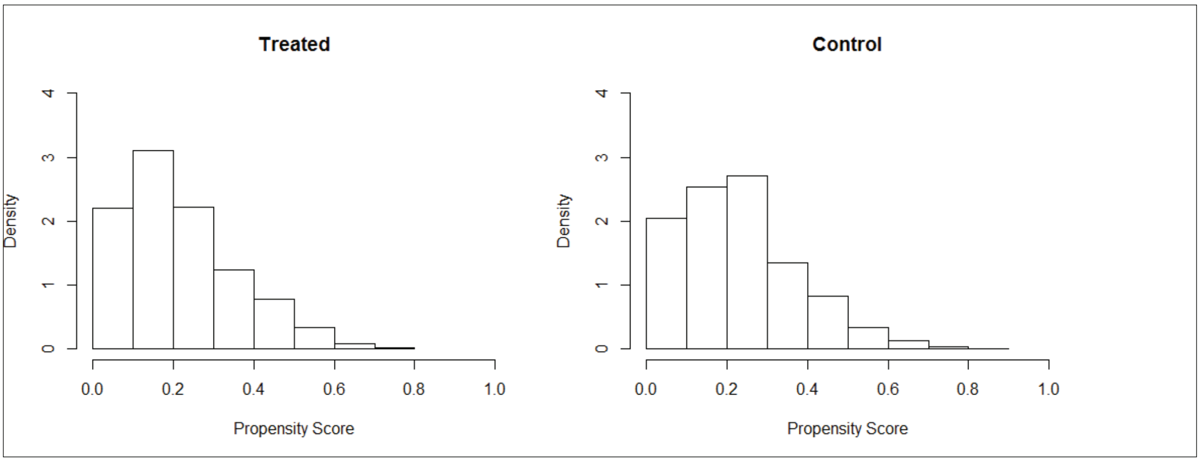

Figure 3: Distribution of propensity scores for treated (left) and controls (right).

4.2 Results from *Matching* and treatment effect estimation

The quality of the *matching* algorithm is based on the achieved balance between treated and control group. The applied Greedy algorithm has the best results regarding the *matching* balance in comparison to other algorithms. Out of 239 potential participants, the *matching* procedure develops a new sample with 227 pairs consisting of one treated and one control. Through this, the sample increased its balance between the two groups (participants and controls) for all variables, which are not statistically significantly different, using conventional levels and the t-test, anymore (see Table 2).

Table 2: Mean values of variables for participants and controls before and after Propensity-Score Matching for the whole sample.

	Potential participants	Potential controls		Selected participants	Selected controls
Number of farms	239	810		227	227
Dummy permanent crop farms	0.050	0.059		0.048	0.048
Dummy forage farms	0.029	0.033		0.031	0.035
Dummy cash-crop farms	0.130	0.279	***	0.137	0.159
Dummy dairy farms	0.452	0.307	***	0.454	0.441
Dummy granivore farms	0.163	0.095	**	0.145	0.163
Dummy region south	0.247	0.247		0.233	0.225
Dummy region west	0.100	0.088		0.101	0.093
Dummy konv farming	0.816	0.819		0.815	0.837
Age	52.280	54.207	**	52.595	51.907
Labour	1.824	1.487	***	1.777	1.814
Utilised agricultural area (log)	3.488	3.309	***	3.465	3.484
Share of rented land	0.287	0.242	**	0.280	0.294
Livestock density	1.125	1.125	***	1.106	1.106
Share of equity	0.905	0.905		0.911	0.903
Non-farm income (log)	7.466	7.375		7.409	7.265
Livestock (log)	3.038	2.344	***	3.003	2.976
Dairy cows (log)	1.549	1.094	***	1.559	1.535
Pigs (log)	1.837	1.363	**	1.769	1.860

t-test for equally of means: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

With the new sample of 227 pairs gained from *matching* approach the ATT is computed by comparing the mean development of the farm income from 2003 to 2010 of participants and controls. This results in an ATT for the farm income of 7197 Euros, which can be interpreted as the amount of farm income which treated farms could increase more than controls. The ATT has a standard error of 2656.4 and t-statistic of 2.71, which indicates a statistical significant difference between the means at the 1% level or better.

4.3 Sensitivity analysis

Even though the ATT for the farm income is positive, we cannot be sure that controlling for observable covariates is enough to draw causal conclusions. Therefore we apply sensitivity analysis to test the robustness of the result. The results of this analysis are displayed in Table 3. The first column of Table 3 is the value of the parameter Γ, which should indicate the difference in the odds of farm participating or not caused by an unobserved variable. In the second and third column the upper and lower bound of the p-value from Wilcoxon Sign ranking test and the fourth and fifth the upper and lower bound of the Hodges-Lehmann point estimates for the sign rank test is shown. In the first row the parameter is set to one, assuming total randomisation through *matching*. The sensitivity analysis shows that through the increase of Γ up to 1.08, the upper bound of the p-value exceeds the 5%-level. This indicates that the result is highly vulnerable to unobserved bias. This also leads to a widening of the HL treatment estimates and therefore increasing the uncertainty through selection bias. When the parameter increases to 1.38, the HL treatment effect is even shown to become negative.

Table 3: Rosenbaum bounds parameters for the results of the whole sample

parameter	**Wilcoxon p-value**		**HL treatment estimate**	
(Γ)[1]	**Lower bound[2]**	**Upper bound[3]**	**Lower bound[4]**	**Upper bound[5]**
1.00	0.021	0.021	4,265	4,265
1.02	0.015	0.029	4,012	4,520
1.04	0.011	0.038	3,752	4,788
1.06	0.008	0.049	3,466	5,046
1.08	**0.006**	**0.063**	**3,230**	**5,266**
1.10	0.004	0.079	2,938	5,521
1.12	0.003	0.098	2,682	5,807
1.14	0.002	0.119	2,449	6,036
1.16	0.001	0.143	2,213	6,255
1.18	0.001	0.169	1,995	6,468
1.20	0.001	0.198	1,752	6,712
1.22	0.000	0.229	1,519	6,911
1.24	0.000	0.262	1,302	7,134
1.26	0.000	0.297	1,060	7,340
1.28	0.000	0.333	864	7,609
1.30	0.000	0.370	659	7,840
1.32	0.000	0.408	458	8,052
1.34	0.000	0.446	253	8,285
1.36	0.000	0.484	64	8,481
1.38	0.000	0.522	-95	8,678
1.4	0.000	0.558	-260	8,903

[1] Odds of differential assignment due to unobserved factors,
[2] Lower bound significance level (on assumption of under-estimation of treatment effect),
[3] Upper bound significance level (on assumption of over-estimation of treatment effect),
[4] Lower bound point estimate (on assumption of under-estimation of treatment effect),
[5] Upper bound point estimate (on assumption of over-estimation of treatment effect).

4.4 Results for stratified subsamples

The subsamples consist of 108 participants and 249 non-participants in the dairy subsamples and 39 treated and 77 non-treated in the granivore subsample. An individual logit model is applied for each subsample. The models are adapted by farm type-specific covariates. The estimates and significance levels of the model can be seen in Table 4 and Table 5. Thus, we included the share of dairy cows in the dairy subsample and the number of pigs variable in the granivore subsample. The estimation shows that in both models these additional covariates are not statistically significant but we are convinced that they play a major role in the decision to participate in the investment support programme (see also Dantler et al., 2010). Furthermore the estimates in both models are similar to the model with the whole sample except for the fact that labour and age are not statistically significant anymore. The models correctly predict about 70% and 76% respectively of the farms attending the programme and both are statistically significant at the 0.1% level or better, as measured by the likelihood ratio test.

Table 4: Covariates estimates of logit-models explaining programme participation for the subsample of dairy farms

	Estimate	Std. Error	z value	
Intercept	-8.77	2.08	-4.23	***
Dummy region south	-0.26	0.32	-0.80	
Dummy region west	0.14	0.34	0.41	
Dummy konv farming	-0.03	0.31	-0.11	
Age	-0.01	0.01	-0.71	
Labour	0.33	0.27	1.21	
Utilised agricultural area (log)	1.14	0.32	3.58	***
Share of rented land	0.69	0.55	1.26	
Livestock density	0.80	0.36	2.23	*
Share of equity	1.43	0.81	1.76	.
Non-farm income (log)	0.25	0.07	3.77	***
Dairy cows (share of all livestock)	-0.07	0.86	-0.08	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5: Covariates estimates of logit-models explaining programme participation for the subsample of granivore farms

	Estimate	Std. Error	z value	
Intercept	-8.77	2.08	-4.23	***
Dummy region south	-0.26	0.32	-0.80	
Dummy region west	0.14	0.34	0.41	
Dummy konv farming	-0.03	0.31	-0.11	
Age	-0.01	0.01	-0.71	
Labour	0.33	0.27	1.21	
Utilised agricultural area (log)	1.14	0.32	3.58	***
Share of rented land	0.69	0.55	1.26	
Livestock density	0.80	0.36	2.23	*
Share of equity	1.43	0.81	1.76	.
Non-farm income (log)	0.25	0.07	3.77	***
Pigs (share of all livestock)	-0.07	0.86	-0.08	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The distribution of the bounded propensity scores is quite similar for treated and controls in the dairy subsample but is more distinctive in the granivore subsample (see Figure 4 and 5). This results in a more challenging *matching* procedure for the granivore subsample in order to fulfill the common-support assumption. The Greedy *matching* algorithm finds 104 pairs for the dairy and 27 pairs for the granivore, which increases the balance of the subsamples for each selected covariate (see Table 9 and 10 in the Appendix). Balance of covariates is checked by the t-test, which shows no statistical significant difference on the conventional levels.

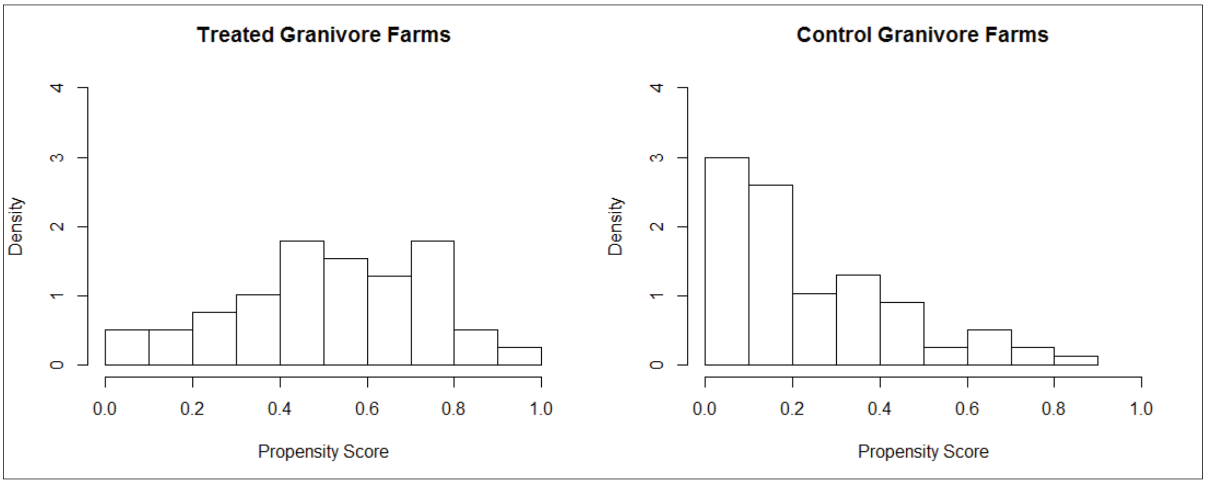

Figure 4: Distribution of propensity scores for treated (left) and controls (right) in the dairy subsample

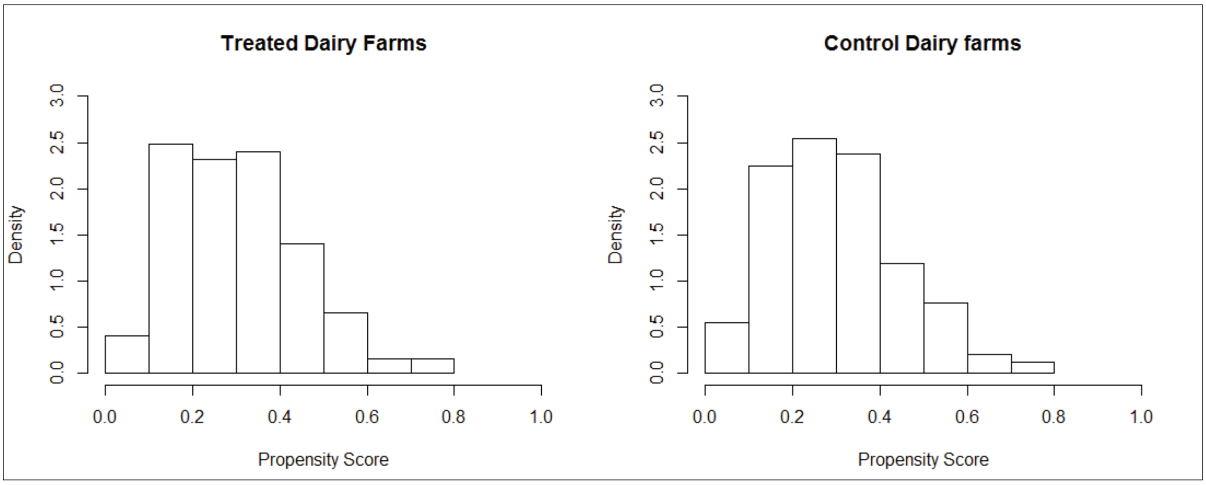

Figure 5: Distribution of propensity scores for treated (left) and controls (right) in the granivore subsample

Using the matched subsamples we can estimate the ATT in the farm income for dairy as well for granivore farms similar to the procedure when the whole sample is used. The farm income of treated dairy farms increases in average in the analysed period by about 1,200 Euros more than the control. The t-statistic is very low and therefore the result is not statistically significant. In contrast, the average development of farm income of treated granivore farms is 18,600 Euros higher and statistically significant at the 1% level or better (see Table 6). This reveals the heterogeneity and variability in the average results when the ATT is estimated with the whole sample.

Table 6: ATT in the farm income (in Euros) for the subsample of dairy and granivore farms

	Estimate	Std. Error	t-stat
Dairy subsample	1,232	2,548	0.477
Granivore subsample	18,612	6,864	2.711 ***

t-test for equally of means: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Stratification of the heterogeneous sample also leads to an increase in the robustness of the results. This is shown through the sensitivity analysis in Table 7 and Table 8, where the statistical significance and the magnitude of the treatment effect changes at a higher parameter than for the whole sample. For the dairy subsample the ATT is statistical insignificant for the assumption of randomisation but exceed the 5%-level when the parameter increases by 30%. In comparison the parameter has to increase by 50% to change the conclusion of the granivore sample.

Table 7: Rosenbaum bounds parameters for the results for the subsample of dairy

parameter	**Wilcoxon P-value**		**HL treatment estimate**	
(Γ)[1]	**Lower bound**[2]	**Upper bound**[3]	**Lower bound**[4]	**Upper bound**[5]
1	0.309	0.309	1,374	1,374
1.05	0.237	0.388	790	1,892
1.1	0.178	0.469	229	2,327
1.15	0.131	0.547	-321	2,868
1.2	0.095	0.621	-790	3,358
1.25	0.068	0.687	-1,217	3,859
1.3	**0.048**	**0.746**	-1,651	4,310
1.35	0.033	0.796	-2,209	4,793
1.4	0.023	0.839	-2,696	5,140
1.45	0.015	0.874	-3,066	5,544
1.5	0.010	0.903	**-3,456**	**6,017**
1.55	0.007	0.926	-3,901	6,348
1.6	0.005	0.944	-4,293	6,748
1.65	0.003	0.958	-4,693	7,036
1.7	0.002	0.969	-5,025	7,389

[1] Odds of differential assignment due to unobserved factors
[2] Lower bound significance level (on assumption of under-estimation of treatment effect).
[3] Upper bound significance level (on assumption of over-estimation of treatment effect).
[4] Lower bound point estimate (on assumption of under-estimation of treatment effect).
[5] Upper bound point estimate (on assumption of over-estimation of treatment effect).

Table 8: Rosenbaum bounds parameters for the results for the subsample of granivore farms

parameter (Γ)[1]	**Wilcoxon P-value**		**HL treatment estimate**	
	Lower bound[2]	**Upper bound**[3]	**Lower bound**[4]	**Upper bound**[5]
1	0.007	0.007	17,261	17,261
1.05	0.005	0.009	16,565	17,733
1.1	0.004	0.012	15,856	18,014
1.15	0.003	0.015	15,207	18,573
1.2	0.002	0.019	14,072	19,169
1.25	0.001	0.024	13,282	19,406
1.3	0.001	0.029	12,766	19,979
1.35	0.001	0.035	12,400	20,817
1.4	0.001	0.041	11,948	21,456
1.45	0.000	0.048	11,497	21,786
1.5	**0.000**	**0.055**	**11,230**	**22,160**
1.55	0.000	0.063	10,611	22,626
1.6	0.000	0.071	10,073	24,862
1.65	0.000	0.080	9,825	25,003
1.7	0.000	0.090	9,466	25,201

[1] Odds of differential assignment due to unobserved factors
[2] Lower bound significance level (on assumption of under-estimation of treatment effect).
[3] Upper bound significance level (on assumption of over-estimation of treatment effect).
[4] Lower bound point estimate (on assumption of under-estimation of treatment effect).
[5] Upper bound point estimate (on assumption of over-estimation of treatment effect).

5 Discussion and conclusions

The heterogeneity of farms and the problem of self-selection are challenging a evaluation of treatments in agriculture. This is particularly the case for rural development measures, which have voluntary participation and heterogeneous outcomes. But knowledge about the selection mechanisms for a certain treatment, in combination with econometric methods, can help to overcome these problems. Next to Instrumental Variable estimation the *Propensity Score Matching* method has become a popular tool in evaluation.

Basically, *matching* creates a new sample by identifying similar controls for each participating individual based on observed covariates. The selection of these covariates is a central issue and of high sensitivity. It is necessary to identify those variables which have the greatest influence on the decision to participate and on the outcome. PSM uses the probability of participation for each unit, estimated by a binary regression model, to reduce the *matching* dimension to one. In this paper we apply *PSM* in combination with the *Difference-in-Difference Estimator* to assess causal effects in the farm income of the farm-investment programme in Austria.

The results show a statistically significant and positive ATT (227 farms) in farm income per year by roughly 7,000 Euros. This might give a quite positive résumé of the farm-investment support programme in order to enhance the competitiveness of farms. But we cannot be sure if *matching* - including the difference-in-difference estimation - could reduce all the selection bias in the result. Particularly since this analysis deals with heterogeneous data the danger of hidden bias rises (Rosenbaum, 2005a). Therefore we apply sensitivity analysis to measure the effects of violation of the independence assumption. The sensitivity analysis for our model reveals that the causal conclusions are quite vague and can change with only a small amount of hidden bias. We split the sample in subsamples for the most favoured farm types, dairy and granivore farms in order to gain more homogenous samples. Then the *matching* procedure is

done individually and the resulting effects differ dramatically. Whereas the effect on farm income for fostered dairy farms (104 farms) is not statistically significant, the effect for treated granivore farms (27 farms) is more than 18,600 Euros and statistically significant. Furthermore the results of the sensitivity analysis show that the models applied for the subsamples are slightly more robust to hidden bias than the model for the whole sample.
The results indicate, on the one hand, that the effect for a small and specific number of farms exceeds the average effect by a high amount. Therefore the splitting of the sample and the effects shows a more accurate picture of the treatment. On the other hand, the increased robustness through sample splitting can be explained by the fact that some group of units, e.g. different farm types, should not be paired with each other in order to derive causal effects, and that homogenous samples might also allow more suitable parametric models and coefficient estimates.

Therefore, especially in the context of agricultural treatment evaluation using observational studies, the need for homogenous samples is of server importance. Much attention needs to be focused on the *Matching* procedure, as the method has to obtain the independence assumption and the homogeneity in the sample. Even though the *Matching* procedure is basically a stratification of the sample, *Matching* on the estimated propensity score might often be misleading and encourage hidden biases. A much more effective method would therefore be the application of exact *Matching*, where treated and non-treated are exactly matched on their covariates and perfect stratification is done. This is especially the case when the inclusion of more covariates cannot describe opting for greater participation. Even though the exact *Matching* approach is limited to a small number of *matching* variables, next to individual adjustments it allows transparency for non-scientific stakeholders in the evaluation process. This is particular necessary as practical information is important for finding covariates. A large amount of work has to be put into pooling information and applying covariates which are plausible for the institutional environment, in which the study is carried out (Lechner, 2002). Transparency is also necessary, when the results are presented, as Rosenbaum (2010) argues*: "An observational study that is not transparent may be overwhelming or intimidating, but it is unlikely to be convincing."* (Rosenbaum, 2010, 147).

All in all, we find that *matching* can help to solve the problems of heterogeneity and self-selection in agricultural studies. *Matching*, at least, confronts the researcher with the process of causal exposure and also the limitations of available data. This is especially relevant in the context of agriculture, where management decisions are always dependent on the unique relationship between farm household and the farm enterprise, on-site and political conditions and also on personal attitudes of the farm manger. All these complex and unobservable factors make it difficult to explain selection mechanism in agriculture. However, *Matching* is definitely a useful tool to balance and pre-process the dataset and understand the direction of causal relationships. In special circumstances, causal claims can be drawn from the result.

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Appendix

Table 9: Mean values of variables for participants and controls before and after Propensity-Score Matching for the dairy subsample

	Potential participants	Potential controls		Selected participants	Selected controls
Number of farms	108	249		104	104
Dummy region south	0.185	0.225		0.192	0.231
Dummy region west	0.213	0.197		0.192	0.240
Dummy konv farming	0.787	0.767		0.788	0.769
Age	52.824	53.964		52.817	52.154
Labour	1.771	1.636	*	1.752	1.812
Utilised agricultural area (log)	3.369	3.149	***	3.341	3.320
Share of rented land	0.285	0.224	*	0.284	0.264
Livestock density	1.292	1.295		1.292	1.291
Share of equity	0.922	0.906		0.925	0.917
Non-farm income (log)	7.718	7.109	*	7.694	7.925
Livestock (log)	3.412	3.192	***	3.404	3.332
Dairy cows (log)	2.789	2.599	**	2.806	2.761
Pigs (log)	0.796	0.734		0.768	0.793

t-test for equally of means: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 10: Mean values of variables for participants and controls before and after Propensity-Score Matching for the granivore subsample

	Potential participant s	Potential controls		Selected participants	Selected controls
Number of farms	39	77		27	27
Dummy region south	0.256	0.247		0.111	0.259
Dummy region west	0.000	0.013		0.000	0.000
Dummy konv farming	0.974	0.961		0.963	0.963
Age	51.821	54.208		53.630	53.333
Labour	1.730	1.503	*	1.687	1.576
Utilised agricultural area (log)	3.565	3.121	***	3.508	3.413
Share of rented land	0.300	0.241		0.262	0.260
Livestock density	1.687	1.560		1.506	1.728
Share of equity	0.904	0.864		0.932	0.940
Non-farm income (log)	7.490	7.218		7.392	7.207
Livestock (log)	3.969	3.390	***	3.815	3.812
Dairy cows (log)	0.053	0.073		0.077	0.139
Pigs (log)	5.944	5.404	*	5.947	5.915

t-test for equally of means: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Awareness and Attitudes towards Biotechnology Innovations among Farmers and Rural Population in the European Union

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Abstract: The paper analyses the impact that European Union (EU) farmers' and rural population's awareness of biotechnology innovations and access to/trust in information on these issues (amongst other *a priori* determinants) have on their perceptions of risks and benefits of the applications of biotechnology innovations, and attitudes towards their implementation in practice. We employ structural equation models (SEM) with observed and latent variables. SEM is a statistical technique for testing and estimating relationships amongst variables, using a combination of statistical data and qualitative causal assumptions. We use an Eurobarometer dataset (2010) about awareness/acceptance of biotechnology innovations and run SEM models for ten EU countries, which include older and newer Member States. The variables included are socio-demographics, access to biotechnology information, trust in information sources on biotechnology innovations, attitudes towards the importance and impact of science and technology on society, perceptions of the risks and benefits of the applications of biotechnology innovations and attitudes towards their implementation in practice. Results between the different EU countries are comparable and, alongside other determinants, trust in information sources will significantly impact perceptions of risks and benefits of the applications of biotechnology innovations, and attitudes towards their implementation in practice. This underlines the importance of information and knowledge to acceptance of biotechnology innovations, which should be a key point on policy-makers' agenda of developing the economic and environmental efficiency in the agricultural sector and rural sustainability in Europe. Increasing awareness of biotechnology innovations that safeguard people and the environment in order to enable informed debate and decisions will help enhance sustainability of rural areas.

Key words: biotechnology innovations, farmers and rural population, European Union, information and knowledge, biotechnology attitudes, structural equation models.

1 Introduction

Feeding a growing population against limited resources and mitigating climate change imply an increasing need for innovation, which requires a coordinated effort from decision makers, industry and the public. Capitalising on innovations offered through agricultural biotechnology will contribute to increase the economic and environmental efficiency in the agricultural sector and rural sustainability in Europe. Hence, awareness of biotechnology innovations amongst both industry (*e.g.*, farmers) and the public (*e.g.*, rural population as a whole) is a key factor influencing their attitudes and potentially leading to positive behavioural change.

There is an increasing literature analysing people's biotechnology attitudes (Allum *et al.*, 2008; Bauer, 2005; Bruhn, 2003; Durant *et al.*, 2000; European Commission, 2008; European Commission, 2010; Frewer *et al.*, 1996; Phipps and Park, 2002; Teisl *et al.*, 2002). They state that knowledge and information are significant factors influencing attitudes and perceptions of biotechnology.

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The paper analyses the impact that European Union (EU) farmers' and rural population's awareness of biotechnology innovations (biofuels, resistance to disease in apples, genetically modified food, animal cloning) and trust in information on these issues (amongst other *a priori* determinants) have on their perceptions of risks and benefits of the applications of biotechnology innovations, and attitudes towards their implementation in practice.

2 Data and Methods

2.1 Data

The data used in this study were extracted from the Dataset Eurobarometer 73.1: Life Sciences and Biotechnology. The Eurobarometer survey was carried out by TNS Opinion & Social through face-to-face interviews of citizens in the 27 Member States of the European Union plus Croatia, Iceland, Norway, Switzerland and Turkey (Eurobarometer, 2010).

The original database includes data on socio-demographics (education, gender, age, occupation, number of children living in the household, religion, political affiliation, perceived level in society); access to biotechnology information; trust in information sources on biotechnology innovations; attitudes towards the importance and impact of science and technology on society; perceptions about biotechnology regulation; perceived responsibility to ensure that biotechnologies benefit everyone; interest about scientific discoveries and technological developments; perceptions about public involvement in decision-making about science and technology; perceptions of the risks and benefits of the applications of biotechnology innovations; and attitudes towards their implementation in practice. The questionnaire included explanatory statements about biotechnologies.

We selected datasets for ten countries (Great Britain, Austria, Belgium, Finland, France, Netherlands, Poland, Portugal, Slovakia and Slovenia). The countries have a good geographical coverage (Western, Northern, Southern and Central-Eastern Europe) and include old and new European Union (EU) member countries. A main reason for the choice of countries was to analyse populations at the opposite ends as regards their attitudes towards the implementation in practice of biotechnology innovations. Namely, as regards their attitudes towards biotechnology developments to increase resistance to disease in apples, Poland and Finland support the concept, while Slovenia does not. As regards their attitudes towards biofuels, Slovakia and Netherlands support the concept, while Austria does not. As regards their attitudes towards cloning, Slovakia and Slovenia support the concept, while Belgium and France do not. As regards their attitudes towards genetically modified foods, Great Britain and Portugal support the concept, while France does not. The datasets have between 110 and 261 observations. The variables included in the analysis are socio-demographic (gender, age, number of children (0-14 years old) living in the household, education, occupation – farmer, religion), trust in information sources on biotechnology issues, self-assessed level of biotechnology information, perceptions about risks and benefits of the applications of biotechnology innovations, and attitudes towards the implementation in practice of biotechnology innovations.

2.2 Method

We use structural equation models (SEM) with observed and latent variables to test the influence of *a priori* identified determinants on attitudes towards biotechnology innovations. SEM is a statistical technique used to test and estimate causal relationships amongst variables, some of which may be latent, based on a combination of statistical data and qualitative causal assumptions. Latent variables are not directly observed but inferred from other variables that are directly measurable (Bollen, 1989). The concept of causality may be controversial (Mueller, 1996), however, SEM is not intended to ascertain causes but to assess the accuracy of the causal relationships *a priori* identified in the literature. Hence, SEM is mostly used as a confirmatory analysis/theory testing tool.

SEM may consist of two components, namely the measurement model (which states the relationships between the latent variables and their constituent indicators), and the structural model (which designates the causal relationships between the latent variables). The measurement model resembles factor analysis, where latent variables represent 'shared' variance, or the degree to which indicators 'move' together. The structural model is similar to a system of simultaneous regressions, with the difference that in SEM some variables can be dependent in some equations and independent in others.

The model is defined by the following system of equations in matrix terms (Jöreskog and Sörbom, 2007):

The structural equation model: $$\eta = B\eta + \Gamma\xi + \zeta \qquad (1)$$

The measurement model for y: $$y = \Lambda_y \eta + \varepsilon \qquad (2)$$

The measurement model for x: $$x = \Lambda_x \xi + \delta \qquad (3)$$

Where: η is an mx1 random vector of endogenous latent variables; ξ is an nx1 random vector of exogenous latent variables; B is an mxm matrix of coefficients of the η variables in the structural model; Γ is an mxn matrix of coefficients of the ξ variables in the structural model; ζ is an mx1 vector of equation errors (random disturbances) in the structural model; y is a px1 vector of endogenous variables; x is a qx1 vector of predictors or exogenous variables; Λ_y is a pxm matrix of coefficients of the regression of y on η; Λ_x is a qxn matrix of coefficients of the regression of x on ξ ; ε is a px1 vector of measurement errors in y; δ is a qx1 vector of measurement errors in x.

The paper estimates SEM with the normal-theory maximum likelihood (MLE) method using the statistical package Lisrel 8.80 (Jöreskog and Sörbom, 2007).

Latent variables and indicators

Table 1 presents a description of the latent variables and their corresponding indicators. There are nineteen latent variables with their corresponding 48 indicators forming sixteen models, namely: three models estimating the impact of determinants on attitudes towards genetically modified foods (Great Britain, France, Portugal); six models estimating the impact of determinants on attitudes towards artificially introducing either a resistance gene from another species or a gene that exists naturally in wild/crab apples into an apple tree to make it resistant to mildew/scab (Poland, Slovenia, Finland); three models estimating the impact of determinants on attitudes towards biofuels (Austria, Slovakia, Netherlands); and four models estimating the impact of determinants on attitudes towards cloning (Belgium, France, Slovenia, Slovakia).

Table 2 presents a series of descriptive statistics for the indicators of the latent variables included in the models.

Table 1. Description of latent variables and their corresponding indicators

Latent variable	Indicator	Statement	Variable type
genders	gender	gender	dichotomous
ages	age	age	categorical
childs	child	number of children (0-14 years old) living in the household	categorical
educs	educ	education	categorical
farmers	farmer	occupation - farmer	dichotomous
relig	relig1	God beliefs	categorical
info	info1	How informed do you feel about new medical discoveries	ordinal-three-point Likert scale
	info2	How informed do you feel about new scientific discoveries and technological developments	ordinal-three-point Likert scale
infojob	infojob1	Trust in newspapers, magazines and television which report on biotechnology	dichotomous
	infojob2	Trust in industries which develop new products with biotechnology	dichotomous
	infojob3	Trust in university scientists who conduct research in biotechnology	dichotomous
	infojob4	Trust in consumer organisations which test biotechnological products	dichotomous
	infojob5	Trust in environmental groups who campaign about biotechnology	dichotomous
	infojob6	Trust in national government making laws about biotechnology	dichotomous
	infojob7	Trust in retailers who ensure our food is safe	dichotomous
	infojob8	Trust in the European Union making laws about biotechnology for all EU Member States	dichotomous
	infojob9	Trust in ethics committees who consider the moral and ethical aspects of biotechnology	dichotomous
	infoj10	Trust in medical doctors	dichotomous
gmaware	gmohear	Have you ever heard of genetically modified (or GM) foods before?	dichotomous
gmoatd	gmoatd1	GM food is good for your country's economy	ordinal-four-point Likert scale
	gmoatd2	GM food helps people in developing countries	ordinal-four-point Likert scale
	gmoatd3	GM food is safe for future generations	ordinal-four-point Likert scale
	gmoatd4	GM food is safe for your health and your family's health	ordinal-four-point Likert scale
	gmoatd5	GM food does no harm to the environment	ordinal-four-point Likert scale
gmo	gm	The development of GM food should be encouraged	ordinal-four-point Likert scale
appatdo		Artificially introducing a resistance gene from another species into an apple tree to make it	

		resistant to mildew/scab:	
	appatdo1	is a promising idea	ordinal-four-point Likert scale
	appatdo2	would still mean that eating apples will be safe	ordinal-four-point Likert scale
	appatdo3	will harm the environment	ordinal-four-point Likert scale
	appatdo4	is fundamentally unnatural	ordinal-four-point Likert scale
	appatdo5	makes you feel uneasy	ordinal-four-point Likert scale
appleo	appatdo6	should be encouraged	ordinal-four-point Likert scale
		Artificially introducing a gene that exists naturally in wild/crab apples which provides resistance to mildew/scab:	
	appatds1	will be useful	ordinal-four-point Likert scale
appatds	appatds2	will be risky	ordinal-four-point Likert scale
	appatds3	will harm the environment	ordinal-four-point Likert scale
	appatds4	is fundamentally unnatural	ordinal-four-point Likert scale
	appatds5	makes you feel uneasy	ordinal-four-point Likert scale
apples	appatds6	should be encouraged	ordinal-four-point Likert scale
	statd1	Even if it brings no immediate benefits, research adding to knowledge should be supported by Government	ordinal-five-point Likert scale
statd	statd2	New inventions will always be found to counteract any harmful effect of scientific/ technological developments	ordinal-five-point Likert scale
	statd3	The benefits of science are greater than any harmful effects it may have	ordinal-five-point Likert scale
biofuels	biofuel	To what extent do you think biofuels should be or not be encouraged?	ordinal-four-point Likert scale
	sbiofuel	To what extent do you think sustainable biofuels should be or not be encouraged?	ordinal-four-point Likert scale
	clonat1	Animal cloning in food production is good for your country's economy	ordinal-four-point Likert scale
	clonat2	Animal cloning in food production helps people in developing countries	ordinal-four-point Likert scale
clonat	clonat3	Animal cloning in food production is safe for future generations	ordinal-four-point Likert scale
	clonat4	Animal cloning in food production is safe for your health and your family's health	ordinal-four-point Likert scale
	clonat5	Animal cloning in food production does no harm to the environment	ordinal-four-point Likert scale
cloning	clon	Animal cloning in food production should be encouraged	ordinal-four-point Likert scale

* Some of the variables described above were measured on a four-point Likert scale (as originally designed in the Eurobarometer questionnaire), which excluded the middle alternative of 'neither agree nor disagree'. The literature is divided as regards the impact the number of scale points used for Likert-type items have on the reliability of responses. After reviewing a number of studies with contradictory results, Alwin and Krosnick (1991) found that five-point scales are not more reliable than four-point scales and that middle alternatives may lower reliability of measurement (they may become more valuable in longer response forms, e.g., seven-point scales). In addition, the original options of response in the Eurobarometer questionnaire included the 'don't know' option, which would account to some extent for the ambiguous opinions, usually captured by the neutral 'neither agree

nor disagree'. While, again, not straightforward, this might increase reliability/reduce reliability errors by filtering out respondents with wide latitudes of acceptance/rejection (Alwin and Krosnick, 1991). In our analysis we treated the 'don't know' responses as missing data and discarded those observations.

Table 2. Descriptive statistics (mean and standard deviation) for the variables

	GMO						Apple						Biofuels								Cloning					
	GB		FR		PT		PL		SI		FI		AT		SK		NL		BE		FR		SI		SK	
	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
gender			1.59	.493	1.56	.498	1.55	.499	1.53	.500	1.52	.502	1.50	.501	1.58	.495	1.51	.501	1.53	.500	1.59	.493	1.53	.500	1.58	.495
age			4.04	1.593	3.47	1.779	3.69	1.670	3.92	1.597			3.70	1.499	3.34	1.519	3.75	1.634	3.96	1.651	3.89	1.684	3.92	1.597	3.37	1.664
child			.62	.898	.39	.772	.60	1.021	.33	.711			.41	.792	.69	.997			.40	.840	.53	.930	.33	.711	.68	.981
educ			3.43	1.098	2.62	1.010	3.21	.975	3.36	1.049			2.96	.922	3.17	.688			3.69	1.104	3.52	1.135	3.36	1.049	3.17	.690
farmer	.05	.209	.11	.316	.05	.222	.11	.310	.08	.274	.11	.318	.12	.324	.06	.243	.15	.359	.10	.307	.14	.352	.08	.274	.09	.280
relig1	1.81	.773	2.09	.830	1.29	.574	1.14	.413	1.89	.778	1.68	.698	1.56	.674	1.30	.591			1.90	.792	2.18	.837	1.89	.778	1.38	.667
info1	2.10	.649	1.95	.572	2.60	.574							2.39	.576	2.40	.598										
info2	2.20	.688	2.04	.607	2.64	.532	2.49	.633	2.27	.611	2.37	.598	2.45	.622	2.53	.560			2.35	.628	2.06	.632	2.27	.611	2.47	.629
infojob1			1.42	.496	1.16	.365	1.13	.341					1.16	.366	1.10	.298					1.48	.501				
infojob2															1.09	.291	1.13	.337	1.16	.366						
infojob3			1.06	.238	1.08	.276	1.08	.271	1.17	.376					1.06	.231	1.03	.180	1.06	.241	1.06	.234	1.17	.376	1.13	.341
infojob4	1.12	.325	1.10	.296											1.06	.242			1.05	.223	1.07	.263	1.31	.465	1.19	.391
infojob5	1.31	.465			1.09	.284			1.27	.443	1.35	.479									1.20	.399	1.27	.443		
infojob6	1.47	.503																	1.19	.392						
infojob7			1.29	.454															1.17	.379						
infojob8	1.52	.503							1.30	.459															1.14	.343
infojob9																							1.23	.424		
infoj10					1.08	.268	1.12	.329	1.12	.323											1.10	.296	1.12	.323		
gmohear			1.12	.328	1.46	.500																				
gmoatd1	2.44	.698	2.95	.859																						
gmoatd2			2.66	.944	2.54	.866																				
gmoatd3	2.56	.785	3.30	.771	2.90	.779																				
gmoatd4	2.55	.884	3.20	.885	3.02	.865																				

gmoatd5			3.16	.926																						
gm	2.70	.893	3.23	.877	2.94	.819																				
appatdo1							2.54	.976	2.98	.971	2.73	.989														
appatdo2							2.83	.955	3.22	.803	3.00	.900														
appatdo3							2.18	.915	1.95	.895	2.08	.870														
appatdo4							1.76	.692	1.54	.754	1.75	.797														
appatdo5							1.96	.814	1.70	.815	2.21	.974														
appatdo6							2.85	.986	3.28	.813	3.02	.949														
appatds1							1.97	.887	2.43	1.017	2.02	.934														
appatds2							2.47	.932	2.38	.982	2.58	.936														
appatds3							2.59	.959	2.44	1.027	2.67	.887														
appatds4							2.34	.950	2.00	.980	2.60	.878														
appatds5							2.47	.934	2.25	1.016	2.75	.984														
appatds6							2.21	.991	2.60	1.022	2.16	1.039														
statd1													2.68	1.099	2.05	.915										
statd2													2.49	.850	2.52	.887										
statd3													2.70	.879	2.59	.902										
biofuel													1.94	.873	1.62	.642	2.00	.910								
sbiofuel													1.74	.765	1.54	.622	1.43	.629								
clonat1																			3.17	.720	3.22	.847	3.47	.717	2.93	.805
clonat2																			2.84	.884	3.08	.913	3.00	.946	2.69	.837
clonat3																			3.12	.768	3.45	.703	3.33	.829	2.97	.809
clonat4																			3.15	.787	3.41	.794	3.43	.789	3.06	.834
clonat5																			2.91	.856	3.16	.911	3.02	1.007	2.83	.819
clon																			3.39	.709	3.56	.665	3.45	.766	3.08	.775
Sample Size	110		197		231		196		233		133		261		224		192		220		242		233		222	

3 Results and Discussion

We tested the models and the path diagrams for the estimated models are conceptually presented in Figure 1 to Figure 4 [6].

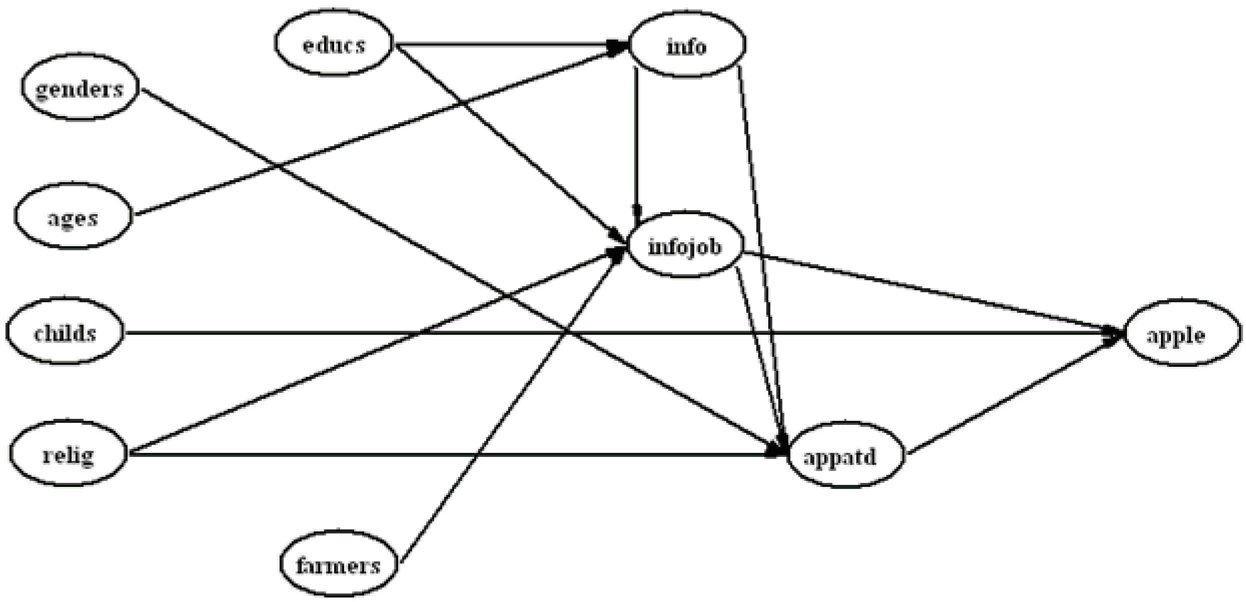

Figure 1. Conceptual diagram for 'apple' models

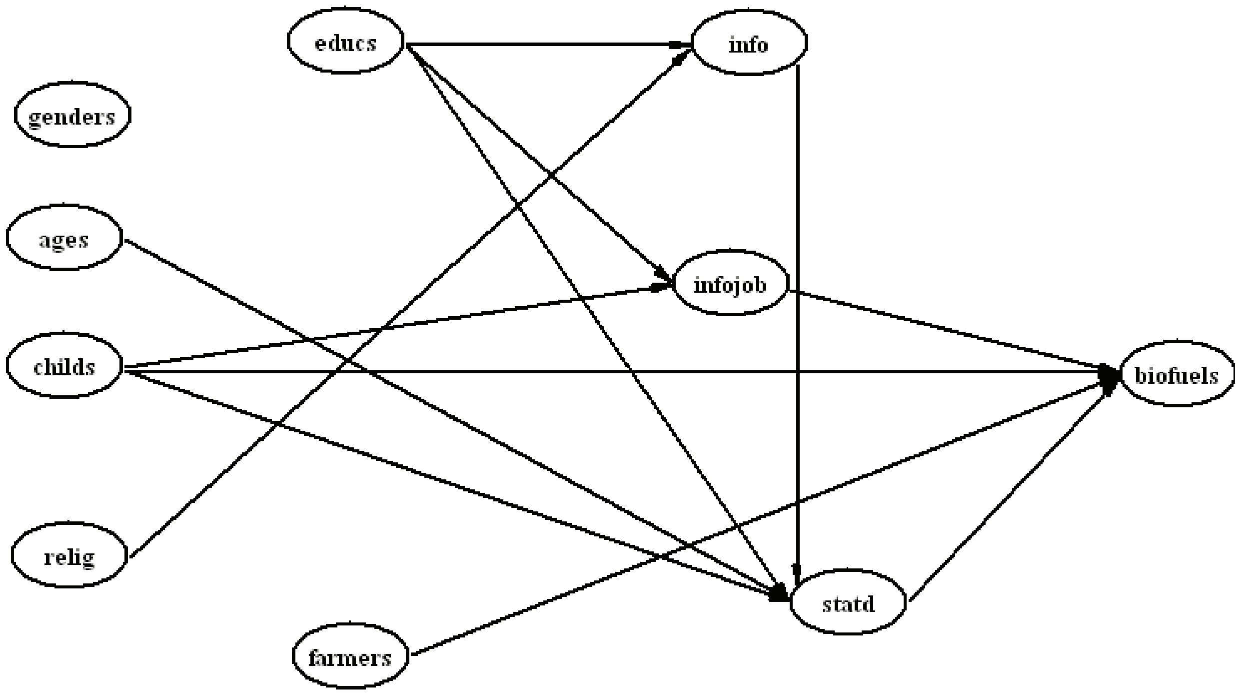

Figure 2. Conceptual diagram for 'biofuels' models

[6] Path diagrams for each of the 16 models (standardised solution) are available on request.

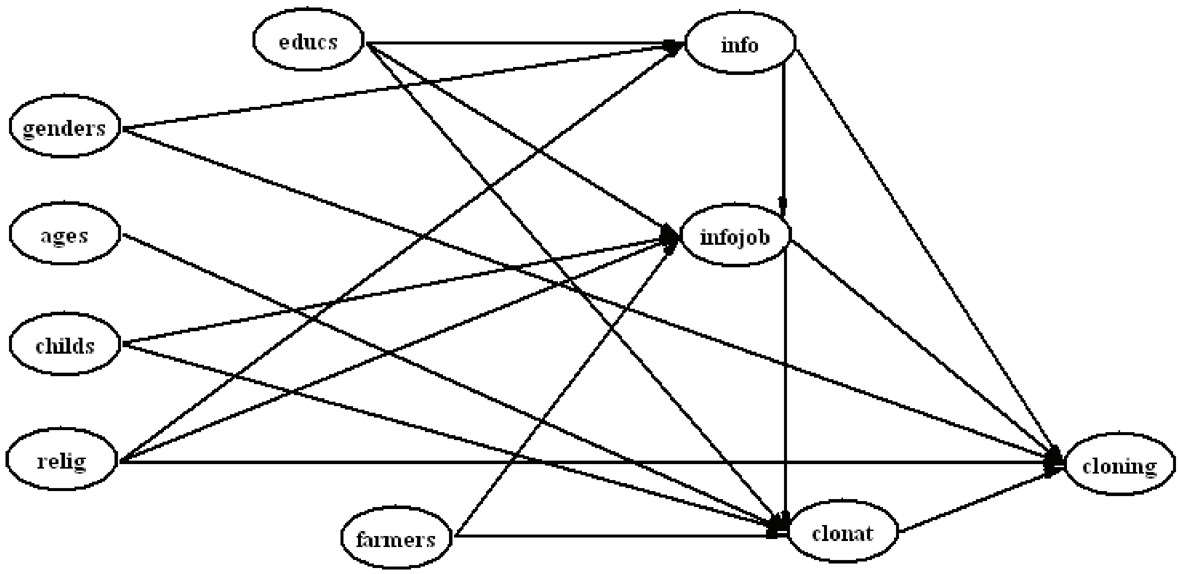

Figure 3. Conceptual diagram for 'cloning' models

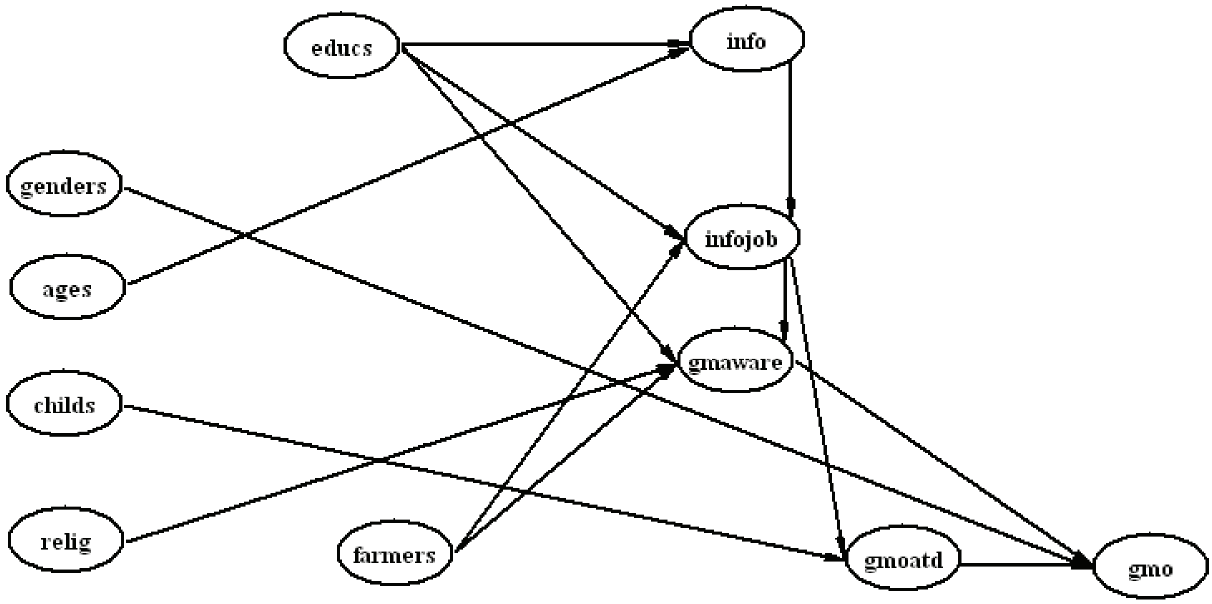

Figure 4. Conceptual diagram for 'GM' models

All models have a good fit according to the measures of absolute, incremental and parsimonious fit (Hair et al., 2006). The main goodness of fit (GoF) indicators (estimated and recommended values) for the estimated models are presented in Table 3.

Table 3. Goodness of fit indicators

GoF indicators	GMO			Apple-other species			Apple-same species			Biofuels			Cloning				Recommended value
	GB	FR	PT	PL	SI	FI	PL	SI	FI	AT	SK	NL	BE	FR	SI	SK	
Degrees of Freedom	52	132	100	90	111	29	85	105	32	59	98	12	126	124	124	81	
Normal Theory Weighted Least Squares Chi-Square	96.97	166.16	188.46	123.79	146.85	64.94	129.31	110.22	68.10	143.91	130.76	12.04	204.34	160.47	152.87	249.29	Low
Normed chi-square	1.86	1.26	1.88	1.38	1.32	2.24	1.52	1.05	2.13	2.44	1.33	1.00	1.62	1.29	1.23	3.08	[1-3]
Root Mean Square Error of Approx. (RMSEA)	0.089	0.036	0.062	0.044	0.037	0.097	0.052	0.01	0.092	0.074	0.039	0.0043	0.053	0.035	0.032	0.097	<0.10
Non-Normed Fit Index (NNFI)	0.76	0.89	0.81	0.88	0.86	0.92	0.74	1.00	0.94	0.81	0.87	1.00	0.80	0.85	0.90	0.83	>0.90
Comparative Fit Index (CFI)	0.81	0.91	0.86	0.91	0.89	0.96	0.82	1.00	0.96	0.88	0.90	1.00	0.83	0.88	0.92	0.89	>0.90
Incremental Fit Index (IFI)	0.82	0.92	0.86	0.91	0.89	0.96	0.83	1.00	0.96	0.88	0.91	1.00	0.84	0.88	0.93	0.89	>0.90
Standardised Root Mean Square Residual (SRMR)	0.097	0.058	0.074	0.065	0.064	0.058	0.057	0.046	0.075	0.057	0.056	0.043	0.069	0.056	0.056	0.060	<0.08
Goodness of Fit Index (GFI)	0.87	0.92	0.91	0.93	0.93	0.92	0.92	0.96	0.91	0.93	0.94	0.98	0.91	0.93	0.93	0.88	>0.90
Adjusted Goodness of Fit Index (AGFI)	0.81	0.88	0.87	0.89	0.90	0.81	0.88	0.94	0.82	0.87	0.90	0.96	0.87	0.91	0.91	0.79	>0.90

Additional testing of the appropriateness of the models was achieved by comparing each of the estimated models with other models that acted as alternative explanations to the proposed models, in a competing models strategy (we used a nested model approach, in which the number of constructs and indicators remained constant, but the number of estimated relationships changed). The results across all types of goodness-of-fit measures favoured the estimated models in most cases. Therefore, we confirmed the accuracy of the proposed models and discarded the competing ones.

An acceptable level of overall goodness-of-fit does not guarantee that all constructs meet the requirements for the measurement and structural models. The validity of the SEM was assessed in a two-step procedure, the measurement model and the structural model.

In the measurement model we tested the reliability of the single-indicator latent variables, namely we tested the 'theory-testing extremes' of reliability within the range of 0.7 to 1 (Ping, 2008) and determined that none of the structural coefficients became non-significant at these extremes. The reliability of the single-indicator latent variables was assumed the value of 0.99.

After assessing the overall model and aspects of the measurement model, the standardised structural coefficients for both practical and theoretical implications were examined. Table 4 presents the standardised total effects on the variables representing the perceived risks and benefits of the applications of biotechnology innovations, and attitudes towards the implementation in practice of biotechnology innovations, of all the other latent variables included in each of the sixteen models.

Table 4. Standardised total (direct and indirect) effects on behavioural latent variable (t-values in parentheses)

Observed/ latent variables	GMO			Apple-other species			Apple-same species			Biofuels			Cloning			
	GB	FR	PT	PL	SI	FI	PL	SI	FI	AT	SK	NL	BE	FR	SI	SK
	Total effects on perceived risks and benefits of the applications of biotechnology innovations															
	Total effects on 'gmoatd'			Total effects on 'appatdo'			Total effects on 'appatds'			Total effects on 'statd'			Total effects on 'clonat'			
genders			0.09 (3.28)	-0.02 (-1.74)	0.02 (1.76)	0.29 (2.50)	0.12 (2.09)	0.11 (2.17)	0.27 (2.65)	0.22 (3.17)				0.01 (1.42)	0.06 (1.07)	0.04 (2.55)
ages		0.00 (0.07)	0.03 (2.12)				0.00 (-0.87)			0.27 (3.40)			0.00 (0.94)	0.01 (1.24)		0.21 (4.77)
childs		0.08 (2.12)	-0.02 (-0.61)							0.31 (4.18)						0.13 (3.26)
educs		-0.11 (-3.03)		-0.01 (-1.65)	0.00 (-1.34)		-0.03 (-0.94)	-0.06 (-1.83)		-0.05 (-0.61)			-0.01 (-1.33)	-0.01 (-1.31)	0.00 (-1.07)	0.22 (1.27)
farmers	-0.11 (-2.65)	0.06 (2.76)	-0.02 (-2.02)	0.03 (1.83)		-0.39 (-3.48)	0.04 (2.13)		-0.36 (-3.50)				0.17 (2.89)	0.01 (0.18)	0.18 (3.05)	-0.13 (-2.11)
relig			-0.13 (-3.98)	-0.05 (-2.07)	-0.11 (-2.23)		0.14 (2.74)	-0.07 (-1.34)	-0.06 (-1.94)	-0.07 (-2.08)			0.00 (-1.06)	-0.07 (-1.61)		-0.05 (-1.66)
info	-0.14 (-2.61)	0.16 (2.39)		0.03 (1.84)	0.04 (1.84)	0.13 (1.32)	-0.15 (-1.70)	-0.15 (-1.65)		0.53 (5.97)			0.06 (1.64)	0.06 (1.73)	0.03 (1.18)	0.28 (4.83)
infojob	0.39 (3.31)	0.31 (2.24)		0.18 (2.01)	0.19 (2.51)		0.38 (3.20)	0.30 (2.99)	-0.35 (-5.21)				0.45 (3.25)	0.29 (2.55)	0.14 (2.40)	0.60 (8.09)
gmaware			0.17 (3.07)													
	Total effects on attitudes towards the implementation in practice of biotechnology innovations															
	Total effects on 'gmo'			Total effects on 'appleo'			Total effects on 'apples'			Total effects on 'biofuels'			Total effects on 'cloning'			
genders		0.17 (2.34)	0.02 (0.95)	-0.02 (-1.75)	0.02 (1.76)	0.25 (2.45)	0.08 (2.10)	0.09 (2.17)	0.23 (2.75)	0.05 (2.15)	0.18 (3.05)	0.05 (2.09)		0.01 (1.44)	0.04 (1.06)	0.13 (4.33)

ages		0.00 (0.07)	0.00 (0.90)				0.00 (-0.73)			0.06 (2.21)		-0.02 (-0.35)	0.00 (0.95)	0.01 (1.26)		0.14 (4.84)
childs		0.08 (2.11)	-0.01 (-0.61)				0.04 (1.90)			-0.18 (-2.58)						0.06 (2.03)
educs		-0.18 (-3.44)	0.04 (3.11)	-0.01 (-1.66)	0.00 (-1.34)		-0.06 (-1.67)	-0.05 (-1.83)		0.08 (2.47)	-0.02 (-1.50)		-0.01 (-1.34)	-0.01 (-1.33)	-0.01 (-1.43)	0.28 (2.04)
farmers	-0.10 (-2.64)	-0.01 (-0.26)	-0.01 (-2.01)	0.03 (1.83)	0.07 (1.42)	-0.19 (-2.03)	0.05 (2.24)		-0.27 (-3.30)	0.19 (2.92)	0.04 (0.61)	-0.07 (-2.20)	0.19 (2.97)	0.01 (0.18)	0.25 (5.04)	0.00 (-0.09)
relig		-0.03 (-1.89)	-0.02 (-0.97)	-0.05 (-2.08)	-0.08 (-2.23)	0.10 (1.97)	0.05 (1.08)	-0.06 (-1.34)	-0.05 (-1.93)	-0.02 (-1.69)			0.00 (-1.06)	-0.10 (-1.65)		-0.03 (-0.94)
info	-0.13 (-2.60)	0.17 (2.49)	0.09 (2.49)	0.03 (1.85)	0.03 (1.84)	0.09 (1.32)	-0.07 (-1.04)	-0.12 (-1.65)	0.09 (1.67)	0.12 (2.62)	0.12 (1.67)		0.07 (1.65)	0.08 (1.78)	0.05 (1.72)	0.21 (3.25)
infojob	0.35 (3.29)	0.35 (2.32)	-0.37 (-5.34)	0.18 (2.02)	0.14 (2.51)	-0.42 (-10.35)	0.45 (3.62)	0.25 (2.99)	-0.29 (-4.96)	0.37 (5.37)	0.71 (3.03)	0.20 (1.99)	0.50 (3.36)	0.42 (2.72)	0.26 (2.77)	0.63 (12.85)
gmaware		0.15 (2.01)	0.11 (3.10)													
gmoatd	0.89 (4.57)	0.95 (5.97)	0.64 (5.73)													
appatdo				0.97 (5.81)	0.71 (6.16)	0.73 (11.76)										
appatds							0.69 (5.05)	0.83 (6.71)	0.83 (10.42)							
statd										0.22 (2.78)	0.20 (2.40)					
clonat													0.82 (5.64)	0.96 (5.06)	0.62 (5.79)	0.68 (13.16)

Table 4 shows that the only variables which are significant in all models are variables 'infojob' and 'gmaware'.

The variance explained in the 'gmo' models varies from 37% in France, 40% in Great Britain to 51% in Portugal. The variance explained in the 'apple-same species' models varies from 32% in Poland, 36% in Slovenia to 65% in Finland. The variance explained in the 'apple-other species' models varies from 35% in Slovenia, 36% in Poland to 65% in Finland. The variance explained in the 'biofuels' models varies from 14% in Netherlands, 25% in Austria to 30% in Slovakia. The variance explained in the 'cloning' models varies from 35% in Belgium, 42% in France, 43% in Slovenia to 54% in Slovakia.

In terms of individual effects, perceptions about risks and benefits of the applications of biotechnology innovations (biofuels, resistance to disease in apples, genetically modified food, animal cloning) have the strongest impact on attitudes towards the implementation in practice of biotechnology innovations, with values from 64% to 95% in the gmo models, 69% to 97% in the apples models, 20% to 22% in the biofuels models, and 62% to 96% in the cloning models.

Trust in information sources on biotechnology issues has the strongest impact on perceptions about risks and benefits of the applications of biotechnology innovations, and second strongest impact on attitudes towards the implementation in practice of biotechnology innovations, with values from 14% to 60% and, respectively, from 14% to 71%.

Self-assessed level of information on biotechnology issues shows mixed impacts; while significantly influencing both perceptions about risks and benefits and attitudes towards the development of genetically modified foods (values from 9% to 17%), it is not significant in the apples models, and is significant only in some of the biofuels (Austria) and cloning (Slovakia) models.

Similarly, education significantly influences both perceptions about risks and benefits and attitudes towards the development of genetically modified foods (values from 4% to 18%), it is not significant in the apples models, and is significant only in some of the biofuels (Austria) and cloning (Slovakia) models.

Gender has a lower but significant impact on attitudes towards the implementation in practice of biotechnology innovations in a small majority of models. As regards the other socio-demographic factors, children living in the household and age have a lower impact and significant only in a few models.

Religious beliefs do not significantly influence perceptions about risks and benefits of the applications of biotechnology innovations and attitudes towards the implementation in practice of biotechnology innovations, with the exception of apples-other species models, where it takes values from 5% to 10%.

Compared to the rest of the rural population, farmers have significantly different perceptions about risks and benefits of the applications of biotechnology innovations and attitudes towards the implementation in practice of biotechnology innovations in a number of models, namely: gmo models in Great Britain and Portugal; apples models in Poland and Finland; biofuels models in Austria and Netherlands; cloning models in belgium and Slovenia.

Overall, the ranking of determinants' impact on attitudes towards the implementation in practice of biotechnology innovations is similar in the majority of models, with perceptions about risks and benefits of the applications of biotechnology innovations as strongest determinant, followed by trust in information sources on biotechnology issues with strong influence, then by self-assessed level of biotechnology information, education and gender with lower impact and ending with religion, children and age, with the lowest influence. This supports findings from the literature that knowledge and information will always impact biotechnology attitudes and perceptions (Allum *et al*., 2008; Bauer, 2005; Bruhn, 2003; Durant *et al*., 2000; European Commission, 2008; European Commission, 2010; Frewer *et al*., 1996; Phipps and Park, 2002; Teisl *et al*., 2002).

4 Conclusion

The paper analysed the impact that European Union (EU) farmers' and rural population's awareness of biotechnology innovations and access to/trust in information on these issues (amongst other a priori determinants) have on their perceptions of risks and benefits of the applications of biotechnology innovations, and attitudes towards their implementation in practice. Results between the different EU countries are comparable and, alongside other determinants, trust in information sources will significantly impact perceptions of risks and benefits of the applications of biotechnology innovations, and attitudes towards their implementation in practice. This underlines the importance of information and knowledge to acceptance of biotechnology innovations, which should be a key point on policy-makers' agenda of developing the economic and environmental efficiency in the agricultural sector and rural sustainability in Europe. Increasing awareness of biotechnology innovations that safeguard people and the environment in order to enable informed debate and decisions will help enhance sustainability of rural areas.

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Effects of biogas production on inter- and in-farm competition

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Annotation: Biogas production is one of the influential innovations of recent decades in German agriculture. Due to high guaranteed energy prices biogas production led to distortions in agricultural and land markets. This paper provides insights in effects of biogas production on farms, farm structures and rural areas for the region Altmark, Germany, for the period 2012-2026 by using the agent-based simulation model AgriPoliS. AgriPoliS enables to simulate agricultural structural change and impacts of policies based on a linear programming approach. To maximize the household-income, farm agents can invest, produce and compete against each other on the land rental market. To analyse effects of biogas production, biogas plants, possible substrate mixtures and feed-in remunerations are introduced in the model. In our analyses, we focus on 1) the choice of production of farms, 2) the competition between farms, and 3) impacts on rural areas including environmental issues and labour market. Our simulation results show that biogas production provides especially for farmers with high management capabilities and large farms a profitable income opportunity. On average, biogas farms cannot increase their profitability. As result of an increased value added through biogas production and high competition among farms, rental prices increase and thus a high share of the value added is transferred to the land owners. Biogas production leads to an intensification of land use, especially to increases in cultivation of grass and maize silage instead of meadows and other crops, and in livestock production. This may cause negative environmental effects. On the other hand both, the intensification and the biogas production have positive effects on the labour market as biogas farms have an additional workforce demand.

Key words: biogas production, agricultural production, agent-based model AgriPoliS, land rental prices.

1 Introduction and Background

Biogas production is one of the most influential innovations of recent decades in German agriculture. Supported by guaranteed feed-in tariffs and priority connection to the electricity grid regulated by the Renewable Energy Sources Act (in German: Erneuerbare-Energien-Gesetz, EEG) (AEE, 2012a) farms were able to rapidly adapt to the new opportunities. Between 2006 and 2011 the total number of plants doubled while the capacity even increased to more than two-and-a-half times. In 2011, more than 7,000 biogas plants with an average plant capacity of 402 kW produced renewable energy in Germany (AEE, 2012).

Because of the guaranteed feed-in tariffs for 20 years, investments in biogas plants promise to be secure and very profitable for farmers, particularly if manure is available. On the other hand, the high profitability leads to new dynamics on land markets. Several studies show that the higher the biogas production in a region the stronger is the increase in land purchase and rental prices. For example, Braun, Lorleberg and Wacup (2007) found that biogas producers in North Rhine-Westfalia (West Germany) have a much higher willingness to pay for arable land and especially grazing land than food producing farmers. Kilian et al. (2008) find that high shares of biogas production led to higher rental prices in Bavaria. Habermann and Breustedt (2011) detect differences of impacts of biogas production between West and East Germany. They examine in their spatial econometric analysis that “agricultural biogas

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production, measured as the share of acreage cultivated with energy crops, increases the rental rates in Western Germany significantly" (Habermann and Breustedt, 2011), but that does not hold for Eastern Germany. Habermann and Breustedt explain the insignificance in East Germany by referring to the average larger size of East German farms, which causes less pressure to rent land for growing biogas substrates. In a more recent study, Hüttel et al. (2012) demonstrate that biogas production measured in kW per sub-district has a significant positive impact on sales prices of auctioned land in Saxony-Anhalt, East Germany. As an interim summary, effects of biogas production on land rental markets may vary for different regions and farm sizes. Nevertheless, increases in rental prices might be at least partly driven by biogas producers as they need feed for their biogas plants and are able to bid high prices for land because of the high guaranteed feed-in tariffs. Finally, biogas production may also lead to a different production structure of farms. Feed and food production are increasingly displaced by renewable energy crops such as maize and ley. Furthermore manure is a cheap co-substrate, but it needs cattle and therefore also feed.

Besides many effects on agricultural structures and developments, also rural areas are affected by the new dynamics. On the one hand, biogas producing farms can serve as an employer in rural areas and, furthermore, the newly created biogas branch generates jobs for selling, building and maintaining biogas plants (O'Sullivan et al., 2012). On the other hand, monocultures, ploughing-up of grassland to grow maize, and increasing traffic (transport of substrates and digestates) might affect the environment and the living conditions of rural inhabitants.

While impacts of biogas production on land markets and, thus, farm competition with regard to rental prices have been analysed in the past, impacts on farm competition and cultivation with focus on East German agriculture are underrepresented. The present paper seeks to fill this gap by studying impacts of biogas production in the East German region Altmark. The Altmark region is one of 25 selected German bioenergy regions ('Bioenergieregionen', BMELV, 2012a) because it offers a huge potential of biomass from several sectors. Among them is the agricultural sector with a high proportion of specialized dairy farms and grassland.

The present paper analyses in the first place impacts of biogas production on agriculture. The focus is on three aspects: Firstly, on the competitiveness of production activities within a farm (we call this in-farm competition), secondly on the competitiveness of farms within a region (we call this inter-farm competition) and thirdly on the impact of biogas production on rural areas, including environmental issues and labour markets. Different to other studies we use in our analysis an agent-based simulation model, namely AgriPoliS, which enables simulation of agricultural structural change and the impact of policies on agriculture. The simulation results enable to examine in-farm competition by comparing revenue shares of production branches, as well as cultivation sizes and livestock keeping. Besides, we analyse profits of biogas and non-biogas farms, rental prices for arable and grazing land as well as farm size developments which represent the inter-farm competition. The cultivation size of different crops, number of animals and the annual working units employed on farms provide information about the impact of biogas production on rural development, environment and labour market.

The paper proceeds as follows. The next section introduces the agent-based model AgriPoliS together with the case study region Altmark. In section 3 simulation results for a time period of 15 years are analysed and discussed. The paper ends with conclusions in section 4.

2 Methodological approach and case study region

To analyse the impact of biogas production we use the agent-based model AgriPoliS (Agricultural Policy Simulator, e.g. Happe et al., 2006). In this chapter we describe the model features and the study region Altmark in East Germany.

2.1 The agent-based model AgriPoliS

AgriPoliS is an agent-based model which enables to simulate regional agricultural structures and their developments over time in response to different policies (see Happe, 2004; Happe et al. 2008, Sahrbacher et al. 2012). A detailed documentation of the current version can be found in Kellermann et al. (2008), and a protocol following the ODD standard (Overview, Design concepts and Details) is available in Sahrbacher et al. (2012a).

In AgriPoliS a number of individual agents acts and also interacts in an environment which maps agriculturally related regional and structural characteristics. First, the region has to be initialised by adapting the model to the real region. This happens on two levels. On the one hand, statistical data about regional agriculture and data of individual farms (usually data from the farm accountancy data network (FADN)) are used to map the regional characteristics of agriculture regarding number of farms, farm types and farm orientations, amount of arable and grazing land, number of livestock in the region, size classes in hectares and number of livestock per farm. In a programming approach based on the method of Balmann, Lotze and Noleppa (1998) and further developed by Sahrbacher (2003), typical farms are identified from a large number of individual farms. By minimizing the deviation between the sum of the weighted characteristics of individual farm types and the overall characteristics of the region, it is determined how often the different farm types should be weighted to map this region as accurately as possible. Apart from a farm's factor endowment and size, farms differ in the management skills, which influence the variable costs of production processes, and in the age of machinery, buildings. The management skills and the ages are varied randomly to ensure heterogeneity among agents.

On the other hand, the organization, i.e. possible production processes and investments, of the selected typical farms is projected by adapting model farms to the selected real farms. Therefore, a linear programming model is built, in which the selected typical farms' data on factor endowments (quota, facilities, labour, capital, land, etc.) is incorporated. Furthermore, various production and investment alternatives are entered, from which the farms can choose to optimally utilize their factor endowments. All options must be typical for the region and are calibrated such that in the beginning of each simulation, the derived model farms choose nearly the same production processes as the real farms they represent. For the different types of production, each farm can choose between a number of investment alternatives of different size to capture size effects due to decreasing investment costs and labour requirements per unit.

Besides deciding on products and investments, farms can also extend their capacities by renting agricultural land, buying production quotas, and employing workers. Furthermore, capital can be borrowed on a short- and long-term basis. In contrast, capacities can be set free, e.g., land rental contracts can expire, quotas can be rented out, hired labour can be dismissed or family workers can be employed outside the farm. Furthermore, liquid assets may be invested outside the farm. All decisions on production, investment and redundancy of capacities are based on a one period mixed-integer programming. In case of renting land farms compete for free land via an auction on the land rental market. Generally, it is assumed that each farm operates independently to maximize its individual household income or profit in case of legal persons. The resulting decision behaviour of the agents is rational, but myopic. Strategic decisions considering future changes in the technical and economical conditions are currently not included in the model. Farms are assumed to expect constant environmental conditions for future periods and adjust their price expectations adaptively from period to period. Policy changes are anticipated one period in advance and included in the decision.

Finally, farms can also leave the sector if they are illiquid or expect a lack of coverage of opportunity costs.

2.2 Case study region

The case study region is the Altmark region with its two districts Stendal and Altmarkkreis Salzwedel. The Altmark is located in the German Federal State of Saxony-Anhalt, approx. 50-150 km west of Berlin. In this structurally weak region, agriculture is of high importance for the rural development. By offering jobs to 6 % of employed people, farms are considerable employers, especially because income opportunities outside the farms are scarce and the unemployment rate is above 10 %. Bioenergy production could save existing and create new jobs. Altmark is, not only therefore, a predestined region to study effects of biogas production on farms and rural areas. Being characterized by large arable farms as well as large mixed farms with livestock, Altmark is a good representative of East German agricultural regions. The importance of livestock production is emphasized by the fact that around 40 % of the dairy cows and 53 % of the specialised dairy farms in Saxony-Anhalt were located in Altmark in 2007. The proportion of grassland is comparatively high (nearly 27 %).

Since 2009 the Altmark is one of 25 so-called bioenergy regions (BMELV, 2012a) in Germany because it offers a huge potential of biomass from several sectors. In the long run, one aim of this initiative is to generate regional value added by the extension of bioenergy production to support sustainable developments of rural areas (Regionale Planungsgemeinschaft Altmark, 2012). With a high proportion of specialized dairy farms and grass land, agriculture provides many possible usages of biomass for energy production, e.g. biogas. Many farms already invested in biogas production in recent years: in 2010 a total number of 65 biogas plants produced energy, whereof 26 were owned by regional investors, mainly farmers or agricultural cooperatives. Besides many positive synergy effects of biogas production regarding, e.g., energy recovery in local households there are also critical voices in society concerning the building of biogas plants. In a SWOT analysis of the “bioenergy-region Altmark“, Regionalverein Altmark e.V. (2008) mentioned acceptance problems in the public as well as conflicts, fears or resistance on local level which may prevent the implementation of bioenergy projects. However, there is less potential for conflicts in the field of biogas compared to other areas of renewable energies such as wind power plants. Despite all prejudices and reservations against bioenergy, there have not been any serious conflicts in the Altmark so far. Problems with existing biogas plants have only concerned individual cases. But from the perspective of nature and environmental protection, there are more and more critical arguments against further extension of bioenergy, such as negative effects due to ploughing up of grassland, cultivation of agricultural monocultures and increasing pressure on the use of sensitive areas (cf. Regionalverein Altmark e.V., 2008).

2.3 Modelling Altmark region in AgriPoliS

To capture the regional agricultural structure as good as possible, typical farms for the representation and their weights have to be identified as described in section 2.1. Therefore, most recent available statistics on regional agricultural characteristics (e.g. number of farms, livestock, farm size classes etc.) and FADN data of regional farms are used (cf. Balmann et al., 2010). Because agricultural statistics were last available for 2007, we also used FADN data for 2006/07 and start simulations in 2006. The up-scaling procedure resulted in 33 typical farms which represent with their weights 968 model farms. The 968 farms differ in their type of farm, available capacities, management capabilities, which influence their variable costs, and in the age of machinery and buildings.

Model farms are able to produce crops and livestock. The assumptions for those different production processes come from data bases of contribution margins of crops (LLFG, 2009) as well as feed and livestock (MLUV, 2008). The reference year to which the region is calibrated is the financial year 2006/07.

Focus of this paper is biogas production. Thus, biogas production is introduced in the model. Farms can choose between different options of plant sizes and substrate mixtures. Overall, three plant capacities (150, 450, 800 kW), and three mixtures with different shares of maize and grass silage, liquid cattle manure, and rye grain are offered. Table 1 shows the assumptions on the biogas plants with their revenues from feed-in tariffs, the investment and calculated substrate costs as well as the needed working time to operate the plant. The investments costs per kW are assumed to decrease with increasing plant size. Investment and production data for biogas production were taken from KTBL (2010); the guaranteed feed-in remuneration, consisting of a basic payment and bonuses, is based on the EEG 2009 and 2012 (BMJ, 2008, 2010 and 2011).

Table 1. Assumptions on biogas production from 2012 to 2026

	150 kW	**450 kW**	**800 kW**
Feed-in tariff in 1,000 Euro/year (dep. on mix)	208-213	544-579	935-992
Investment costs in Euro	850.000	1.825.000	2.650.000
Investment costs in Euro/kW	5.667	4.056	3.313
Calculated substrate costs in 1,000 Euro/kW (w/o costs for manure)	74 -92	202-256	341-431
working hours (dep. on mix)	894-1.064	1.344-1.581	1.839-2.227

Source: Own assumptions according to BMJ (2011), KTBL (2010).

In reality the basic remuneration is oriented towards the time of building of the biogas plant. Accordingly, a plant built later receives lower basic feed-in tariffs. For simplification we did not consider such a dynamic degression of feed-in tariffs. Background is that in reality not only remuneration would decrease but it can also be assumed that investment costs decrease because of efficiencies, e.g., by up to 5 % according to Prognos AG (2010). Therefore, we assume constant remunerations during the period 2012 to 2026 according the EEG 2012. Both, the decreasing investment costs and degressive remuneration would in reality more or less neutralize each other. Furthermore, we have not implemented a minimum use of lost heat so far.

Table 2. Assumptions on substrate mixtures from 2012 to 2026

	Mix 1	**Mix 2**	**Mix 3**
Maize silage	20 %	60 %	20 %
Grass silage	20 %	10 %	20 %
Whole-crop-silage	-	-	40 %
Cattle manure	60 %	30 %	-
Rye grain	-	-	20 %

Source: Own assumptions according to Grundmann et al. (2006), KTBL (2010).

In reality the Renewable Energy Sources Act changed in 2012. This is considered in the model as well. From 2006 to 2012 the former EEG 2009 is applied, from 2012 assumptions shown in Tables 1 and 2 are considered. The main difference of the EEG 2012 to the EEG 2009 lies in the allowed shares of substrates. In 2012 a maximum limit of 60 % of maize silage, corncob mix and grain kernel was introduced. This limitation is also used in the model as can be seen in Table 2. From 2012 on, farms can choose between three mixtures to produce biogas. With Mix 3 it is even possible to operate a biogas plant without cattle manure. More common in reality is the use of manure and maize silage (see Mix 1 and Mix 2).

To illustrate the effects of biogas production, we compare a biogas scenario with a reference scenario. In the reference scenario farms cannot invest in biogas plants while in the biogas scenario biogas production is available. In both scenarios, farms have the same conditions apart from the availability to invest in biogas plants in the biogas scenario. No model farm has been given a biogas plant as capacity in the beginning of simulations, i.e. in 2006, because the most substantial growth began first in 2005/06 after the EEG was revised and statistical data about existing biogas plants in the Altmark region in 2006 were not available.

3 Results and Discussion

As illustrated above, biogas production offers both threats and opportunities for farms and has impacts on land markets as well as on the cultural landscape. We analyse impacts of biogas production on farms and the rural area in the Altmark region while focusing on three aspects: 1) the choice of production of farms, 2) the competition for land between farms, and 3) impacts on environment and labour market. With the agent-based model AgriPoliS we simulate two scenarios: the biogas scenario and the reference scenario. Simulations start in calendar year 2006. Our analyses were made for the period 2012 to 2026.

3.1 In-farm competition

Before we present results regarding the choice of production of farms, we introduce characteristics of biogas and non-biogas model farms in 2012 (Table 3).

In general, not every farmer is able to invest in a biogas plant. Size, management capability and resources such as capital and labour are prerequisites to invest and succeed. Because biogas production is a knowledge-intensive and demanding business, farmers need high management capabilities to be successful in this production branch. Thus, only model farms with a high management capability invest in biogas plants. On average, model farms which invest in biogas have due to higher management skills ca. 1.8 % less variable costs in all production processes, i.e. also in biogas production, while all other farms only save ca. 0.8 % on average in 2012.[2] Biogas farms are on average also larger than non-biogas farms. In terms of European size units (ESU) biogas farms are nearly ten times as large as other farms. The farm size in ha is 3.7 times higher, they keep much more cattle, and have because of their size more equity capital.

In the biogas scenario in 2012, 108 of the 741 model farms (i.e. 14.6 %) own 282 biogas plants with a total capacity of 45 MW. That means every biogas producing farm owns on average 2.6 biogas plants in the model with an average installed capacity of 160 kW per plant or 416 kW per farm. Compared to reality, model farms invest in more but smaller biogas plants. This is due to the fact that model farms can neither choose intermediate sizes, e.g., between 150 and 450 kW nor cooperate and share facilities. Furthermore, model farms do not

[2] The reduced variable costs result from a farm specific management factor. During the initialization of a simulation, every farm is assigned a randomly chosen management factor between 0.8 and 1.2. According to this management factors the variable costs of every production activity are proportionally increased or decreased. The fact that on average the management factor in 2012 is less than 1.0 is based on the endogenous structural change between the initialization of the model for 2006 and 2012. I.e., that in general farms with poor management factors (>1) exit earlier than those with high management skills (<1).

have the opportunity to buy substrates from other farms yet. Therefore, model farms' sizes are mostly too small to invest in larger plants. The smallest farm which invests in a biogas plant manages 290 ha and 240 dairy cows plus offspring.

Nevertheless, the results fit to real observations regarding the total installed capacity per farm and for the whole region. For example in 2011 farms produce 40.95 MW in the model while real production resulted in 41 MW in the Altmark region (2011 is the latest available data; LLFG, 2011). Average plant capacity per model farm in 2011 amounted 369 kW; in Germany it reached at the same time 402 kW on average.

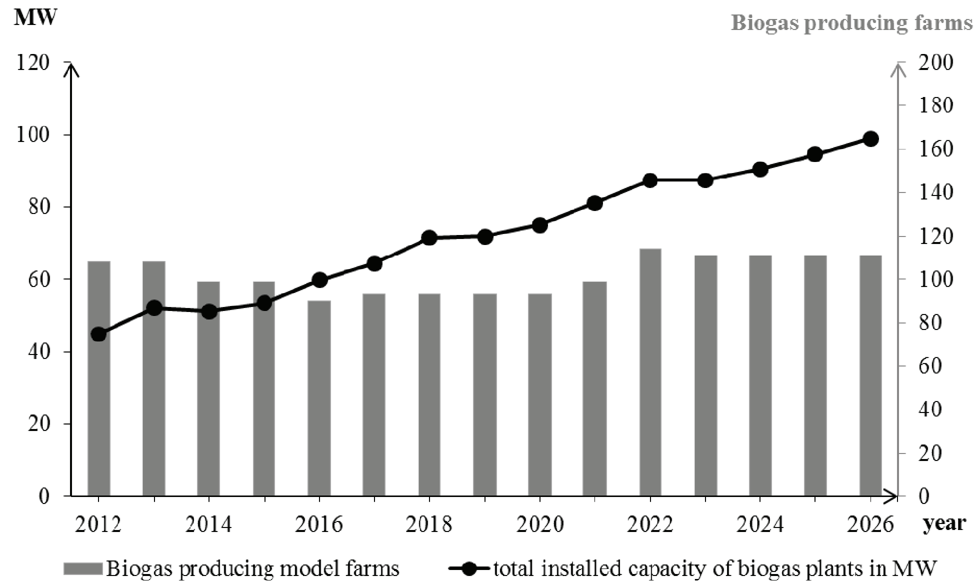
Table 3. Characteristics of biogas and non-biogas farms in the biogas scenario 2012

Characteristics	Biogas Farms	Non-biogas Farms
Number of farms	108	633
Average farm size in ha	996	272
Average farm size in ESU*	661	69
Variable cost saving due to management capability	1.78 %	0.84 %
Number of cattle	500	29
Equity capital in EUR	1,133,071	235,320

* ESU means European size units, one ESU equals to 1,200 Euro standard gross margins.

Source: Own simulation results from AgriPoliS.

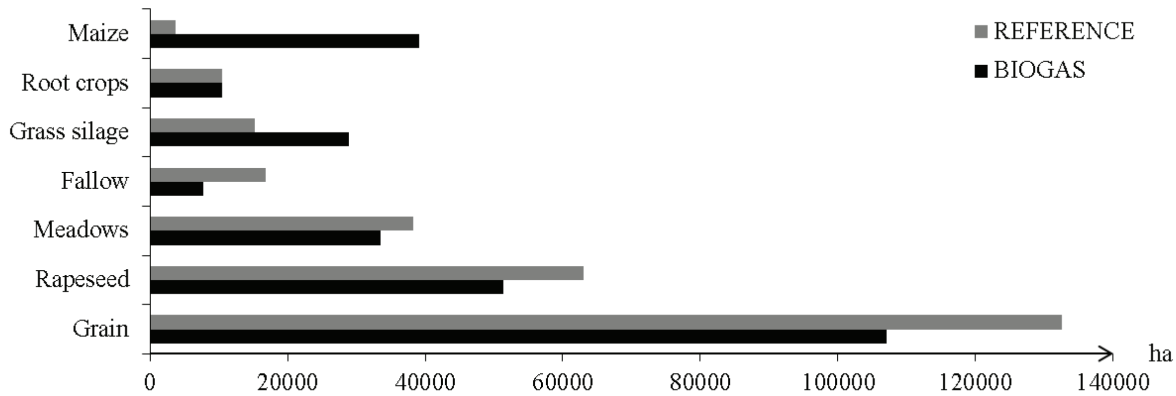
Figure 1 shows the further development of plants and their total installed capacity between 2012 and 2026 in the model. Accordingly, model results support expectations that biogas production will increase further, in particular due to a rise in the installed capacity per farm. During the simulations, farms grow because others quit farming. This offers potentials to invest in larger plants (450 to 800 kW) as well. The almost stable number of plants, while at the same time increasing installed capacity, indicates rising plant sizes. Starting in 2012 with an average installed capacity of 416 kW, biogas farms increase their capacities to 943 kW per farm in 2026.



Source: Own simulation results from AgriPoliS.

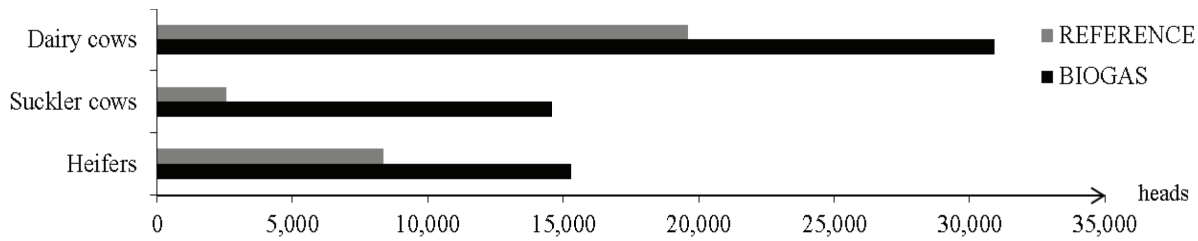
Fig. 1. Number of biogas producing farms and their installed capacity in megawatt in the biogas scenario, 2012-2026 (model results)

Due to these developments the structure of the farms' production changed. According to Brendel (2011) one megawatt electrical power requires about 550 ha of energy crops. Furthermore, the cultivation of energy maize needs much grassland as well as fallow and abandoned land (Brendel, 2011). The simulation results support this. The amount of fallow land decreases and cultivation of maize increases (see Fig. 2). Furthermore, the use of grassland is intensified as the usage changes from meadows to grass silage. Only the increase in suckler cows hinders a stronger decrease of meadows and even higher intensification. But grass and maize silage are not only cultivated for direct use in the biogas plants. To use liquid manure for bioenergy production, more cows are kept in the biogas scenario (see Fig. 3) and demand grass and maize for feed as well. Also Ehrenstein et al. (2012) see this connection: Because maize is predominantly cultivated as feed, livestock may contribute significantly to the maize production.



Source: Own simulation results from AgriPoliS.

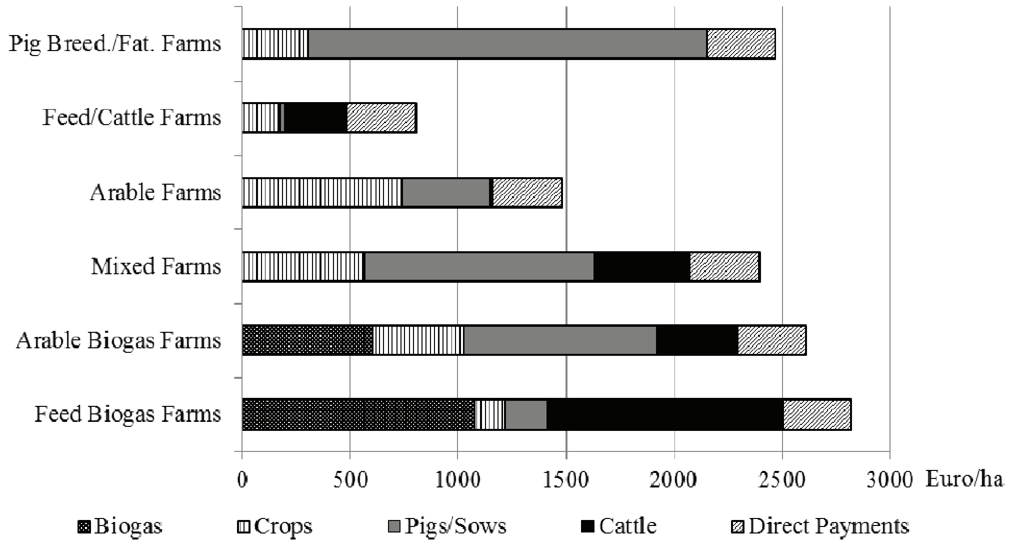
Fig. 2. Cultivation size of different crop types in the reference and biogas scenario, 2020 (model results)



Source: Own simulation results from AgriPoliS.

Fig. 3. Number of cows and heifers in the reference and biogas scenario, 2020 (model results)

Biogas producing farms do not only change their production because of the demand of the biogas plant but also increase their dependency from biogas revenues. Fig. 4 shows the composition of average revenue per ha of various farm types in the biogas scenario. At first it can be shown that revenue per ha differs highly between farm types: feed/cattle farms have with 809 Euro/ha on average the lowest, feed farms with biogas production (feed biogas farms) with an average 2,821 Euro/ha the highest revenue. Interesting is, furthermore, the contribution of the farm branches to the revenue. While pig breeding/fattening farms and arable farms receive their main revenues from their special fields, feed/cattle farms are highly dependent on direct payments. Compared to feed farms without biogas production, feed biogas farms have high revenues in cattle production and additionally the revenues from biogas production. They are far less dependent on direct payments. All other biogas farms (arable biogas farms) have on average absolute higher revenues than non-biogas producers. Furthermore, the dependency on revenues from crop and pig production of arable biogas farms is reduced while biogas production contributes 28 % to total revenues of those farms.



Source: Own simulation results from AgriPoliS.

Note: Feed biogas farms are feed farms with biogas production, arable biogas farms are mixed, arable or pig breeding/fattening farms with biogas production. As can be seen the other farm types do not produce biogas.

Fig. 4. Composition of revenue of different farm types in Euro per hectare in the biogas scenario, averages 2012-2026 (model results)

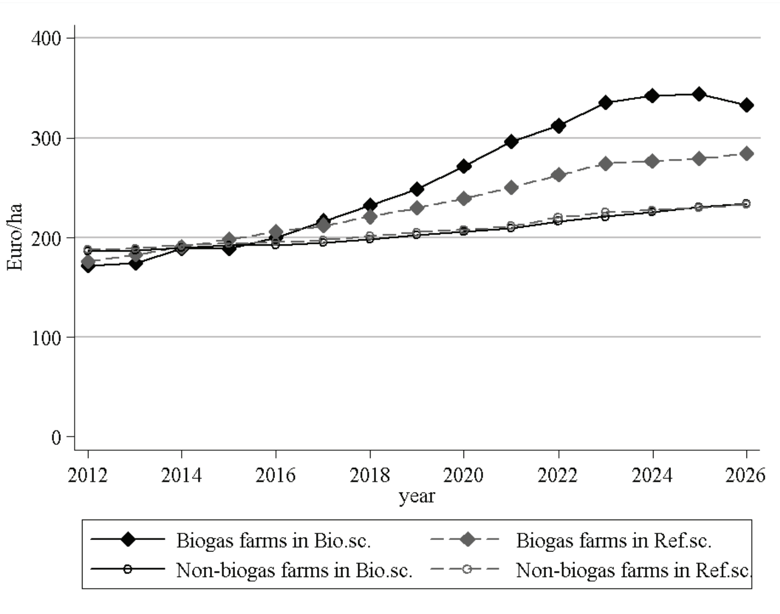
Summing up, farms with biogas production gain a main part of revenues from this new branch. Not only revenues absolutely increase in biogas producing farms, also the composition of total revenue changes on average compared to similar farm types such that biogas production takes over a big part of revenue contribution.

Overall, biogas affects the in-farm competition of the different branches significantly. Because of the complementarity, biogas production offers synergies for cattle production, but at the same time there are competitive effects for other production activities which are substituted. Due to the fact that land is scarce and the biogas plant has to be fed constantly with maize and/or grass silage, a biogas farmer has to reorient his production to the crops which deliver more biomass per ha to avoid feed bottlenecks. That results in both, reality and model to intensification: fallow land and extensive use of grassland decrease while maize cropping and production of grass silage increase.

3.2 Inter-farm competition

Biogas plants have to be fed with energy crops (maize and grass silage) and manure from livestock which also needs feed. Thus, biogas farms need land. At the same time, the total amount of land is limited and can only in rare cases be expanded in Germany. Thus, biogas increases competition for land and land (rental) prices might rise. Furthermore, biogas farms are not only heavily dependent on land, they may also have above average management capabilities (i.e. lower variable production costs) and receive high remuneration payments for delivered energy. Hüttl (2012) stated that because of the high feed-in remuneration for electricity from biogas, in some places the food production oriented agriculture is already displaced by the new energy producers. According to Brendel (2011) these high remunerations cause that traditional farmers may lose rental contracts after expiring to biomass plant operators because the latter can offer higher prices per hectare.

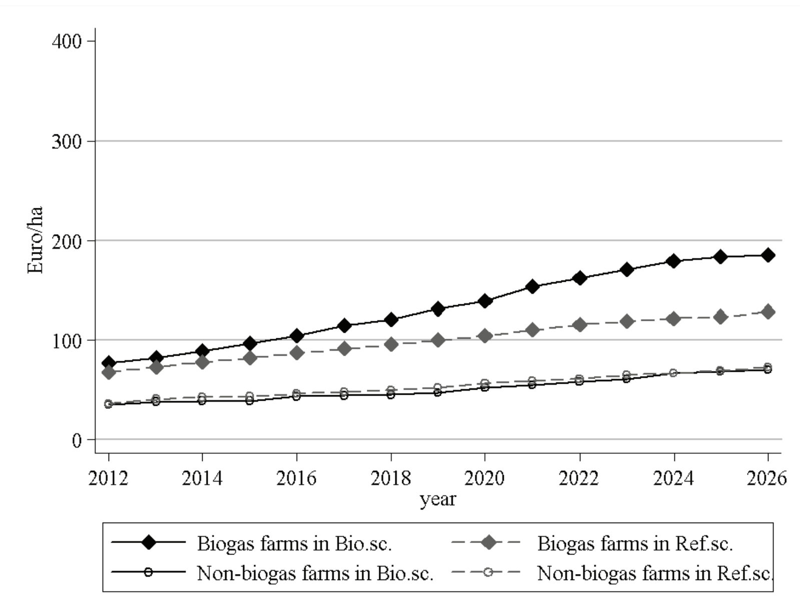
Our simulation results confirm the advantage of biogas producers: the average rental prices for rented arable and grazing land of those farms which produce biogas in the biogas scenario are higher in the biogas scenario than in the reference scenario (Fig. 5 and 6). At the same time non-biogas farms have to pay in both scenarios nearly the same (see Fig. 6).



Note: Biogas farms in Bio. sc.: average rental price for rented arable land of biogas farms in the biogas scenario, Biogas farms in Ref. sc.: average rental price for rented arable land of farms in the reference scenario which invest in the biogas scenario in biogas plants (they do not produce biogas in the reference scenario); same for non-biogas farms in biogas and reference scenarios.

Source: Own simulation results from AgriPoliS.

Fig. 5. Average rental prices for rented arable land in Euro per hectare of biogas and non-biogas farms in the model region Altmark between 2012 and 2026, reference and biogas scenario (model results)



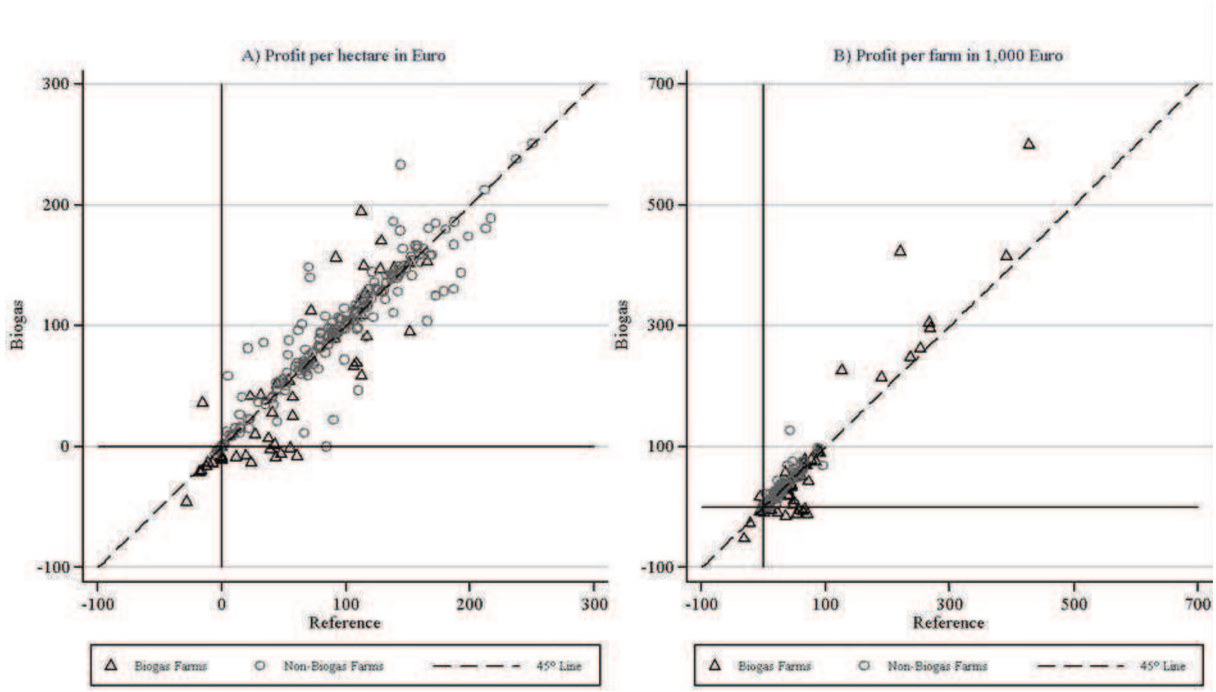
Note: Biogas farms in Bio. sc.: average rental price for rented grassland of biogas farms in the biogas scenario, Biogas farms in Ref. sc.: average rental price for rented grassland of farms in the reference scenario which invest in the biogas scenario in biogas plants (they do not produce biogas in the reference scenario); same for non-biogas farms in biogas and reference scenarios

Source: Own simulation results from AgriPoliS.

Fig. 6. Average rental prices for rented grassland in Euro per hectare of biogas and non-biogas farms in the model region Altmark between 2012 and 2026, reference and biogas scenario (model results)

Furthermore, Fig. 5 particularly shows that prices for rented arable land of biogas farms are also higher in the reference scenario. I.e., farms which invest in biogas production have in both scenarios a higher ability to pay more for land – and these farms also have higher management capabilities (cp. Table 3). Therefore, part of the increase in the rental prices must be independent from the development of biogas production. The management capabilities to save variable costs play a role as well. During simulations less successful farms exit and more and more farms with better management capabilities remain in the sector and grow. The ability of good managers as well as of farms which exploit economies of size allows paying higher prices for land and leads in both scenarios to increased rental prices of their farms.

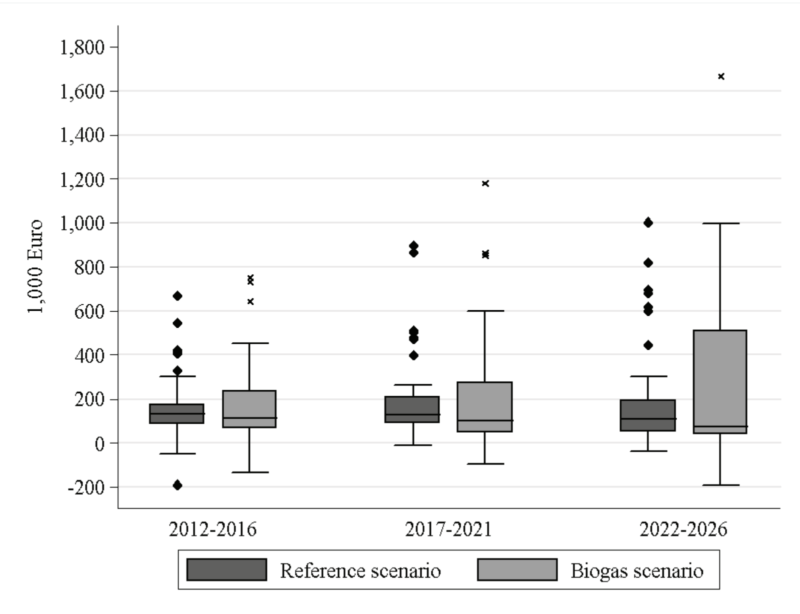
In general, rental prices for land have an impact on the resulting profits of a farm. The more money is forwarded to the land owners, the less money remains for the farmer. Indeed, our simulation results show that some biogas producing farms can increase their average profits between 2012 and 2026 compared to the reference scenario (see Fig. 7). Those benefitting biogas farmers have generally better management capabilities and are larger in hectare size than less successful biogas producers. However, Figure 7 shows as well, that not all biogas farms benefit. Quite some biogas farms lose profits. In comparison to biogas farmers who gain in the biogas scenario, the losing biogas farmers have on average lower management capabilities and are smaller. After investing in a biogas plant they are highly dependent on land to produce substrates for feeding the biogas plant. Because of the high competition for land and the resulting increases in rental prices, these biogas farms lose their initial advantage from biogas. This finding is also supported by Figure 8. Accordingly, the variance of the biogas farms' profits increases significantly compared to the same farms' profits in the reference scenario. This means that competition diminishes the potential profits of biogas very quickly. Only those farms with a real comparative advantage benefit while other investors even lose.



Note: A) The first scatterplot shows average profits per hectare of single biogas and non-biogas farms between 2012 and 2026. Farms which are on the 45° line perform equally well in both scenarios. Farms underneath the 45° line benefit in the reference scenario, farms above the 45° line benefit in the biogas scenario. B) The second scatterplot shows the average profit per farm of single biogas and non-biogas farms between 2012 and 2026 in 1,000 Euro.

Source: Own simulation results from AgriPoliS.

Fig. 7. Average profit A) per hectare and B) per farm of surviving farms between 2012 and 2026 in the reference and biogas scenario (model results)

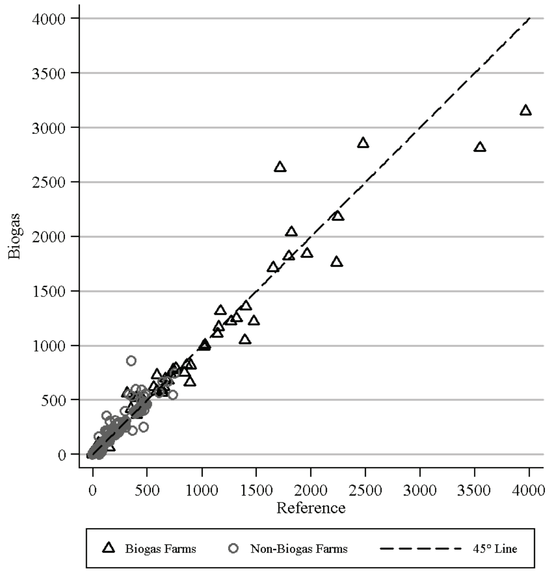


Note: Only biogas farms are considered, i.e. farms which invest in farms in the biogas scenario in biogas plants (they do not produce biogas in the reference scenario).

Source: Own simulation results from AgriPoliS.

Fig. 8. Distribution of average total profits per biogas farm in 1,000 Euro in the time periods 2012-2016, 2017-2021 and 2022-2026, reference and biogas scenario (model results)

Interestingly, Figure 7 shows for the non-biogas farms in contrast no clear disadvantage in the biogas scenario. Some of them even increase their profits per ha as well as on the farm level. However, in general, total profits of surviving biogas farms are much higher (between two and six hundred thousand Euros per farm). This applies also to farm size. Biogas farms have more land than non-biogas farms (cp. Fig. 9).



Note: Average farm size in hectare of single farms between 2012 and 2026. Farms which are on the 45° degree line have equal size in both scenarios. Farms underneath the 45° line are larger in the reference scenario, farms above the 45° line farm more hectares in the biogas scenario.

Source: Own simulation results from AgriPoliS.

Fig. 9. Average farm size of surviving biogas and non-biogas farms between 2012 and 2026 in the reference and biogas scenario (model results)

Fig. 9 also shows that all farms with more than 1,000 ha produce biogas. One explanation for that is that a minimum size is needed to be able to feed a biogas plant with enough substrates. Only large farms have enough capital and resources to build and feed biogas plants. Another important aspect is the better management skills of the biogas farms which allow them to have lower variable costs also in biogas production compared to non-biogas farms. Once invested, biogas farms have the potential to grow faster than other farms because they generate additional money with biogas production and bid higher rents on the land market. The model results show that indeed farms with biogas production grow in the biogas scenario by ca. 77.5 % to 1,484 ha between 2006 and 2026 while non-biogas farms can increase their size on average by ca. 46 % up to ca. 275 ha on average. However, in both scenarios the speed of growth of both farm types is rather similar. In the reference scenario farms which invested in biogas production in the biogas scenario grow by ca. 77 % up to 1,479 ha on average and the other farms by ca. 38.5 % up to 261 ha on average. Obviously, biogas farms do not only compete with non-biogas farms but rather with other biogas-farms. This finding may be specific for Eastern German conditions, where about 45 % of the land is farmed by farms larger than 1,000 ha and some further 23 % by farms with more than 500 ha (BMELV 2012).

In the following, we analyse the stability of farms using the equity ratio to compare the risk of insolvency of biogas and non-biogas farms. A high share of equity can help to cover losses and survive in low price periods. On the other side it should be considered that a reduction of the equity ratio and a simultaneous increase of profits lead to a rise in return of equity (leverage effect). In general, the farms which invest in biogas plants during simulations have a lower equity ratio than other farms in both scenarios. That means biogas farms are less stable than other farms. Biogas farms even worsen their stability when investing in a biogas plant: they have an even lower equity ratio in the biogas scenario than in the reference scenario (cp. Table 4), where the same farms are not able to invest in a biogas plant. That comes as no surprise, given the fact that the investment costs are very high and require a large amount of loan capital. Although biogas farms have a lower stability, farm exits of biogas producers are up to 2024 less often in the biogas scenario than in the reference scenario[3].

Table 4. Equity share and return of equity of biogas farms in the reference and biogas scenario (model results)

	Scenario	2012	2016	2020	2024
Equity ratio in %	Biogas	35.0	37.9	38.6	39.5
	Reference	49.1	53.7	58.8	61.4
Return of equity in %	Biogas	12.3	14.1	11.1	5.3
	Reference	14.5	14.3	13.3	9.5

Note: Biogas farms in the reference scenario are those farms which invest in biogas plants in the biogas scenario (they do not produce biogas in the reference scenario).

Source: Own simulation results from AgriPoliS.

As mentioned before, borrowing capital offers possibilities to increase the return of equity when a farmer can increase profits as well. In contrast, the simulation results show that biogas farms are on average not able to increase their profitability in the biogas scenario compared to the reference scenario. This holds also regarding the return of equity (Table 4).

Summing up, biogas farms are highly dependent on how successful they manage their biogas plants. The potential benefits of high feed-in tariffs result in strong competition among farms. As a result, biogas producing farms pay on average higher rents, they increase the amount of debt capital and have to pay interest for these debts. Thus, instability of biogas farms in the biogas scenario is higher. Nevertheless, biogas production is not the only driver for increasing rental prices and changes in farm size. In the end, the management capabilities of a farm play a major role. Only good managers can operate a biogas plant successfully, i.e. only they succeed to generate higher profits on average than in the reference scenario. Moreover, the comparative advantage of biogas within the farms' production opportunities has a strong impact regarding the question whether a farm benefits from biogas compared to a scenario without this opportunity.

3.3 Impacts on rural area, environment and labour market

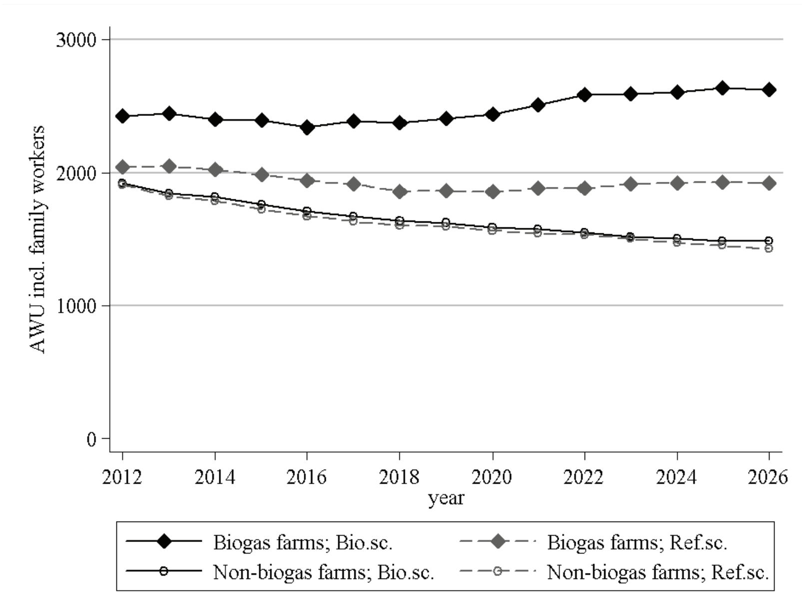
Until now, we discussed the impact of biogas production on farm level and inter farm relations. But there is also a lively public discussion on how biogas production affects rural areas and the environment. Some argue that biogas leads to a critical rise of the share of maize within the crop rotation: Succow (2011) even calls this a serious maldevelopment in biomass utilization. 'Maize encourages erosion, destroys the soil fertility and humus, requires a lot of pesticides and artificial fertilizer, in addition it provides habitat only for few organisms' (Succow, 2011). The increase of maize cropping is also supported by our simulation results (cf. Fig. 2). While in reference scenario farms produce mainly rapeseed and grain and feed their livestock with meadow grass farms intensify their cultivation in the biogas scenario while producing more maize and grass silage. Another effect of biogas production is that idle land is partly brought into production. To sum up, biogas production leads regionally to an intensification of production from meadows and grain to maize and grass silage. Besides the maize cultivation also livestock is growing, because biogas provides an additional income for feed farms as the by-products can be utilized. Fig. 3 shows the increase in livestock. A vicious circle seems to establish: On the one hand, the proportion of maize increases because silage is used as substrate for the biogas plant. On the other hand, biogas production provides

[3] In the years 2024 and 2025 three more biogas farms each and in 2026 six more biogas farms exit the sector in the biogas scenario compared to the reference scenario. Exit reasons of those farms are illiquidity in 2024 and 2026, and opportunity costs in 2025.

additional incentives for livestock production because of the synergies (i.e. manure use). This rise in livestock again drives the demand for maize silage. However, Karpenstein-Machan and Weber (2010) state that a narrowing crop rotation is not a new, bioenergy specific problem: 'Due to specialization and intensification of agriculture since 1980 and the focusing on only a few economically interesting and marketable products, the appreciation of healthy crop rotation and the observance of principles of crop rotation has apparently become less important' (Karpenstein-Machan and Weber, 2010: 312-313).

Not only crop rotation is affected. As already mentioned, more fallow land is used. By reducing fallow land, large scale habitats are harmed and connecting habitat structures for wildlife and plants are lost (Brendel, 2011). But there are also arguments for a positive environmental effect of biogas production: Biogas production has advantages for the use of manure. It not only enables a carbon cycle management because after fermentation the digestate can be used as fertilizer, moreover, the digestate has higher nitrogen availability and a lower aggressiveness than raw manure (Fulton et al., 2011).

Another fact is that biogas production influences the rural development. In Saxony-Anhalt, 1.5 % of employees already work in the field of renewable energy production, whereof the bioenergy sector became the third largest employer after wind and solar energy (Ulrich et al., 2012). Therefore, biogas production can ensure regional incomes as well as employment and promotes the development of rural areas (Fulton et al., 2011). The increase of agricultural employees is also shown in our simulation results (cp. Fig. 10). Accordingly, the biogas scenario leads to an increased employment of 10 to 22 %, partly because of more cattle-based and intensified production. Especially biogas farms employ on average up to 37 % more annual working units (AWU) in the biogas scenario than in the reference scenario.



Note: Biogas farms in Bio. sc.: average rental price for rented grassland of biogas farms in the biogas scenario, Biogas farms in Ref. sc.: average rental price for rented grassland of farms in the reference scenario which invest in the biogas scenario in biogas (they do not produce biogas in the reference scenario); same for non-biogas farms in biogas and reference scenario.
Source: Own simulation results from AgriPoliS.

Fig. 10. Total number of annual working units (AWU) in biogas and non-biogas farms including family workers between 2012 and 2026 (model results)

With regard to the effect on the employment in the whole rural area (besides agriculture), Berenz et al. (2007) mention an important aspect. In their model calculations it is shown that dairy farming has a much higher area-based effect on employment than biogas production. Extending the observation to the downstream areas these differences in labor input are even growing. 'The biogas plant produces electricity, a salable product, which requires hardly any jobs in the downstream area. By contrast, dairy products and animals for slaughter have still to be processed much further to become finally a salable good' (Berenz et al., 2007: 10). Conclusions on environmental aspects cannot be drawn directly. But it can be said that employment of workers in agriculture, number of livestock and the number of land under usage increase. Therefore biogas production can contribute to the development of rural areas as it provides income opportunities for farmers as well as job opportunities. On the other hand, it may imply environmental risks due to an intensified agriculture.

4 Conclusions

We analysed impacts of biogas production regarding the production choice of farms, the competition between farms, and impacts on rural areas including environmental and employment effects. The analysis is based on the agent-based model AgriPoliS which enables to simulate regional agricultural structures and their developments over time. Our case study region is the Altmark region in East Germany because this region is characterized by significant biomass potentials and a high degree of rurality. Agriculture has a considerable share in employment and, thus, agricultural developments may strongly affect the regional development. For the analysis two scenarios are compared: In a biogas scenario it is assumed that farms can invest in a highly subsidized biogas production, while in the reference scenario biogas investments are not possible.

Our analyses showed that on the farm level biogas production provides especially for large farms and with high management skills a profitable income opportunity. Biogas farms gain a main part of revenues from this new branch. Not only revenues absolutely increase, also the composition of total revenue changes such that biogas production takes over a significant part of revenue contribution. It implies an increasing dependency of the whole farm on their biogas plant(s). Furthermore, the whole production structure of a farm changes. Our simulation results have shown that biogas production leads to an intensification of land use, especially to an increase in cultivation of grass silage instead of meadows, maize instead of other crops and to an increase in livestock production. The proportion of maize increases because silage is used as substrate for the biogas plant and as feed in cattle keeping. In general, biogas production provides additional incentives for livestock production because of the synergies (i.e. manure use). As result of an increased value added through biogas production and high competition among farms, rental prices increase. This may be a threat particularly for biogas farms which are smaller and have less management capabilities. On average, biogas farms do not increase their profitability, while the variance of the biogas farms' profits is significantly higher. The main reason for these effects can be seen in the fact that a significant share of the value added is transferred via increased rental prices to the land owners. These rental prices are driven by the marginal land rents of the most efficient biogas farms.

Looking at the impacts of biogas production outside agriculture we find that the implementation of biogas plants can offer new employment potentials in biogas production as well as livestock keeping. Therefore biogas production can contribute to the development of rural areas as it provides income opportunities for farmers as well as job opportunities. But biogas production also causes public concerns regarding the impact on the environment. The detected intensification in the agricultural production may imply environmental risks.

Summing up, we conclude that biogas production provides opportunities especially for larger farms with high management capabilities and for employment in rural areas. It can be a profitable option in times of increasing uncertainty and volatility of agricultural prices due to globalization of the EU agricultural markets.

The development in the bioenergy market is policy driven. Therefore, the market conditions and developments are distorted as the demand for biogas is raised artificially through the guaranteed feed-in tariffs. Long-term effects are difficult to be estimated exactly. As we have shown in our simulation, biogas farms gain a main part of revenues from this new branch which means that also the dependency of farms on the biogas production, specifically on the guaranteed feed-in tariffs and therefore on political decisions is growing. Therefore, reservations and discussions exist on the side of the non-biogas farmers who fear for their (future) competiveness particularly on the land market, as well as on the side of the biogas farmers who are concerned about the stability of political decisions. This is embedded in a public discussion on impacts of biogas production on environment and quality of life in rural areas.

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Relationship Between Prices of Food, Fuel and Biofuel

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Annotation: In this paper, we analyze the relationships between the prices of biodiesel, ethanol and related fuels and agricultural commodities with a use of minimal spanning trees and hierarchical trees. To distinguish between short-term and medium-term effects, we construct these trees for different frequencies (weekly and monthly). We find that in short-term, both ethanol and biodiesel are very weakly connected with the other commodities. In medium-term, the biofuels network becomes more structured. The system splits into two well separated branches – a fuels part and a food part. Biodiesel tends to the fuels branch and ethanol to the food branch. As a part of this paper we also characterize the major biofuels and their agricultural feedstock and we outline their recent quantitative development.

Key words: biofuels, networks, minimal spanning tree, hierarchical tree.

1 Introduction

In this paper, we utilize a straightforward methodology of taxonomy standardly used in networks and complex systems analysis for clear identification of relationships between components of the system. We apply the methodology on the system of biofuels and related agricultural and fuel commodities. We quantify these relationships over different market phases and time dimensions using a graphical display of price transmission network. In this way, we contribute to important policy discussion about impact of biofuels and energy prices on food prices.

Biofuels became of high interest after the oil crisis of the 1970s as a possible replacement for fossil liquid fuels used in transportation. Increased interest in climate and environmental issues in last three decades also contributed to the popularity of biofuels as alternative fuels. Global production of biofuels experienced a rapid increase since then, especially during the last decade. The main drivers behind this growth are government policies such as mandates, targets and subsidies which have been justified on the grounds of energy security and climate change considerations. However, the concerns raised by the global food crisis in 2007/2008 and ambiguity with respect to environmental impact of biofuels led many government to reconsider their earlier optimism with respect to biofuels.

Very important factor leading to expansion of ethanol was a phase-out of the gasoline additive methyl tertiary butyl ether (MTBE) which was used as an oxygenate to raise the octane number. MTBE was banned or restricted in multiple US states (California, New York, etc.) since it was found to contaminate ground water where it leaked from tanks and pipelines. Unlike other ingredients contained in gasoline fuel, MTBE dissolves in water during the gasoline spills and moves away from spill sites with water flow. MTBE was classified as a possible carcinogen. The fuel industry therefore substituted ethanol as an alternative source of oxygen for fuel blends.

Biofuel production has increased continuously worldwide over the last years. In 2009, global ethanol production reached nearly 75 billion liters in more than 40 countries. That year, the

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ethanol production was 40 billion liters in the USA, 26 billion liters in Brazil and 3 billion liters in the EU. Global biodiesel production totaled almost 19 billion liters worldwide in 2009. The biodiesel production reached 2.2 billion liters in the USA, 1.5 billion liters in Brazil and 9.4 billion liters in the EU. The FAPRI biofuel production forecasts for 2019 are 65 and 5.4 billion liters of ethanol and biodiesel, respectively for the USA, 52 and 2.9 billion liters of ethanol and biodiesel, respectively for Brazil, 6.9 and 13.1 billion liters of ethanol and biodiesel, respectively for the EU. The land used for biofuels was estimated in 2008 at around 20 million ha worldwide, or around 1% of the global agricultural land, of which about 8 million ha was used for sugarcane plantation in Brazil. The share of ethanol on the US total gasoline motor transportation fuel use measured in gasoline-equivalent gallons was 6.5% in 2010. Corresponding share of biodiesel on the US diesel transport fuel use was 0.8% in 2010. Since the US use of diesel as transportation fuel at less than 50 billion gallons yearly is equal to approximately 1/3 of gasoline use, the overall share of biofuels on the US transportation fuel use was 5.1% on an energy-equivalent basis in 2010. This relatively small share sharply contrasts with a very large contribution in Brazil, where ethanol from sugar cane replaced already 50 percent of gasoline for transport in 2009.

Biofuel use represents an important share of global cereal, sugar and vegetable oil production. According to 2010 Agricultural Outlook of OECD-FAO, sugarcane will remain the single most biofuel-oriented commodity. Its global share to be used for the ethanol production is expected to rise to 35% in 2019 as opposed to 20% in the baseline period of 2007-2009. The next most used category is molasses with the expected share of slightly less than 25% as compared to slightly less than 20% in the baseline period. Vegetable oil and coarse grains, which have the same share of 9% of their production being used for biofuels in the baseline period, are predicted to diverge somehow with about 13% of the global production of coarse grains being used to produce ethanol in 2019, while the corresponding forecast for vegetable oil conversion to biodiesel is 16%. For sugar beets, a modest increase from currently less than 10% biofuel utilization to about 11% utilization is expected in 2019. Relatively high rate of increase of the biofuel utilization is expected for wheat. But given its low baseline share about 1%, only about 3-4% of its 2019 production is expected to be used for biofuels.

The economics of biofuels constitutes a very active and growing research area as documented in recent review article by Janda et al. (2012). Simulation models of economic impacts of biofuels, which are based on long-run parameters (the leading source being GTAP database of Thomas Hertel and his collaborators, for recent references see Beckman et al. (2011)) and on partial or general equilibrium economic theory, assume links between prices of food, biofuels and fossil fuels. But empirical evidence for these links is largely inconsistent.

Current empirical research on biofuels and fuels price dynamics varies widely from Value-at-Risk estimation (Chang et al., 2011) to various cointegration estimations (Peri and Baldi, 2010) to volatility spillovers (Serra, 2011) and wavelet coherence analysis (Vacha and Barunik, 2012) and others. The common feature of this research is growing sophistication of econometric estimation which usually comes at the cost of imposing many structural or distributional assumptions on the processes underlying the interactions between the prices of biofuels and related commodities. In this article, we present different methodological approach to this problem. We analyze connections between biofuels and related commodities (energy-related and food-related) with a use of minimal spanning trees (MST) and hierarchical trees (HT) to uncover the most important connections in the network of commodities.

MST and HT are methodologically very straightforward approaches using only simple correlations as a starting point with no additional prior assumptions. The MST and HT methods are now being increasingly used for analysis of stocks connections (Bonanno et al., 2004; Tumminello et al., 2007), foreign exchange rates (Jang et al., 2011), import/export networks (Kantar et al., 2011), interest rates systems (Tabak et al., 2009), portfolio selection (Onnela et al., 2002) as well as commodities networks (Tabak et al., 2010; Lucey et al., 2011), yet mainly in the journals of interdisciplinary physics, specifically econophysics.

This paper presents the first MST and HT analysis applied on the network containing biofuels. The advantage of our approach is a natural possibility to include simultaneously different biofuels and many different related commodities into our analysis. This contrasts with previous time-series econometric studies which usually focus only on a small selected group of commodities. Our analysis allows the integration of the principal findings in the literature on price transmission between food, fuels and biofuels markets in a clear and elegant way. The correlation clusters formed as results of our analysis may serve as good starting points for further econometric analysis of the price interactions within these clusters. Indeed, the fact that the MST and HT methodology is very straightforward is not only its advantage but of course its limitation as well – we are not able to comment on causality between commodities, the methodology does not take into consideration possible cointegration or lagged values of variables of interest. Further, as the methodology is constructed for the stationary series, we might loose information if the analyzed series need to be first-differenced to attain stationarity, which is the case for all stationarity-assuming approaches.

In this paper, we focus on the most popular biofuels – ethanol and biodiesel. Ethanol is mainly produced from crops rich in sugar and starch like sugarcane and corn. Biochemical technologies for conversion of sugar and starch are the most technologically and commercially mature today. Biodiesel is produced from oilseed crops like soybean, rapeseed, and oil palm. Therefore, we are mainly interested whether a dynamic behavior of ethanol and biodiesel forms clusters with food commodities and/or energy commodities. Moreover, we want to analyze the behavior at different frequencies (weekly and monthly) to see whether the relationships apply in short and/or medium term. Further, the connections between the commodities might vary for different phases of the market depending on binding regulatory or technological constraints and market development.

The rest of the paper is structured as follows. In Section 2, we present a brief review of a current research dealing with links among biofuels and related commodities. In Section 3, we describe the basic notions of the used methodology. In Section 4, the data choice and description is given. Section 5 presents the results of our analysis. Section 6 concludes.

2 The relation to current research

In this section, we briefly review most recent time-series studies on links between prices of biofuels and related commodities. More detailed recent reviews are provided by Janda et al. (2012) and Zilberman et al. (2012).

Zhang et al. (2009) focus on volatility of ethanol and commodity prices using cointegration, vector error corrections models (VECM) and multivariate generalized autoregressive conditional heteroskedasticity (mGARCH) models. The authors analyze weekly wholesale price series of the US ethanol, corn, soybean, gasoline and oil from the last week of March 1989 through the first week of December 2007. They find that there are no long-run relations among fuel (ethanol, oil and gasoline) prices and agricultural commodity (corn and soybean) prices in recent years.

The same authors further analyze long and short-run interactions with a use of cointegration estimation and vector error corrections model with Granger-type causality tests (Zhang et al., 2010). They examine corn, rice, soybeans, sugar, and wheat prices along with prices of energy commodities such as ethanol, gasoline and oil from March 1989 through July 2008. They find no direct long-run price relations between fuel and agricultural commodity prices and only limited if any direct short-run relationships.

Tyner (2010b) finds that since 2006, the ethanol market has established a link between crude oil and corn prices that did not exist historically. He finds that the correlation between crude oil and corn prices was negative (-0.26) from 1988 to 2005; in contrast, it reached a value of 0.80 during the 2006-2008. However, only the price series are analyzed, which rises serious questions about stationarity of the data.

Du et al. (2011) investigate the spillover of crude oil price volatility to agricultural markets (specifically corn and wheat). They apply stochastic volatility models on weekly crude oil, corn and wheat futures prices from November 1998 to January 2009. Their model parameters are estimated using Bayesian Markov Chain Monte Carlo methods. They find that the spillover effects are not statistically significant from zero over the period from November 1998 to October 2006. However, the results indicate significant volatility spillover from the crude oil market to the corn market between October 2006 and January 2009.

In a pair of papers focusing on the cointegration of prices for oil, ethanol and feedstocks, Serra, Zilberman and co-authors study the US (Serra et al., 2011) and Brazilian (Serra et al., 2011) ethanol markets. In the case of the US, they find the existence of a long-term equilibrium relationship between these prices, with ethanol deviating from this equilibrium in the short term. Further for the US, they find the prices of oil, ethanol and corn to be positively correlated as might be expected. The authors estimate that a 10% perturbation in corn prices boosts ethanol prices by 15%. From the other side, they find that a 10% rise in the price of oil leads to a 10% rise in ethanol. In terms of temporal response time, they find that the response to corn prices is much quicker (1.25 months to full impact) than for an oil price shock (4.25 months). For Brazil, the relevant feedstock is sugarcane. The authors find that sugar and oil prices are exogenously determined and focus their attention on the response of ethanol prices to changes in these two exogenous drivers. The authors conclude that ethanol prices respond relatively quickly to sugar price changes, but more slowly to oil prices. A shift in either of these prices has a very short run impact on ethanol price volatility as well. These commodity markets are not as quick to achieve long-run equilibrium again as those in the US according to these two studies.

Rajcaniova and Pokrivcak (2011) analyze the relationship between fuel prices (oil, gasoline, ethanol) and prices of food (corn, wheat, sugar) serving as ethanol feedstock. They do not find any cointegration in the period January 2005 – July 2008, while they find cointegration among majority of their price time series for more recent time period of August 2008 – August 2010. Pokrivcak and Rajcaniova (2011) investigate the relationship among the prices of ethanol, gasoline and crude oil in a vector autoregression and impulse–response framework. Their results confirm the usual finding in the literature that the impact of oil price shock on transport fuels is considerable larger than vice versa.

The interaction between monthly prices of crude oil, the US gasoline and the US ethanol between 1994 and 2010 is investigated in a joint structural vector auto regression (SVAR) model by McPhail (2011). His structural VAR model allows to decompose price and quantity data into demand and supply shocks. Since the US ethanol demand is driven mainly by government support through blending mandates and tax credits, he assumes that ethanol demand reflects primarily changes in government policy. As opposed to policy driven demand, ethanol supply shocks are determined by changes in feedstock prices. The author shows that policy-driven ethanol demand expansion leads to statistically significant decrease in real crude oil prices and the US gasoline prices. He also shows that ethanol supply expansion does not have a statistically significant influence on real oil prices.

Ziegelback and Kastner (2011) investigate the relationship between the futures prices of European rapeseed and heating oil. They use 2005-2010 daily data to show the asymmetry in price movements. The results of their three-regime threshold cointegration model are similar to the results of Peri and Baldi (2010). Related paper by Busse et al. (2010) deals with the connections between prices of rapeseed oil, soy oil, biodiesel and crude oil during the rapid growth of German biodiesel demand from 2002 until its decline in 2009. They found an evidence for a strong impact of crude oil price on German biodiesel prices, and of biodiesel prices on rapeseed oil prices. However, in both cases, the price adjustment behavior was found to be regime-dependent.

Different results with respect to mutual interactions between the prices of biofuels and related commodities may be due to a number of factors. In our research, we focus on the differences in investment horizon (comparing different frequencies), on the role of technological and regulatory constraints and also on geographic factors of the US and European biofuels markets.

Besides time-series models of interactions between biofuels, agricultural commodities, fosil fuels and raw oil, there is a number of other structural models. Conceptually most simple type of structural models are engineering-like cost accounting models which are used to estimate profitability of an activity for a single price-taking agent, such as an individual farmer or a processor. The production function in such models is typically assumed as a fixed-proportion one. Classical representatives of this class of models are crop budget models which have been used to estimate profitability of cultivation of energy crops based on assumptions about yield, output prices, cost of production and other technological and economic parameters.

More theory-based economic studies, which evaluate the impact of biofuels, are based on partial equilibrium or computable general equilibrium (CGE). These models explain the interaction among supply, demand, and prices through the market clearance using a system of equilibrium equations.

In the partial equilibrium structural models, which are also labeled as sector models, clearance in the market of a specific good or sector is obtained under the assumption that prices and quantities in other markets remain constant. Partial equilibrium models are therefore suitable for providing good indication of short-term response to shocks. Partial equilibrium models often provide a detailed description of the specific sector of interest but do not account for the impact of expansion in that sector on other sectors of the economy. The examples of partial equilibrium models used in the assessment of the impact of biofuel development include AGLINK/COSIMO model developed by OECD and FAO, ESIM model, which was developed by the Economic Research Service of the US Department of Agriculture and which is used by the European Commission since 2001, FAPRI model of the Food and Agricultural Policy Research Institute, and the IMPACT model of the International Food Policy Research Institute.

A number of smaller partial equilibrium models are used for analysis of specific questions related to biofuels. An example of this type of models is GLOBIOM model, which is a global recursive dynamic partial equilibrium model integrating the agricultural, bioenergy and forestry sectors.

CGE structural models compute equilibrium by simultaneously taking into account the linkages between all sectors in the economy. The CGE modeling framework provides an understanding of the impact of biofuels on the whole economy by taking into account all the feedback relations between biofuels and other markets. The most well known CGE studies of biofuels are based on variants of GTAP model which is under continuous development under the leadership of Thomas Hertel since 1991.

The major disadvantage of CGE approach to modeling biofuels is that global CGE models are much stronger in a treatment of the developed countries than in the treatment of the developing countries. In the case of biofuels, this is a serious deficiency since the developing countries are expected to be a big supplier of biofuels in the future. They are also currently a focus of the debate about social and environmental consequences of biofuels production and of the fuel versus food discussion.

3 Methodology

In this section, we describe the basics of construction of minimal spanning trees and hierarchical trees. As this methodology is not well known in the economics literature, we present quite careful description of the methods. For the first application of minimal spanning trees and hierarchical trees to the financial time series and a more detailed description, see Mantegna (1999).

3.1 Distance measure

The interconnections in a group of assets are standardly measured by sample correlation coefficients. For a pair of assets i and j with values X_{it} and X_{jt} and $t = 1,...,T$, the sample correlation coefficient $\hat{\rho}_{ij}$ is calculated as

$$\hat{\rho}_{ij} = \frac{\sum_{t=1}^{T}(X_{it}-\overline{X_i})(X_{jt}-\overline{X_j})}{\sqrt{\sum_{i=1}^{T}(X_{it}-\overline{X_i})^2\sum_{i=1}^{T}(X_{jt}-\overline{X_j})^2}}, \quad (1)$$

where $\overline{X_i} = \frac{\sum_{t=1}^{T} X_{it}}{T}$ and $\overline{X_j} = \frac{\sum_{t=1}^{T} X_{jt}}{T}$ are respective time series averages. Linear correlation ρ_{ij} ranges between -1 (perfectly anti-correlated) and 1 (perfectly correlated) with $\rho_{ij} = 0$ meaning that the pair is uncorrelated. Note that it only makes sense to estimate correlations for the series with well defined means and variances, i.e. weak stationarity of the series is needed.
For a portfolio of N assets, we obtain $N(N-1)/2$ pairs of correlations. Mantegna (1999) showed that the correlation coefficients can be transformed into distance measures, which can in turn be used to describe hierarchical organization of the group of analyzed assets. Distance measure

$$d_{ij} = \sqrt{2(1-\rho_{ij})} \quad (2)$$

is constructed so that it fulfills three axioms of a metric distance:

- $d_{ij} = 0$ if and only if $i = j$;
- $d_{ij} = d_{ji}$;
- $d_{ij} \leq d_{ik} + d_{kj}$ for all k

From the definition of the correlation coefficient, the distance ranges between 0 and 2, while $d_{ij} \to 0$ means that the pair is strongly correlated, $d_{ij} \to 2$ implies strongly anti-correlated pair and $d_{ij} = \sqrt{2}$ characterizes an uncorrelated pair.

3.2 Minimal spanning tree and hierarchical tree

Minimal spanning tree (MST) is used to extract the most important connections in the whole network. For our purposes, the connections are characterized by correlation coefficients between pairs of assets. The basic idea behind MST is to reduce the number of $N(N-1)/2$ pairs to only the $N-1$ most important connections while the whole system remains connected. The procedure is very straightforward and in detail described in Mantegna (1999). In short, we transform the correlation matrix C into a distance matrix D, discarding the diagonal elements (containing zero distances). We then find the closest pair of assets, which creates the first two nodes in the network connected by the first link (with a weight equal to the distance d_{ij}). Each node now has a single edge (the link connected to the node). We proceed to the second closest pair which creates the second pair of nodes. At this point, if a node from the second pair is already present in the network, the new node is simply connected to the existing pair. The steps are repeated until $N-1$ links are reached, while the network must not be closed or create closed loops. If the link would create a loop, it is not added into the network. We use Kruskal's algorithm in our application (Kruskal, 1956).

MST helps us to construct hierarchical trees (HT) which are important for the analysis of clusters. With a use of HT, it has been shown that stocks form clusters based on the industrial branches (Mantegna, 1999; Tabak et al., 2010) and that foreign exchange rates create clusters with respect to the geographical location (Mizuno et al., 2006; Keskin et al., 2011; Jang et al., 2011). In order to construct HT with a use of MST and distance matrix D, we first need to determine the subdominant ultrametric distance matrix D^*. The elements of the matrix D^* are defined as the subdominant ultrametric distances d^*_{ij}. Such a distance is equal to the maximal weight of the link which needs to be taken to move from node i to node j in the MST. More formally, $d^*_{ij} = \max(d_{kl})$, where k and l stand for all nodes connecting i and j (including i and j) in the corresponding MST. In matrix D^*, we find the minimal distance d^*_{ij} and create the first pair of assets. We follow in connecting the assets and if we find more assets with same d^*_{ij}, we connect the clusters together. In the end, we obtain the whole HT which clearly separates clusters of the analyzed variables (Mantegna, 1999). For illustration, consider three commodities a, b and c, which form MST such that $a - b - c$ with $d_{ab} = 0.4$ and $d_{bc} = 0.7$. Since the lowest distance is d_{ab}, then the ultra metric distance is $d^*_{ab} = 0.4$. The second lowest distance is d_{bc} which implies $d^*_{bc} = 0.7$. Now, we need to find d^*_{ac}. To get from c to a in this simple MST, we need to cross b. d^*_{ac} is then a maximum of distances between $a - b$ and $b - c$, i.e. $d^*_{ac} = \max(d_{ab}, d_{bc})$. We arrive at $d^*_{ab} = 0.4$ and $d^*_{ac} = d^*_{bc} = 0.7$, which means that a and b are connected and form a pair while c is separated from this simple cluster as it has the same ultra metric distance from both a and b, and we are able to construct the hierarchical tree. The procedure will be better illustrated on the analyzed dataset arriving at more complicated hierarchical structures in the following sections.

Depending on the structure of HT, we can discuss interconnections between specific clusters or separate assets and commodities. In general, HT translates relatively unstructured MST and creates a unique hierarchical structure. From the point of view of our research and focus on clusters in biofuels and related commodities, HT gives a more informative picture of existing clusters. Without HT, MST would give only limited information.

3.3 Stability of links

The major weakness of the described methodology lies in the fact that the calculated MST and HT might be unstable. Moreover, without further statistical analysis, we cannot be sure whether the links present in the MST are actually the important links in the network or are rather a statistical anomaly, i.e. whether the results are sensitive to the sampling. To deal with

the problem, we use a bootstrapping technique proposed by Tumminello et al. (2007) specifically for MST and HT analysis.
In the procedure, we first construct the original MST and HT. Then, we construct a bootstrapped time series from the original while keeping the time series length fixed (i.e. the observations may repeat in the bootstrapped sample). MST and HT are then constructed for the bootstrapped time series and links are recorded. It is then checked whether the connections in the original MST are also present in the new MST based on bootstrapped time series. We repeat such procedure 1,000 times so that we can distinguish whether the connections in the original MST and HT are the strong ones or statistical anomalies (Keskin et al., 2011). The share of the bootstrapped cases, where the link appears between nodes i and j, will be labeled as b_{ij} with an obvious range $0 \le b_{ij} \le 1$.

4 Data

Biofuels represent a wide range of fuels which are in some way derived from biomass. The wide definition of biofuels covers solid biomass, liquid fuels and various biogases. In the further text, we concentrate on liquid biofuels.
The biofuels are generally classified as conventional (the first generation) biofuels and advanced biofuels (the second, third, and fourth generations). The first generation biofuels are made from food crops rich in sugar or starch or vegetable oil. The most common types of the first generation biofuels are bioalcohols (especially ethanol) and biodiesel. The second generation biofuels are produced from residual non-food parts of current crops, such as stems, leaves and husks that are left behind once the food crop has been extracted, as well as other crops that are not used for food purposes, such as switchgrass, jatropha, miscanthus and cereals that bear little grain, and also industry waste such as wood chips, skins and pulp from fruit pressing etc. The third generation biofuels are obtained from algae. Biofuels created from processes other than the first generation ethanol and biodiesel, the second generation cellulosic ethanol, and the third generation algae biofuels are referred to as the fourth generation biofuels. Fourth generation biofuels are highly experimental and have not yet been even clearly defined. Some fourth generation technologies are: decomposition of biofuels at high temperatures, artificial photosynthesis reactions, known as solar-to-fuel, and genetically modifying organisms to secrete hydrocarbons.
Crops rich in sugar and starch like sugarcane and corn (maize), respectively, supply almost all the ethanol that is produced today. Other major crops being used include wheat, sorghum, sugar beet, and cassava. Biochemical technologies for conversion of sugar and starch are also the most technologically and commercially mature today. Currently prevailing fermentation technologies are based on an extraction of simple sugars in sugar crops, their yeast-fermentation and distillation into ethanol. Starches crops require an additional technological step. They are initially converted into simple sugars through an enzymatic process under high heat. This conversion requires additional energy and leads to an increase in the cost of production. The major drawback of the first generation biofuel crops is that they are important food crops and their use for fuel can have adverse impacts on food supply. Another drawback is that these crops are intensive in the use of one or more inputs such as land, water, fertilizers, pesticides, etc., which have other environmental implications. In the future, the cellulosic sources are expected to displace such crops as the major second-generation source of ethanol. While the first generation ethanol is produced from the sugar or starch part of the plant, which comprises only a small percentage of the total biomass of the plant, the second-generation conversion of lignocellulosic biomass leads to the full use of lignocellulosic material contained in many biomass sources like waste seed husks and stalks and fast growing grasses and trees. Lignocellulosic biomass is composed of polysacharides (cellulose and hemicellulose), which are converted into sugars through hydrolysis or chemical (or combined)

processes. The sugar is then fermented into ethanol using the technologies already utilized for the first generation biofuels.

In contrast to ethanol, biodiesel is produced from oilseed crops like soybean, rapeseed, and oil palm. The most common method of producing biodiesel is transesterification. It is a chemical process by which vegetable oils (like soy, canola, palm, etc.) can be converted to methyl or ethyl esters of fatty acids also called biodiesel. Biodiesel is physically and chemically similar to petro-diesel and hence substitutable in diesel engines. Transesterification also results in the production of glycerin, a chemical compound with diverse commercial uses.

In this paper we analyze weekly and monthly prices of Brent crude oil (CO), ethanol (E), corn (C), wheat (W), sugar cane (SC), soybeans (S), sugar beets (SB), consumer biodiesel (BD), German diesel and gasoline (GD and GG), and the US diesel and gasoline (UD and UG) from 24.11.2003 to 28.2.2011. While the majority of our data were obtained from the Bloomberg database, gasoline and diesel prices were obtained from the U.S. Energy Information Administration and they present average prices of the countries. We use both the US and the German prices to uncover potential connection to ethanol and biodiesel as biodiesel production used to be rather a European activity while ethanol production is more an American activity. Ethanol price is the New York Harbor price for ethanol according to ASTM D4806 specification. This is a denaturated anhydrous fuel ethanol for blending with gasoline. Crude oil price refers to current pipeline export quality Brent blend as supplied at Sullom Voe. Corn price is for Corn No. 2 Yellow. Wheat price is for various types of wheat (No. 2 Soft Red Winter Wheat, No. 2 Hard Red Winter Wheat, No. 2 Dark Northern Spring Wheat, and No. 2 Northern Spring Wheat at par (contract price); and No. 1 Soft Red Winter Wheat, No. 1 Hard Red Winter Wheat, No. 1 Dark Northern Spring Wheat and No. 1 Northern Spring Wheat at 3 cents per bushel over contract price.) Sugar price is for raw centrifugal cane sugar based on 96 degrees average polarization. Soybeans price is for Soybeans No. 2 Yellow. Sugar beets price is for white beet or cane crystal sugar or any other refined sugar. Biodiesel price is for commodity type consumer biodiesel, as reported by F.O. Licht. Daily data are not used in our analysis as the spot markets (ethanol and biodiesel) are not liquid enough and the analysis would not be meaningful.

Taking X_t as Monday closing prices, we analyze returns $r_t = \log(X_t - X_{t-1})$. As we analyze the structure of distances, which are simply transformed correlations, between the commodities, stationarity of the series becomes crucial. The results for three stationarity tests – ADF test with a constant, ADF test without a constant and KPSS test are quite straightforward – all the logarithmic returns are stationary, which implies that we can proceed to the estimation of correlation coefficients and distances from the logarithmic returns series without further adjustments. Note that we try to keep the methodology as straightforward as possible. To do so, we present only the results for unadjusted logarithmic returns, which is standardly done in the literature. We also applied the methodology on AR(1)-GARCH(1,1)-filtered series, i.e. the estimated correlations were robust to autocorrelation and heteroskedasticity in the processes. However, the sample correlations differ only a little for the adjusted series and the resulting MSTs and HTs are qualitatively the same as the ones presented in this paper. Again, the methodology can be extended to various frameworks modeling time-dependent correlations (Long et al., 2011) or even time- and frequency-dependent correlations (Vacha and Barunik, 2012).

5 Results

In this section, we present and comment on the results of the minimal spanning trees and hierarchical trees for the studied network of commodities[6].

[6]All calculations and construction of MST and HT have been conducted and coded in TSP 5.0.

We start with the first few steps of construction of minimal spanning tree for weekly returns to illustrate the procedure. The pair with the highest correlation coefficient – and thus the closest one – consists of German diesel and German gasoline with $d_{ij} = 0.5330$. Therefore, the first connected nodes of the MST are GD—GG. The second lowest distance is the one between US gasoline and US diesel ($d_{ij} = 0.6563$). We now have two pairs of nodes GD—GG and UD—UG in the MST. The next lowest distance is found for SB—SC pair ($d_{ij} = 0.7671$). The MST now contains three separate pairs of nodes – GD—GG, UD—UG and SB—SC. We proceed to the fourth lowest distance and obtain a next pair created by corn and wheat ($d_{ij} = 0.8848$). Again, neither corn nor wheat are connected to the other nodes already present in the MST which implies that the MST is now made of four separate pairs. In the next step, we find that the fifth lowest distance in the distance matrix D is for the German and US gasolines ($d_{ij} = 0.9181$). Both of the nodes are already present in the MST so that we just connect the nodes GG and UG. The MST is now created by two pairs C—W, SB—SC and one quadruple GD—GG—UG—UD. Next pair is formed by soybeans and corn with $d_{ij} = 0.9369$. Corn is already a part of the MST so that soybeans are just connected to the existing couple C—W. The MST is now formed by a pair SB—SC, a triple C—W—S and a quadruple GD—GG—UG—UD. The next closest pair is the one of German gasoline and US diesel. Both nodes are already present in the MST. Moreover, they are both a part of the quadruple GD—GG—UG—UD and are therefore already connected. If we added a new link GG—UD, we would create a loop, which is not desirable. Eventually, no new link is added for this pair. Following these simple rules, we arrive at the final MST presented in Fig. 1a.

In the similar way, we describe the construction of the hierarchical tree for the weekly returns. We start with finding the closest pair in the MST – that is GG—GD pair, which in turn forms the first pair in the HT. Next is the UG—UD pair, which again forms a pair in the HT. In the same way, the C—W and SC—SB pairs are formed. The next lowest distance is between GG—UG link. Now, both nodes are already present in the HT so that we connect the pairs GG—GD and UG—UD but assign the distance $d^*_{ij} = 0.9181$ to all pairs which might be formed by these four nodes. Therefore, the distance between the pairs is now 0.9181. This is graphically shown in Fig. 1b. The next lowest distance in the MST is present for C—S pair. Corn is already a part of the HT and forms a pair with wheat. We now check what the maximum distance between soybeans and wheat is and we find that it is the distance between corn and soybeans. In turn, we assign $d^*_{ij} = 0.9369$ to both possible pairs formed from the three. Graphically, we connect S to the pair C—W. Again, if we follow these simple rules, we finally arrive at the HT presented in Fig. 1b. In the same way, we constructed the HT for monthly frequency.

Let us first focus on the minimal spanning trees for a higher frequency – a trading week. It is clearly visible that the minimal spanning tree is formed from two parts – a food part (SC, SB, W, C, S) and a fuels part (CO, GD, GG, UG, UD, E, BD). In the MST charts, we also show the distances d_{ij} between nodes (regular font) as well as a bootstrapped value b_{ij} (italics in brackets). The bootstrapped value represents the proportion of times when the specific link has been present in the bootstrapped MST. For example, the value of 0.783 for S—CO link means that out of 1,000 bootstrapped realization, the S—CO link has been found in 783 final MSTs. Using these values, we can comment on a strength or a stability of a link in the MST. In the food part of the MST, we observe a triple W—C—S and a pair SC—SB which have been found in all bootstrapped realizations. These links are thus very stable. The connection between the triple and the pair is quite weaker ($b_{ij} = 0.428$). We can see similarly strong connections in the fuels part of the MST, mainly for a foursome GD—GG—UG—UD which has been found in almost all the bootstrapped cases. Both biofuels are linked to the US fuels.

Relatively low bootstrapped value for CO—GD link ($b_{ij} = 0.388$) is caused mainly by the fact that crude oil is correlated to GG, GD, UD and UG at similar levels so that the links alter between the four in the bootstrapped cases.

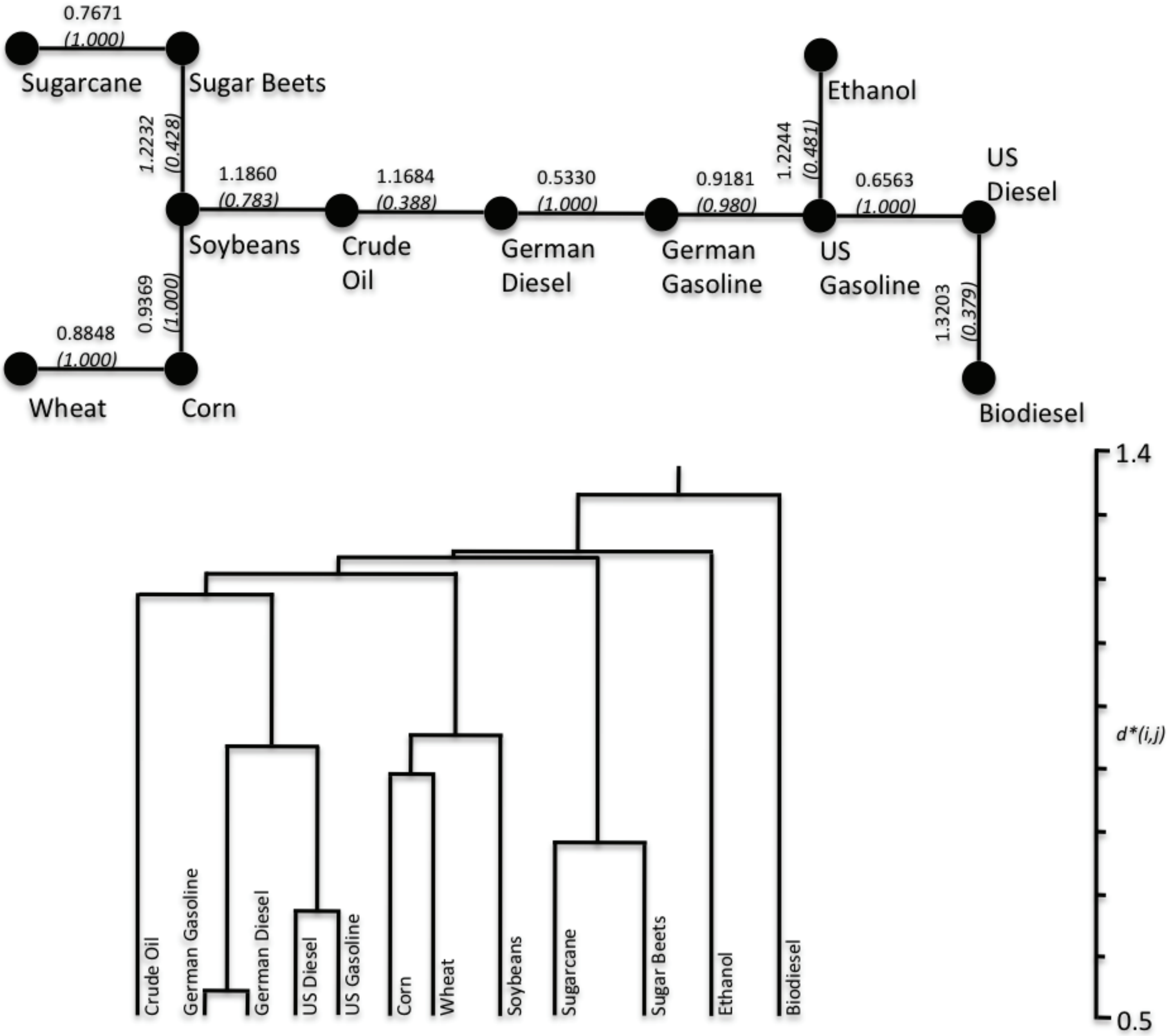

Figure 1a, b. ***Minimal spanning tree (upper picture) and hierarchical trees (lower picture) for network of returns with weekly frequency***

Very similar results can be read from the HT. Here, we can see that there are several clusters – a fuels cluster, a sugar cluster and a fodder cluster. The other commodities – crude oil, ethanol and biodiesel – are quite far from these clusters and thus do not interact much in the short term. Importantly, the biofuels are quite remote from the rest of the network, which can be interpreted in a way that in a short term horizon, the behavior of these biofuels is not dependent on the other analyzed commodities.

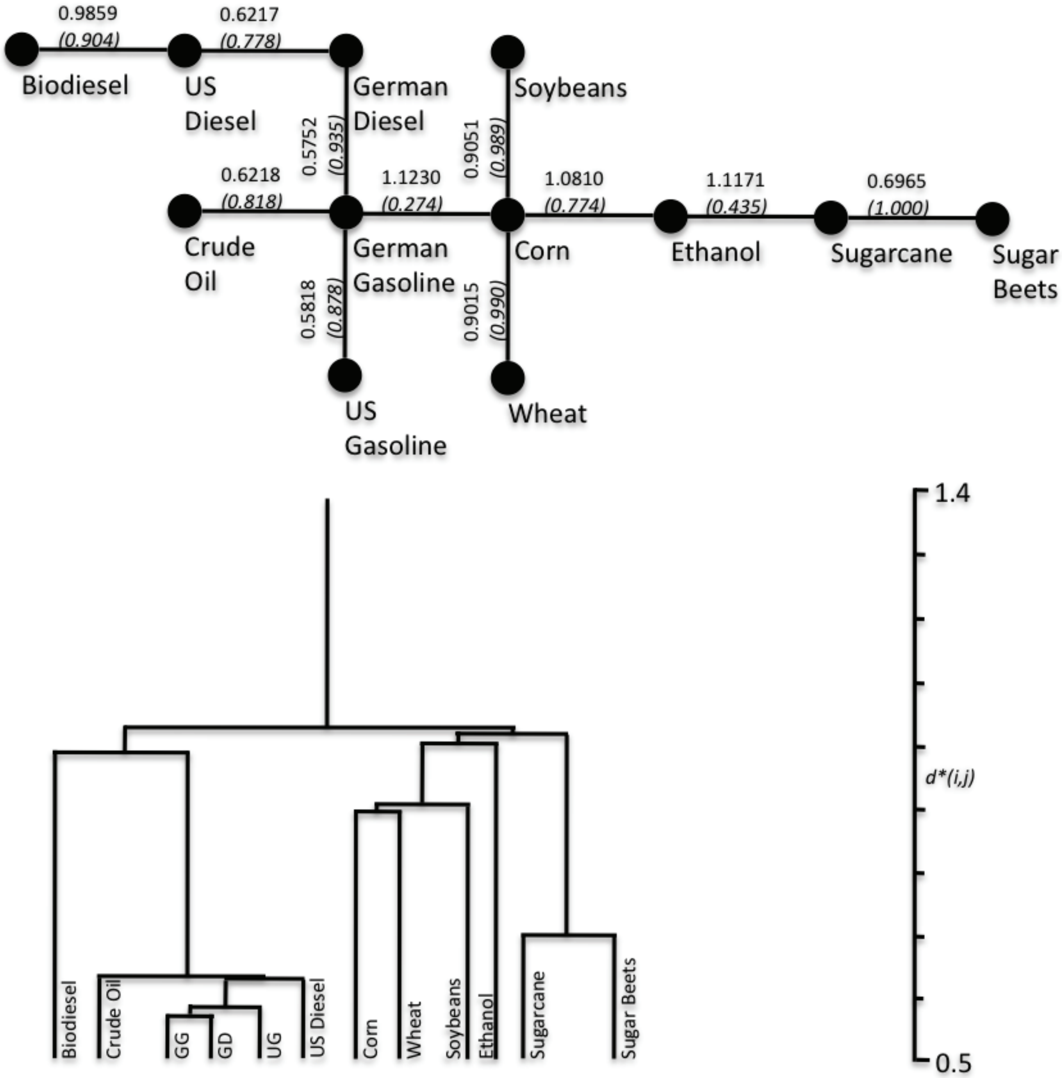

Figure 1c, d. ***Minimal spanning tree (upper picture) and hierarchical trees (lower picture) for network of returns with monthly frequency***

When we look at the relationships between commodities at the lower (monthly) frequency, both MST and HT are getting more structured. The core of the connections remains the same – we still have the three clusters. However, the behavior of the biofuels changes. Ethanol becomes more connected with the food part and biodiesel with the fuels part. Interestingly, the whole network practically splits into two branches – one branch contains all the retail fuels, crude oil and biodiesel and the other branch includes all the analyzed food and ethanol. However, it has to be noted that a distance between the branches is quite low so that the whole system is well correlated. Moreover, difference in the distances between ethanol and C—W—S cluster, then SC—SB from C—W—S—E cluster and then between the whole food cluster and the fuels cluster is very small (all three ultrametric distances are between 1.08 and 1.12), which means that this separation is very unstable. Nevertheless, the average distance between the analyzed commodities decreases from 0.98 for the weekly frequency to 0.84 for the monthly frequency, which implies that the system gets more interconnected with the lower frequency. Apart from the connections of the biofuels to the rest of the network, we observe some other interesting features. First, compared to the weekly frequency, where the GG—GD and UG—UD clusters were well separated, this separation almost disappears for the monthly frequency. This implies that in a short term, behavior of the retail fuels is dominated by geographical features but in medium term, this separation vanishes. Second, crude oil is very well connected to the retail fuels cluster in the medium term, which was not the case for the short term. This implies that it takes several weeks until the effect of the price change of crude oil is reflected in the prices of retail fuels. And last, the feedstock and sugar clusters are well separated for both frequencies.

To summarize the most important findings for ethanol and biodiesel returns with respect to different frequencies, we can say that in the short term, both of these are very weakly connected with the other commodities. Moreover, there is no clear inclination to either of fuels or food parts of the network. In the medium term, biodiesel becomes connected to the fuels section of the system, whereas ethanol gets more connected to the food branch of the system.

Unfortunately, the MST and HT analysis is not capable to find the direction of the effects, i.e. whether the effect comes from food to ethanol or the other way around. However our supplementary follow-up analysis of Granger-causality based on the whole sample of data used in this paper shows that prices of corn Granger-cause prices of ethanol in both short and medium term. We found out that this effect is positive, so that increase in price of corn leads to increase in price of ethanol in relatively short time and the effect disappears quite quickly since the aggregate effect is insignificant starting by the 12th week. We did not find statistically significant Granger causality in the other direction (from ethanol to corn). This is in agreement with the findings of Wixson and Katchova (2012) who show on monthly US data from 1995 to 2010 that price of corn Grange-causes price of ethanol and that ethanol does not Grange-cause wheat. Similar results are reported by Saghaian (2010) who shows that corn price Granger-causes price of ethanol with statistical significance on all conventional levels, but the reversed direction of Granger causality is statistically significant only on 10 percent significance level.

However there also exist studies indicating different causality patterns. For example Zhang et al. (2009) did not find any long-run causality relation between prices of ethanol and corn while in the short-run they found out that prices of ethanol Granger-cause the price of corn. Serra et al. (2011) show that positive causal relationship from ethanol prices to corn prices does not only prevail in the short-run but also in the longer term. However they also show that a shock to corn price when the ethanol price is far away from its equilibrium level will cause an adjustment in the ethanol price in the same direction.

An important starting point for further discussion of our results is the comparison of two major biofuels markets covered in our analysis - US and EU. The EU is historically the largest producer, consumer and importer of biodiesel, which is the most important biofuel in EU. According to Flach et al. (2011) on energy basis biodiesel represents about 80 percent of the total EU biofuels market in the transportation sector. Biodiesel was the first biofuel developed and used in the EU in the transport sector in the 1990s. At the time, the rapid expansion was driven by an increasing crude oil price, the Blair House Agreement of 1992 between US and EU on export subsidy and domestic subsidy reduction and resulting provisions of the EU's set-aside scheme, and generous tax incentives mainly in Germany. The Blair House Agreement allowed the EU to produce oilseeds for non-food use of up to 1 million MT of soybean equivalent. EU biofuels goals set in directive 2003/30/EC (indicative goals) and in the RED 2009/28/EC (mandatory goals) further pushed the use of biodiesel. In addition, the Fuel Quality Directive gave the industry considerable latitude to market higher blends in the fuel supply. This means that the EU orientation on biodiesel was very much induced by public policies originating in 1990s. On the contrary to the EU situation, the US biofuels markets are dominated by ethanol.

The EU policy of setting a single target for all types of biofuel provides a flexibility for EU fuel markets to select a cost-effective biofuels types and technologies. The US approach of sectoral targets is missing this market flexibility, but it may provide market players a long-term confidence for introducing new investments in a broad range of renewable energy sources. More detailed comparison of the US and EU biofuels markets and policies is provided by Tyner (2010a) and Ziolkowska et al. (2010). Because of crucial determining role of government policies in biofuel markets development both in US and EU, it is important to realize that US biofuels mandate was designed in volumes while the EU targets are in energy units. This means that in the US a liter of ethanol was equivalent to a liter of biodiesel as far as volumetric mandates were concerned, while in the EU a kilojoule of ethanol is equivalent to kilojoule of pure biodiesel. According to Tyner (2010a) 1.65 liters of ethanol have an energy equivalent of 1 liter of biodiesel which means that EU system provides an incentive for private sector to use the biodiesel in order to meet the biofuels mandates while the US policy is biased towards the use of ethanol.

Another important difference among EU and US motor fuel markets is much higher share of diesel-engined cars in Europe than in US. This historical difference was again caused by government policies, primarily by taxation of motor fuels. Since the fuel taxes in US were historically much lower than in Europe, the higher fixed cost of diesel engines, as compared to gasoline engines, were more important than variable cost advantage of diesel fuel. In addition the relative tax differences among diesel and gasoline in Europe and US meant that over the period covered in our paper the consumer price of a liter of diesel was higher than that of gasoline in US and vice versa in EU.

From economic point of view, our results show that short-term adjustments, which correspond more to random changes than systematic forces, do not form strong price links in the whole system of biofuels and related commodities. The picture changes by extending the analyzed horizon to one month since the MST and HT constructed with monthly data exhibit considerably more complex structure.

While some earlier evaluations (Mitchell, 2008) pointed to biofuels as a major cause of 2007/2008 food crisis, subsequent research of Hochman et al. (2011) and other authors shows that biofuels were only one of many contributors of price increase. Majority of this research dealing with the role of biofuels in the 2007/2008 food crisis concentrates on ethanol and main agricultural commodities (corn, soybean, rice, wheat) and concludes that the role of biofuels in the price increase was noticeably stronger for corn than for soybeans, with soybean prices driven primarily by the increase in demand due to economic growth. This is in line with our results separating soybeans into a “food subgroup” of MST/HT and placing biodiesel into a distinctive “fuels group” as opposed to ethanol with strong connections to food commodities.

An important policy lesson of our analysis is to emphasize that the general statements about biofuels driving up the prices of agricultural commodities miss a critical distinction between different biofuels. We show that ethanol prices and biodiesel prices have clearly different places in a wide system of biofuels-related commodities. Our results confirm that discussion about food and biofuels prices is primarily relevant for ethanol, but not so much for biodiesel. While we present a strong correlation between prices of ethanol and its major feedstock corn and to a lesser extent other feedstocks, we do not obtain such results for biodiesel. The close connection of major biodiesel feedstock – soybeans – with corn and other grains shows that pricing of soybeans is more driven by its competition with corn for land and water resources and as major components of animal feed in livestock production in US and abroad, especially in China.

6 Conclusions and suggestions for further research

We analyzed the relationships between biodiesel, ethanol and related fuels and agricultural commodities with a use of minimal spanning trees and hierarchical trees. To distinguish between short-term and medium-term effects, we constructed the trees for different frequencies (weekly and monthly).

We found that in the short term, both analyzed biofuels are very weakly connected with the other commodities. In the medium term, the network structure becomes more interesting. The system practically splits into two branches – a fuels part and a food part. Biodiesel tends to the fuels branch and ethanol to the food branch.

Our results contributed to the policy debate about biofuels as possible (major) source of rises in food prices leading to food crises. We confirmed positive correlations among the prices of biofuels and food, but we shoved that the distinction should be made between different biofuels. The policy recommendation of carefully distinguishing between different biofuels is not new to the biofuels and food debate, but so far the distinction was drawn primarily between first generation and second generation biofuels with emphasis on ethanol related feedstock. Our contribution is in highlighting the differences among biodiesel and ethanol with respect to co-movements with food commodity prices and to emphasize time-varying nature of these co-movements. The investigation of time and price varying dynamic causal relations among prices of various biofuels and related commodities is a topic of our further ongoing research in this food-policy relevant area.

Finally, even though the methodology of taxonomy for economic time series is very simple and only transforms the correlations into distances, we were able to find several important results. We identified different biofuel prices network clusters corresponding to different binding constraints for the biofuels price equilibrium formation. The connections among different elements of biofuels network identified in this paper may be used as starting points for more detailed econometric time series investigations (identification of the most important connections in the system, identification of potential collinearity, or even a basis for an optimal portfolio construction). The simplicity of the minimal spanning trees and hierarchical trees methodology allows to include a large number of prices and we therefore expect future research to expand our analysis both in terms of goods and locations in more detail. This will eventually create a good picture of how the relative food and fuel prices relate over space and time.

The taxonomy methodology opens new possibilities for further research. First, a broader range of commodities and assets which might be important in the biofuels discussion – exchange rates, interest rates, commodities futures, stocks, climate conditions, exports and many others – can be included in the MST and HT analysis. A range of possible factors influencing clustering of commodity prices is suggested by Savascin (2011). Second, the proposed methodology can be accompanied by principal component analysis (Pearson, 1901) to give a more complex view on the cluster analysis. Third, conditional (time-varying) correlations can be taken into consideration and incorporated into MST/HT methodology to better describe the evolution in time. However, this would impose a specific model on the data-generating process of the analyzed series, which we wanted to avoid in this paper. Fourth, the time-dependent correlations analysis can be expanded to the frequency domain through wavelets which are able to separate time and frequency characteristics of the series (Vacha and Barunik, 2012). Discrete wavelets and corresponding coherences can be incorporated into the proposed methodology as well while still keeping the framework model-free. And fifth, the biofuels network can be analyzed with a 3D generalization of MST/HT methodology proposed by Song et al. (2011). As a starting point, the proposed methodology and obtained results uncover new frontiers in the biofuels systems research.

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Innovations and Information

Multi-Factor Optimization and Factor Interactions during Product Innovation

Jan Hron, Tomas Macak

Abstract

In this paper, we develop core of an expert system for planning of innovation. The practical outcome of the paper is based on rules determination for search of perspective innovation and its distinguish from commercially unperceptive innovation. The second practical outcome of the paper is a research of interactions between factors during optimization of the product.

In general, we gain process synergy, which can be a source of competitive advantage during product innovation in the presence of organizational complexity by systematically moving through the process definition, control, and improvement elements. The improvement elements can cause interactions between these elements (or factors/process parameters). First, we have to distinguish between synergistic and antagonistic interactions. For synergistic interaction can be used graphic illustration - lines on the plot do not cross each other. In contrast, for antagonistic interaction, the lines on the plot cross each other. In this case, the change in mean response for factor at low level is noticeable high compared to high level. Searching for positive interactions leading to the creation of synergies in the performances we can do at each stage of management innovations. At first, we realize only part of the possible gain, with unrealized potential remaining. Using process control, over time, we stabilize our process and obtain additional limited gain. Using process improvement, we can realize additional gain (it looks as short vertical line during the time), with some potential gain remaining. When new, feasible options develop, we can redefined our process and continue with our control and improvement efforts. Hence, each process-related issue definition, control, improvement has a distinct role to play. Confusion between roles or the omission of any of the roles creates disharmony and frustration in the production system, which ultimately limits production system effectiveness and efficiency. Sometimes, in the presence of confusion, it is possible that effectiveness and efficiency may decrease. In this situation, we hope to learn from our negative factor interactions (or failures) and subsequently improvement trends in long term with using sophisticated methods and own intuition.

This paper objective is to create rules for planning innovation expert system. According to this rules will be possible to distinguish perspective innovation from commercially unperceptive innovation. The second paper objective is to explore interactions between factors during a product optimization. For this purpose will be used the methodology based on minimization of logic functions and design of experiments (analytical tools of DOE).

Key words:

Innovation, expert system, multi-criteria optimization, effectiveness, efficiency, synergy, process improvement, logic function, redundancy factor, design of experiments.

1 Introduction

In current business management, inovation strategy is often connected to the possibility of creating a competitive advantage, based mainly on a wide range of production benefits. One of the critical factors to initiate diversification is the increasing frequency of changes in a company's environment, and also an increase in competitive pressure expressed by shortening a product's life cycle The problem is well-known (ILBERY, 2006). As a result, the advantages resulting from both vertical and horizontal process integration are reduced. Because there are usually more innovative ideas to widen a business' activities than it would be normally possible to implement, it is essential to choose the ideas with the largest potential for commercial success. This article focuses on the design of classifiers that would enable the create the factor optimization and factor interactions investigation during a product innovation.

2 Methods

This paper objective is to create rules for planning innovation expert system. According to this rules will be possible to distinguish perspective innovation from commercially unperceptive innovation. The second paper objective is to explore interactions between factors during a product optimization. For this purpose will be used the methodology based on minimization of logic functions and design of experiments (analytical tools of DOE).

3 Results and Discussion

We have to establish four binary variables for the oral formulation of the function to differentiate the perspective vision of strategic diversification. First, we will define the system inputs to evaluate the strategic potential of innovation and its binary association:

Innovation criteria (coefficient):

$$K_i, \quad \text{where is: } i \in \{1,2,3,\} \text{ a } K_i \in \{0,1\}$$

Criteria (coefficient) *K*1 – Residual potential of commercialized diversification (ZPKD) represents the actual potential in the product competitiveness:

$$K_1 = \prec \begin{matrix} 0 \\ 1 \end{matrix} \succ \textit{coefficient ZPKI} \prec \begin{matrix} \text{occur between } \langle 0; 0,5) \\ \text{occur between } \langle 0,5; 1\rangle \end{matrix}$$

The product (business plan) residual time created within diversification ***tR,*** that is expressed through the time rate between the time of the used change in the producer's portfolio and the assumed time of diversification lifecycle (time that the farmer has the production capacity available for production during the diversification activities). The other factor is the so-called Product Residual Unsaturation created within diversification ***nR,*** which is characterized by the relation among the number of producers that already commercialized similar products and the number of producers that (not only within their activities' diversification) use the market opportunity (or are motivated by grants) to modify their production portfolio during the lifecycle of the private farmer's diversified activities life cycle.

In case we want the ZPKD to be the quantity with growing values preferences, it is essential to subtract the residual time ***tR*** and the residual saturation ***nR*** from 1. Then we count the residual diversification time **tR** as:

$$t_R = 1 - \frac{t_i}{t_n} \tag{1}$$

where:
ti = the time of the product usage that is created within the activities diversification (in years);
tn = assumed time of the realized diversification lifecycle (in years).

The residual innovation unsaturation *nR* is expressed as:

$$n_R = 1 - \frac{n_i}{n_n} \qquad \textbf{(2)}$$

where:
ni = the number of producers that already commercialized a similar product (to the product created within the diversification activities),
nn = the estimated number of producers that use a similar product to modify their product portfolio during the diversification life.

Due to the fact that both ***tR*** and ***nR*** are ratio quantifiers, it is possible to fuse them or to intersect them. If we define the domain of definition for ZPKD as: 1,0*PKD*□, it is necessary to define the residual potential of commercialized diversification by the intersection between ***tR*** and ***nR***:

$$ZPKD = \sqrt{t_R \times n_R} = \sqrt{\left(1 - \frac{t_i}{t_n}\right) \times \left(1 - \frac{n_i}{n_n}\right)}; \qquad \textbf{(3)}$$

ZPKD is formed by the square power because variations ***tR*** and ***nR*** are being multiplied from the maximum values. Therefore, it is essential to extract the square root of these variations to make the ZPKIrepresentative as a one-dimensional quantifier (as a geometric average). For instance, a product, made thanks to the farmer's business activities diversification, hit the market one year ago and has the supposed 5-years long lifecycle's length. A similar product has been produced by 2 out of 4 competitors.
According to (3) ZPKD is equal to:

$$ZPKD = \left(1 - \frac{1}{5}\right) \times \left(1 - \frac{2}{4}\right) = 0{,}632 \approx 63\%\ z\ \max(ZPKD)$$

If we assume a linear growth in number of producers in time, using the particular market urge (state grant policy, supply leakage in the particular market segment, etc.), the reference value of the ZPKD will occur between ⟨min *ZPKI*, max *ZPKI*⟩ and it is in value 0.5. The question is, whether the ZPKD should occur in front of the 0.5 borderline or behind. Of course there is an answer that the ZPKD should be higher than the reference value 0.5 (ideally equal to maximum that is 1). However, this single-valued definition does not respect the differentiated business strategies that use besides diversification strategies also integration strategies. Exactly those agro-businessmen that use for instance vertical integration (forward and backward) to create a competitive advantage could be advantageous to establish a product that has the ZPKD value smaller than 0.5. This contribution focuses mainly on evaluating the efficiency of strategic diversification that is applied on its production portfolio. Someone, who tries to set a competitive advantage based on business activities risks lay-out, will a priori assume that the ZPKD value should be above the 0.5 value (max = 0.5) for the positive innovation judgment.

Criteria (coefficient) *K2* – Financial evaluation of the necessary investment to diversification realization

There are many of various dynamic methods used for investments evaluations (concerning the development and implementation of the particular product portfolio diversification), such as the discount time of return, the internal profit ratio etc.) NPV method – Net Present Value – which enables the immediate recognition of non-profitable investment (it commonly equals to 0). If the investment is financially non-profitable, this method enables to clearly compare it with other innovation alternative which will be more profitable. Net Present Value is calculated as:

$$NPV = \sum_{i=1}^{n} \frac{CF_i}{(1+r)^{tn}} - IN \qquad (4)$$

Coefficient (criteria) *K3* – Risk of the innovation commercial success

Business risk, connected to commercial success of the offered product, is commonly defined by probability factors We estimate the empirical record that is helpful while recognizing these. We divide those into the relative percent occurrence through the histograms and the additive curve. Based on the probability division law, we try to find the probabilities of the particular values of the random quantity. Discrete quantities characterizing the risk of the new product's/service's development are usually described by this law. By a certain level of abstraction and fulfilment of the condition of the "properly short" period of marking the monitored quantity (for example product's demand), we are able to mould the discrete quantity upon the probability volume *f(x)* – as the following relation:

$$P(x_1 < X \leq x_2) = \int_{x_1}^{x_2} f(x)\, dx$$

(5)

Random quantity X reaches values x and particular probability $P(X = xi)$ for each xi reaches values *p(x)*. Furthermore, this random quantity X reaches values x in the interval *(x1, x2)* with the probability that equals to *f(x)* integral after increments *dx* when the following conditions are fulfilled:

$$x_1 \leq x_2 \quad a \quad \int_{-\inf}^{+\inf} f(x)\, dx = 1 \qquad \textbf{(6)}$$

After implementing the fuzzy set **I** for all free guiding variables, it is possible to proceed to the fuzzification itself - the method was significantly improved (KOSKO, 1997). This procedure is illustrated in the figure 2.1.

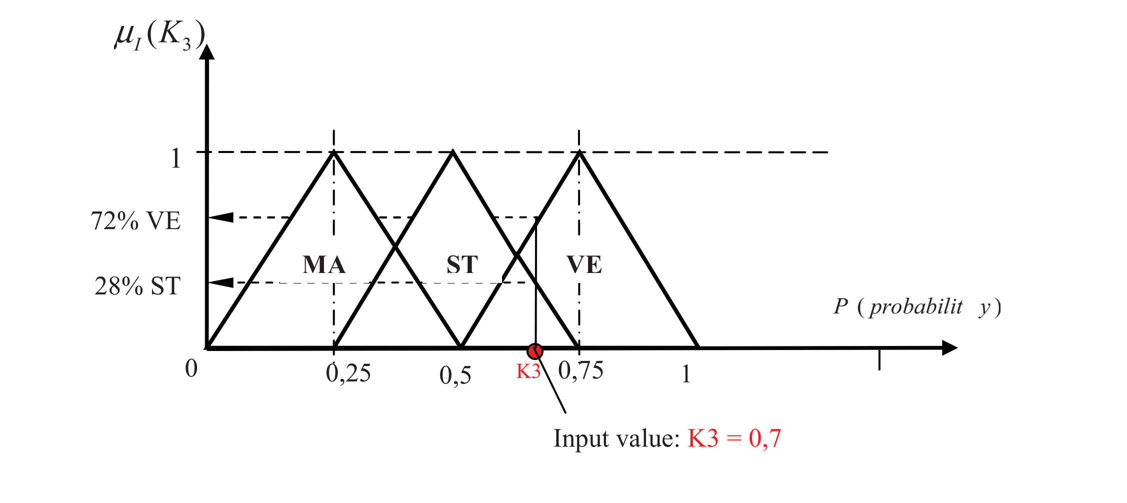

Fig. 3.1 Fuzzification of risk of the innovation commercial success

Figure 3.1 illustrates the assignment of point values of the criteria for the **risk of the innovation commercial access K_3** to the fuzzy set represented by the three subsets (MA, ST, VE). This assignment is done by the method of the so-called relevance (membership) function estimate in a parametric way. Its principle is based on the expert estimation of three points (parameters) of the input function for each subset. Parameter, which is the leftmost, is excluded from the fuzzy set (for a subset of MA it is the point [0,25, 0]). The second point that we determine is one that certainly belongs to the fuzzy subset. For our case of a subset of MA it is **of the innovation commercial access K_3** value belonging to the top of the "triangle", therefore the point [0,25 , 0]. If this point definitely belongs to the fuzzy set, we can guarantee 100% membership rate, i. e. in the range of our scale by the value of 1. This means that for the input value, in our case 25 % of risk probability, the fuzzified value = 1 is assigned. This yields a top of the fuzzy subset of MA ([0.25, 1]). The third parameter that is specified is the point that is still included into the fuzzy subset. In our case, it is [0.5, 0]. Following that determination, we can define the fuzzy subset of MA. Its geometrical interpretation represented by the triangle MA is obtained by combining the three identified parameters, i. e. points [0, 0], [0.25, 1] and [0.5, 0].

In an analogous way, as shown in Figure 3.1, we would find the other two subsets ST and VE. The practical question is, in what other way than an expert way it is possible to determine the position of centroids of the fuzzy set, respectively the range of these fuzzy sets. References [x] offer the solution by means of the weight functions.

The weight values w_{MA}, w_{ST}, w_{VE} were received from the ratios of central points (centroids) for single output fuzzy sets. If the fuzzy set MA value of weight function equals one (i. e. $w_{MA} = 1$), then remaining two weight functions (w_{ST}, w_{VE}) will be calculated from the ratios of centroids of these sets to the centroids of the MA set. The position of centroids on the horizontal coordinated axe for fuzzy set of MA is equal to 0.25 points (weight function for the fuzzy set of MA was equal to 1. At the same time, the ratio of weight function to the value of a relevant centroid should be the same (constant) for all fuzzy sets. If we express this condition in a mathematical way, we get:

$$\frac{w_{MA}}{centroid(MA)} = \frac{w_{ST}}{centroid(ST)} = \frac{w_{VE}}{centroid(VE)} = konst \;;$$

From this it follows: $centroid(ST) = \frac{w_{ST}}{w_{MA}} \times centroid(MA) = ;$

$$centroid(VE) w_{VE} = \frac{w_{VE}}{w_{MA}} \times centroid(MA) = .$$

Such generally conceived weighting functions can then be transformed into interval units (variables), by means of which the relevant fuzzificated variable is characterized. More sophisticated methods can be seen in the use of methods for the design of experiments, specifically using the Full Factorial Experiment (FFE). The following procedure is indicated to determine the fuzzy set ST (middle) for Fuzzification of **Risk of the innovation commercial success**. Here we use the idea that the entire range of input values corresponding to this set should have, due to the interaction with other significant factors (**residual innovation unsaturation**, F**inancial evaluation of the necessary investment to diversification realization**) such a variability of output values (here the agregated vaulue), which would not exceed a predetermined reliability interval (here chosen at 95%). If we verified that all values within the interval of the fuzzy set have little interaction, that means that we can use all the values from the fuzzy set, and thus we can optimize the production process according to another criterion (for example the economic one, with the cost optimization of production given by the durability of the production system). If we verify that the change of fuzzy set interaction for the **Risk of the innovation commercial success** of the set ST is not important between the extreme points of this set, then we can use the whole range of values of this fuzzy set to optimize the inovation process without the system reduction of the output quality of the products.

For this inovation optimization process, we have employed a Full Factorial Experiment (FFE) (MONGOMERY, 2008) and each trial was replicated twice to observe variation in results within the experimental trials. The results of the FFE are shown in next Table 3.1.

Trial (standard order)	Trial (randomized order)	K1 Cutting speed ***v*** *(A)*	K2 Cutting depth a_p *(B)*	K3 Feed ***f*** *(C)*	Response (aggregated unit)		Average (aggregated unit) K2 K3
1	***4***	***-1***	***-1***	***-1***	***1.757***	***1.745***	***-1 -1***
2	3	-1	+1	-1	1.326	1.368	***+1 +1***
3	2	-1	-1	+1	1.671	1.720	$A_{B,C(-1)}$
4	***1***	***-1***	***+1***	***+1***	***1.802***	***1.738***	1.7605
5	***8***	***+1***	***-1***	***-1***	***1.905***	***1.896***	***-1 -1***
6	7	+1	+1	-1	1.890	1.963	***+1 +1***
7	6	+1	-1	+1	1.878	1.867	$A_{B,C(+1)}$
8	***5***	***+1***	***+1***	***+1***	***1.744***	***1.709***	1.8135

Tab. 3.1 Results from a 2^3 full factorial experiment and average response values

The relative difference between average response $A_{B,C(+1)}$ and $A_{B,C(-1)}$ can be computed using the following equation:

$$RD = \frac{A_{B,C(+1)} - A_{B,C(-1)}}{\frac{A_{B,C(+1)} + A_{B,C(-1)}}{2}} = 0.29658 = 3\ \% < 5\%\ significance\ level$$

(Fuzzy set size is therefore all right)

4 Conclusion

In this paper, we develop core of an expert system for planning of innovation. The practical outcome of the paper is based on rules determination for search of perspective innovation and its distinguish from commercially unperceptive innovation. The second practical outcome of the paper is a research of interactions between factors during optimization of the product.

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Open innovation in the Hungarian wine sector

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1. Introduction[4]

Adopting an open innovation process is the new mantra of the Food and Beverage (F&B) sector. To illustrate, Heinz, one of the largest multinational corporations (MNC) operating in the sector, recently re-focused its R&D and innovation strategy on an open innovation platform, including all relevant phases of food production, thus from agriculture to health science[5]. Unilever, another F&B giant, re-shaped its CSR policy (Unilever Sustainable Living Plan) with a renewed innovation platform fully re-focused on an open innovation approach[6]. In 2004 Barilla group, one of the largest pasta-makers in Europe, funded a branch-company, Academia Barilla, as an open (web-based) platform to collect traditional recipes from the Italian cuisine, and to use them to produce world-class food products[7]. SMEs are also increasingly joining the club of open-innovators, especially through industrial and knowledge-based clusters[8].

This trend can be seen as a reaction of food companies to their exposure to severe (and increasing) competitive pressures worldwide. Adopting an effective innovation process to successfully introduce and develop new products to the market has become one of the most important strategies for food companies (Karantininis et al., 2010). However, whether it is more effective to speed up the innovation process by sharing ideas and resources with other companies, or to innovate in-house in a more closed system is still under debate in the academic domain (Sarkar an Costa, 2008).

Chesbrough (2003) has been the first to introduce the concept of 'open innovation'. The idea of open innovation indicates that a company is increasingly using inflows and outflows of knowledge to speed up the internal innovation process, and expand the markets for external use of innovation (Chesbrough, 2006). From a theoretical perspective, the open innovation literature has focused on different topics such as (i) the degree and type of openness (i.e. outbound or inbound), (ii) effectiveness, (iii) context and (iv) process (Huizingh, 2011). In this respect a gap in the literature is an understanding of open innovation in the different stages of the innovation process, from the idea generation to the commercialization phase.

Moreover, if we look at the empirical studies on open innovation, most of them draw on evidence from high-tech industries such as equipment, computers, ICT or pharmaceuticals (e.g. Christensen et al., 2005; Dittrich and Duysters, 2007; Fetterhoff and Voelkel, 2006) and have a prevalent focus on large companies and multinational corporations (Chesbrough, 2003, 2006). Empirical investigations on open innovation in SMEs operating in the F&B sector are relatively scarce in literature (Huston and Sakkab, 2006; Sarkar and Costa, 2008;

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[5] http://www.heinz.com/our-food/innovation/research-development.aspx (last access 10-08-2012)
[6] http://www.unilever.com/innovation/collaborating-with-unilever/open-innovation/ (last access 10-08-2012)
[7] http://www.academiabarilla.it/italian-food-academy/sede/default.aspx (last access 10-08-2012)
[8] An example is FoodValley operating in the Netherlands (http://www.youtube.com/watch?v=hEg0a2xCePo)

Vanhaverbeke and Cloodt, 2006; Enzing et al., 2011). Archibugi et al. (1991) indicate that a more open system of innovation is particularly interesting for food companies, which normally rely even more on external resources than other industries (see also Enzing et al., 2011). Moreover, some specific features of the innovation pattern in food companies make that looking at only internal, closed innovation processes (i.e. the effort in R&D) is a misleading indicator of food companies' innovation capacity (Avermaete et al., 2004; Galizzi and Venturini, 2008; Capitanio et al., 2010). On the other hand, a strong R&D department and access to well-trained and expert human resources is a necessary condition to adopt a more open innovation system (Wang and Ahmed, 2007).

This paper contributes to the existing literature by addressing the issue of open innovation in the different phases of the innovation process in SMEs operating in the F&B sector. The issue is particularly controversial in the wine sector, where innovative marketing strategies have to be combined with sometimes "exclusive" and "secret" recipes, which make the quality of the products unique. The uniqueness of the empirical investigation is twofold: (i) this survey is the first one in the Hungarian agri-food sector, aiming at purely the knowledge and innovation characteristics of the enterprises and (ii) the survey is the first in Hungary concentrating on a natural resource based industry. The uniqueness is very much coupled with economic interest, because in the developing countries the innovation process in natural based sectors (especially the wine industry in the New World of Wine countries, like e.g. Chile) has generated huge economic wealth during the last 20 years (Anderson, 2005). One of the most critical questions to be answered by wine companies is how to arrange external ties with other companies and research organizations - potentially leading to a successful innovation system - without compromising unique and highly specific assets. Therefore, understanding the main factors that lead wine companies to adopt an open, rather than a closed, innovation system is the main research question of this paper. We aim at "unbundling" the open innovation process and analyse whether the degree of openness of wine companies varies in the different stages of innovation, whether patterns of openness and common factors that can predict them do exist. More specifically, we analyse the relationship between dynamic capabilities, namely the adaptive and absorptive capabilities of the firm, and open innovation in three main stages of the innovation process: idea creation, development and commercialization. We also control for sector and regional specific conditions.

The Hungarian wine industry presents an interesting case for research on the issue of open innovation. Wine contributes significantly to the total turnover in the Hungarian F&B industry. Wine typically offers opportunities for strong value creation and can be marketed as a premium processed F&B product. However, in recent years the Hungarian wine industry has been left behind in worldwide trends on premium and super-premium wine markets (Wittwer, 2007).

The dataset allows to incorporate differences in regional conditions that can support or constrain the opportunities that companies have to participate in open innovation networks.

The literature on open innovation predicts a low degree of openness in low-tech companies (Dahlander and Gann, 2010), including SMEs operating in the F&B sector (Sarkar and Costa, 2008). However, we find that open innovation is quite extensive in the Hungarian wine industry: 25-30% of companies generate, develop and commercialise the majority of new ideas in cooperation with other partners. As a second result, we find that the degree of openness decreases as a company moves through the consecutive stages of innovation. In other words, Hungarian wine companies are significantly more likely to use outside ideas in the idea generation and development stages than in the commercialization stage. This contradicts findings in the literature (Lee et al., 2010). However, conclusions from this earlier research focused on the importance of outbound activities in the later innovation stages, while our data only allow us to look at the inbound open innovation processes (i.e. the 'buy' decision with respect to knowledge and technology transfer). This may explain our outcomes. Finally, we use a multivariate probit model to determine the factors that drive the degree of openness at different innovation stages. The multivariate probit allows the binary dependent variables to be correlated. As dependent variable we use an indicator of the presence of openness at the three main stages in the innovation process, more specifically the share of in-house idea generation, idea development and idea commercialization. The independent variables are derived from the literature and include indicators of (1) companies' dynamic capabilities, such as absorptive and adaptive capabilities, which are hypothesised to be a precondition to benefit from open innovation; (2) control variables such as companies' age, size, legal form and the role of external networks. Since the cross-sectional nature of our data does not allow us to completely avoid issues of endogeneity, reverse causality and omitted variables problems, the results of the econometric estimations should be interpreted as correlations and not as casual relationships.

Furthermore, results show that there is a high positive correlation between the degree of openness in different stages of the innovation process. The use of the multivariate probit model is therefore justified. This result leads us to conclude that companies are inclined to be open (or closed) throughout the whole innovation process. Drivers that stimulate openness in idea creation in a company may therefore also contribute to a positive attitude towards openness in idea development and commercialisation and vice versa. Furthermore, the estimation provides evidence that larger wine companies have more open innovation processes. Other significant results are the positive impact of access to specialised regional suppliers and the negative impact of a company's age. The former seems to indicate that supplier-buyer relationships are crucial in stimulating knowledge and technology transfer. The latter shows that older wine companies rely more on in-house innovation processes.

2. Open innovation processes, dynamic capabilities and institutions in the Food and Beverage sector

2.1. Defining open innovation in the F&B sector

What makes food companies substantially different from other manufacturing companies is their higher dependency on natural resources - not limited to e.g. fossil fuels – and their need for specific (often tacit and local) know-how in their production processes. Transforming an often heterogeneous and discontinuous flow of raw materials into standardized and marketable products is at the core of a food business. Therefore, more than being involved in ground-breaking and radically innovative projects, food companies (including multinational corporations) are more likely to be active in a very targeted process of stakeholder and technology adaptation (Rama, 2008; Enzing et al., 2011). As a result, when scholars look at R&D activities in the F&B sector they are often inclined to see food companies as conservative, slow-growing and mature businesses, where innovative activities are less likely to occur (Sakar and Costa, 2008; Capitanio et al., 2010). On top of that it is rather difficult to assess the degree of openness of the innovation system adopted by a food company. To illustrate, if a wine-maker is producing a world-class wine using and adapting a "local recipe" (which is often the case), this is not regarded as an open innovation approach, though it is fitting in the concept of "increasingly using inflows and outflows of knowledge to accelerate the internal innovation process, and expand the markets for external use of innovation" (Chesbrough, 2006).

A review of the literature on open innovation in the F&B sector performed by Sarkar and Costa (2008) clearly indicates two main shortcomings in this domain: on the one hand, few empirical evidence is available to thoroughly assess whether food companies are approaching open innovation in a different way than other manufacturing companies; on the other hand, most of the contributions in this literature use proxies to measure the presence and degree of open innovation, for example through the presence and number of external ties (see also Enzing et al., 2011). The literature also indicates potential differences of open innovation features in the different stages of innovation (i.e. idea generation, development and commercialization) (Sarkar and Costa, 2008). The question is how to measure and assess open innovation in food companies.

Van de Vrande et al. (2009) measure open innovation by identifying technology exploration and exploitation practices. As pointed out by Huizingh (2011) using external ties as a proxy of openness is potentially misleading because it only captures one of the components of the concept, such as the inbound/outbound dynamics. Thus being engaged in a partnership with someone (i.e. a research organization) does not necessarily mean that you are internally making use of your partner's knowledge (*inbound innovation*), nor that you are using internal knowledge to exploit resources provided by your partner (*outbound innovation*). In effect it merely highlights the underpinning mechanisms and trends leading to an open innovation process (Gassman et al., 2010; Huizingh, 2011). Parida et al. (2012) point out that inbound open innovation refers more to exploring and integrating external knowledge to develop and exploit technology. Outbound open innovation is the practice of exploiting technological capabilities, combining internal with also external paths of commercialization (Chesbrough 2003; Chesbrough and Crowther 2006).

In line with this literature review, we conceptualize the measurement of open innovation as "the proportion of innovations entirely generated within the company as opposed to the ones generated in co-operation/collaboration with universities, research organizations, regional customers and/or suppliers, other F&B companies, venture capitalists and industry/cluster associations or business assistance centres". We apply this definition to the different stages of innovation, namely the *idea generation* phase (discovering market opportunities or problems to be solved, envisioning areas for technical breakthrough, developing initial insights, basic and applied research), *idea development* phase (developing a deeper conception of products or services, building a model of a product or service, product or process testing) and *commercialization* phase (production, promotion, distribution, and sales of a product/service/technique). In line with Parida et al. (2012) this conceptualization emphasizes more an inbound than an outbound open innovation process. Inbound open innovation is prevailing in low-tech industries (Chesbrough and Crowther, 2006), where the exploration and exploitation of external knowledge through networks of collaboration is more likely to occur than new venture spin-offs for technology development and / or licensing-out technologies to other organizations (Parida et al., 2012). It is more difficult to understand whether significant differences occur in the different stages of innovation. Lee et al. (2010) argue that high tech companies can be more prone to use an open innovation process in the commercialization phase. While high-tech companies show superior capabilities in the phases of creation and development of new technologies, they might suffer from a lack of marketing capabilities when it comes to the phase of commercialisation (Lee et al., 2010). Enzing et al. (2011) show that F&B companies need to implement open innovation processes from idea creation to commercialization. In fact, while they are more likely to engage in large networks of collaboration with upstream partners to use and adapt technologies to innovate their processes, they engage with downstream partners (i.e. retailers) to overcome challenges in introducing new products to the market (Enzing et al., 2011). Based on this literature we formulate the following hypothesis:

H1: *The degree of openness in the innovation process does not differ between the three different stages of the innovation process.*

2.2. The role of company dynamic capabilities

Factors that contribute to a company's openness, such as dynamic capabilities, must be seen as the main explanatory variables when analysing open innovation (Dahlander and Gann, 2010; Huizingh, 2011). As mentioned earlier, the role of openness and connected capabilities is even more important in F&B companies because they have even more intense interactions with both upstream and downstream partners than other types of companies (Enzing et al., 2011). F&B companies may develop some specific capabilities due to the peculiarities characterizing their innovation pattern. On the one hand, F&B companies are mainly "market-pulled" businesses, therefore involved in incremental rather than radical food product innovations (Grunert et al., 1997; Galizzi and Venturini, 2008; Elzing et al., 2011). In this respect, they benefit the most from the interaction with downstream partners, such as retailers and distributors, in order to make the introduction onto the market of new products successful. On the other hand, F&B companies are "technology-pushed" (Capitanio et al., 2010). Therefore, they are mainly process-innovation oriented through adaptation of equipment and the use of new technologies developed by upstream (high-tech) industries to create new food products (Archibugi et al., 1991; Garcia Martinez and Burns, 1999; Capitanio et al., 2010). In line with these statements, we use dynamic capabilities to explain differences in degree and patterns of open innovation in F&B companies. Teece et al. (1997) extensively discusses the relationship between dynamic capabilities and innovation-based competition in different industries. In this framework dynamic capabilities are seen as a subset of competences and resources which allow the firm to create new products and processes, and respond to market changes (Teece at al., 1997). Wang and Ahmed (2007) highlight the presence of two main types of dynamic capabilities, namely the *absorptive capabilities*, as a way in which companies create and absorb, integrate and re-configure external knowledge from other organizations (Cohen and Levinthal, 1990); and *adaptive capabilities*, as a way in which companies are able to explore and exploit external opportunities in the market (or the geographical context) (Staber and Sydow, 2002). Based on these concepts we develop the following research hypotheses:

H2: *Open innovation in the idea creation and development phase is more likely to occur in the presence of dynamic capabilities developed with upstream partners*

H3: *Open innovation in the commercialization phase is more likely to occur in the presence of dynamic capabilities developed with downstream partners*

3. Data and empirical strategy

First we describe the data. The survey was carried out in 2006 in the 22 Hungarian wine regions, as part of the T 046882 OTKA (Tóth, 2009) research with the assistance of the National Council of Wine Regions. Altogether 115 questionnaires were completed representing an average of 5 questionnaires for each wine region. As the statistical representativeness could not be achieved, the research results are relevant on country level.

The examined time period (2004-2006) is the same when the EU had to face with the aggressive market penetration of new wine producing countries (Australia, Chile and South Africa), taking wine reforms in force. The new EU framework is more market oriented and competitive, therefore for the Hungarian wine sector – with almost only SME companies – fostering, adapting and spreading the innovation is more crucial than ever. Table 1 reports our main variables.

Tab 1. – Descriptive statistics

Variables			Obs.	Mean	S.D.	Min.	Max
Panel A: Open innovation variables							
Presence of open innovation at idea generation phase (>25% ideas created with outsiders)		OIgeneration	115	0.635	0.484	0	1
Presence of open innovation at idea development phase (>25% ideas developed with outsiders)		OIdevelopmt	115	0.548	0.500	0	1
Presence of open innovation at commercialization phase (>25% ideas coming from outside)		OIcommerce	115	0.426	0.497	0	1
Panel B: Dynamic capabilities variables							
Absorptive capabilities	Presence of high-skilled workers	educ_skill	92	0.304	0.280	0	1
	Percentage of English-speaking workers	eng_skill	115	20.643	25.380	0	100
	Percentage of workers familiar with ICT	ICT_skill	115	44.757	37.235	0	100
	The firm is dependent on specific knowledge	spec_know_depend	114	5.518	1.465	1	7
	The firm owns specific know-how	own_spec_know	114	5.105	1.319	2	7
Adaptive capabilities	The firm has intensive info exchanges with buyers	buy_info	114	5.193	1.211	1	7
	The firm has intensive info exchanges with suppliers	supl_info	114	4.307	1.446	1	7
	Reciprocity in sharing know-how with competitors	rec_info	114	3.500	1.581	1	7
Panel C: Control variables							
	Number of workers	size	115	11.296	19.916	0	130
	Age of the firm	age	105	11.095	6.631	1	47
	Legal status (1 if private partnership)	legalform	115	0.574	0.497	0	1

Panel A in table 1 describes the open innovation variables. We identify open innovation in the Hungarian wine companies when at least 25% of the new ideas have been created / developed / commercialised together with partners outside the boundaries of the firm. All three measures are based on self-assessment of top-managers. Panel B refers to variables related to dynamic capabilities. We proxy absorptive capacities through the presence of highly-educated workers, the percentage of workers who are able to use English for business relations and the percentage of workers that have a familiarity with ICT. Furthermore, we include variables that are based on the assessment of top-managers about the firm's dependence on specific knowledge and the level of know-how specificity that is present in the company. To proxy adaptive capabilities we use the intensity of information exchanges the company has with both upstream (suppliers) and downstream parties (sellers) and the reciprocity in sharing know-how with competitors. As controls we use firm size, age and legal status (whether a wine company is a private partnership instead of a cooperative or other legal forms).

We now describe our empirical strategy. We consider correlations between our measures of open innovation and dynamic capabilities of F&B companies:

(1) $O_j = \alpha + \beta_1 D_j + \beta_2 C_j + \varepsilon_j,$

where O_j refers to our open innovation variables, such as the proportion of ideas entirely generated, developed or commercialized in collaboration with other partners of company j, where j=1,....115. D_j refers to a vector of company dynamic capabilities, I_j to a vector of institutional variables, and C_j refers to a vector of company control variables.

4. Results

As a first result we can see from table 1 that the degree of openness decreases as we move through the different stages of the innovation process. While open innovation occurs in 63% of the surveyed companies in the idea generation phase, this share has decreased to 55% and 43% in the development and commercialisation phase respectively. To test hypothesis 1 we perform pearson's chi-squared test to determine independence of the variables OIgeneration, OIdevelopment and OIcommerce. The test strongly rejects independence and hence confirms that the degree of openness is strongly correlated in the three different stages of the innovation process in Hungarian wine companies. In other words, we accept hypothesis 1. Moreover, the positive correlation between the degree of openness in different stages of the innovation process also justifies the use of the multivariate probit model. We can conclude that companies are inclined to be open (or closed) throughout the whole innovation process. Drivers that stimulate openness in idea creation in a company may therefore also contribute to a positive attitude towards openness in idea development and commercialisation and vice versa.

In table 2 we present our results on correlations between open innovation variables and dynamic capabilities in Hungarian wine companies.

Tab. 2 – Multivariate probit results

	OIgeneration			OIdevelopment			OIcommerce		
Variable	Coef.		Std. Err.	Coef.		Std. Err.	Coef.		Std. Err.
Presence of high-skilled workers	0.1596		0.6401	0.0430		0.5624	0.7054		0.60613
Percentage of English-speaking workers	0.0189	*	0.0099	0.0029		0.0071	0.0068		0.00802
Prercentage of workers familiar with ICT	0.0015		0.0065	0.0040		0.0052	-0.0059		0.00525
The firm is dependent on specifci knowledge	-0.1465		0.1301	-0.1208		0.1104	-0.0673		0.10143
The firm owns specific know-how	-0.2466	*	0.1432	-0.0224		0.1245	-0.1256		0.12784
The firm has intense info exchanges with buyers	0.0322		0.1506	-0.0536		0.1279	0.24994	*	0.14356
The firm has intense info exchanges with suppliers	0.3106	**	0.1231	0.0868		0.1055	0.10555		0.11103
Reciprocity in sharing know-how with competitors	-0.1224		0.1429	-0.1077		0.1141	-0.1741	*	0.10474
size	0.0184		0.0151	0.0211	*	0.0124	0.0103		0.008
age	-0.0494	*	0.0287	-0.0181		0.0236	-0.0519	**	0.02536
legal form	-0.2764		0.3579	-0.5377	*	0.3030	-0.4972		0.31389
constant	1.3445		1.0627	1.0813		0.8964	0.205		0.94027
Corr_gener_dev	0.83902	***	0.08653						
Corr_com_gener	0.66411	***	0.12792						
Corr_dev_com	0.84704	***	0.07919						

The results in table 2 confirm hypothesis 2: open innovation in the idea generation phase is more likely to occur in the presence of intensive information exchanges with suppliers. Furthermore, we find evidence in line with hypothesis 3, namely that open innovation in the commercialisation phase is stimulated by information flows between the wine companies and downstream buyers. This points to the relevance of other value chain actors in the innovation process in the wine industry but with an important distinction between the players that affect the first stages of the innovation process (idea generation) as compared to the later stages (commercialisation).

Other dynamic capabilities that play a role in explaining the degree of openness include the skill level of the labour force and the degree of in-house specific knowledge. In line with the the literature, companies that adopt an open innovation process have access to a well-educated workforce. Furthermore, access to own specific know-how in the company is negatively correlated with the openness of the innovation process. This may point to a trade-off between openness and own innovation capacity. Reciprocity in information exchange with competitors, on the other hand, is negatively correlated with open innovation.
Finally, the control variables show a significant effect of firm size (positive), firm age (negative) and legal form. The former indicate that larger and younger firms are more likely to have an open innovation process. Companies established as private partnerships, on the other hand, are less likely to engage in open innovation.

5. Discussion and conclusions

In general we conclude that both the regional (access to suppliers) and the company-specific (age and size) context affect the openness of innovation processes in the Hungarian wine industry. It remains to be investigated to what extent this is related to the actual costs of openness or to the limitations in accessing its potential benefits for individual companies. A better understanding of the process of innovation is therefore crucial to improve the competitive position of the Hungarian wine sector. From a rural development perspective, this may provide valuable information for policymakers that are interested in creating an innovation-friendly environment.

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Survey of Recent Innovations in Aromatic Rice

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Annotation: This paper provides situations of aromatic rice demand, and international standards. The history and recent developments of traditional and evolved aromatic rice varieties, namely Basmati rice and Jasmine rice, are reviewed. The emerging aromatic rice innovations from developed countries such as the U.S. and other Asian countries generate a threat to these traditional aromatic rice producers such as India, Pakistan, and Thailand. Under WTO Trade Related Aspects of Intellectual Property Rights (TRIPS) Agreement, Geographical Indication (GI) provides a means to protect traditional knowledge and products that are recognized as quality or reputation attributable in the geographical areas, but only if the GI is also protected in the country of origin. India and Pakistan governments still have not registered Basmati rice as GI product though the attemp has been made by NGO, and is still pending. Thailand, on the other hand, already registered GI Thung Kula Ronghai Jasmine rice to specific areas in Northeast Thailand whre the best qualtiy jasmine rice is attributable to the location. Yet, Thung Kula Ronghai Jasmine rice is not protected under GI in other countries. Economic issues realted to GI rice are reviewed and disucssed.

Key words: Aromatic Rice, Innovation, Research and Development, Breeding, Geographical Indication, Trade Related Aspects of Intellectual Property Rights

1 Introduction

Rice is a stable food in Asia. Its production is also concentrated in Asia. The ten largest rice producers, namely China, India, Indonesia, Bangladesh, Viet Nam, Myanmar and Thailand are located in Asia. While China and India alone supply nearly half total world rice production, Thailand and Vietnam are the two largest rice exporters (FAOSTAT 2012). In 2009, Thailand and Vietnam exports accounted for 48% of total world milled rice exports (FAOSTAT 2012). Philippines, Saudi Arabia, Malaysia, Cote d'Ivoire, Iran, Iraq, Cameroon, Brazil, Yemen and China are the ten largest importers of milled rice. Although most of largest importers of milled rice in terms of quantity are located in Asia and South Africa, the import values of milled rice in France and United Kingdom are among the largest (the 7th and 10th) in the world (FAOSTAT 2012).

The productions and exports of rice from major countries are increasing over time, and more prominently in Vietnam. This is due to the success of rice breeding to improve productivity. The developments in rice varieties have been focusing on yield improvement to meet with the demand of the poor, particularly in developing countries. The most prominent technology breakthrough is the green revolution of high yielding semi-dwarf rice varieties developed by International Rice Research Institute (IRRI) that has been rapidly adopted in several Asian countries during the 1960s.

However, recent rice breeding programs also aim at improving traits to cope with both biotic stresses such as pest resistant and abiotic stresses such as drought and heat tolerant that become increasingly prominent due to the global warming problems. Nevertheless, because rice producing and exporting countries continue to face more competition from stringent trade regulations and changes in consumers' preferences towards higher quality rice, new developments in rice breeding increasingly emphasize on improving quality. Grain quality is one of the major objectives of national rice breeding programs in countries that are self-sufficient in rice production (Juliano and Duff, 1990). Quality rice varieties are notable by high market price. These varieties receive more attentions in the niche markets such as aromatic rice, low amylose rice (for diabetes), and nutrient enriched rice (i.e. golden rice for vitamin A deficiency). Though market for quality rice might be smaller than regular rice, it could generate high value thus more income for farmers.

Among quality attributes of milled rice such as amylose content (AC), gelatinization temperature, gelatinize consistency, kernel length and breadth, shape, size, endosperm, kernel color and kernel elongation, protein content, vitamins and minerals, aromatic attribute receives much attention in the breeding programs recently. This is due to an increasing demand of importing countries towards aromatic rice. Currently, there is still a lack of information on available innovations, for adopters and imitators, and there is insufficient economic analysis to provide policy recommendations for countries interested in promoting aromatic rice research. The objective of this paper is to review recent innovations in aromatic rice varieties. The surveys economic impact studies of recent aromatic rice innovations are discussed. Special attention is on the protection of aromatic rice varieties in the context of geographical indication under Trade Related Intellectual Property Rights (TRIPS).

2 Aromatic rice demand and markets

Aromatic rice contains several biochemicals, but the most significant one is identified as 2-acetyl-1-pyrroline (2AP). It gives a popcorn-like or pandan (*Pandanus amaryllifolius*)-like odor. In Asia, particularly in Thailand, pandan extract is used in several Thai sweets to add flavor. This pandan-like odor makes aromatic rice highly desirable in particular countries. Aromatic rice is perceived as premium quality in several rice-consuming countries though consumer preferences towards aromatic rice are different in among countries. Aromatic rice fetches high prices in some international markets including South Asia, the Middle East, and particularly India, Pakistan, and Thailand (Kaosa-ard and Juliano, 1992). The Middle Eastern consumers highly prefer long grain, well-milled rice with strong aroma while European consumers prefer long grain rice with no scent. To them, scent indicates spoilage and contamination (Efferson, 1985). However, recent studies show that European consumers demand for aromatic rice varieties, particularly Basmati, significantly increases since the early 1990s, primarily in the U.K., and expect a further increase in aromatic rice consumption throughout Europe due to increasing number of immigrants from far-east countries and the growing interest in ethnic cuisine (Ferrero and Nguyen, 2004).

In Asia, Chinese consumers prefer semi-aromatic rice to pure aromatic rice (Singh *et al.*, 2000); however, Chinese Hong Kong consumers prefer Thai rice for its fragrance with intermediate AC. Thai rice supplied to Hong Kong also is superior (i.e. more carefully selected and milled) than what supplied elsewhere (Kaosa-ard and Juliano, 1992). Damardjati and Oka (1992) found that large proportion of urban Indonesian consumers, particularly in Medan and Ujung Pandang, preferred aromatic local variety but not necessarily purchased as they had to trade off between quality and price. On the contrary, Philippines consumers do not give preferences to aroma, particularly among medium income group, and only less than one third in the low and high income groups give preferences towards aromatic characteristics (Abansi *et al.* 1992). For Indians, aroma is rated the highest desired trait followed by taste and elongation after cooking.

The study by Suwannaporn and Linnemann (2008) found that consumers from rice-eating countries have higher preferences for Jasmine rice than non-rice-eating countries, and it is most preferred by Thais. The unique texture and aroma gives Jasmine rice from Thailand a perception of expensive quality rice among most Chinese and Taiwanese. Furthermore, the U.S. and Canadian consumers have high preferences for long grain rice, and Jasmine rice is well preferred. Suwansri *et al.* (2002) also found that Asian American consumers prefer imported Jasmine rice to American gorwn aromatic rice.

Two prominent aromatic rices in the world market include Basmati grown in India and Pakistan, and Khao Dawk Mali or Jasmine rice grown in Thailand. Among rice traded in the world market, aromatic rice (Pakistan Basmati and Jasmine rice--Thai fragrant) has been given the highest value. Table 1 shows that the price of Thai Jasmine rice is nearly double the price of regular Thai white rice while the price of Basmati rice is almost the same and frequently valued higher than Jasmine rice. Jasmine rice is continuously being an important export commodity of Thailand; it generates highest value of exports among all rice export commodities from Thailand. Since 2002 Jasmine rice has accounted for more than 20% in quantity and more than 30% in value of total rice exports from Thailand (Table 2).

The U.S., Hong Kong, China, Singapore and Côte d'Ivoire are major export markets of Thai Jasmine rice during the past five years. These five export destinations alone hold more than 50% of total Jasmine rice exports from Thailand (Table 3).

Table 1. Export price of rice. USD/□one, F.O.B.

Year	Thai White 100% Second Grade	U.S. Long Grain 2.4%	Viet 5%	Thai 5%*	Pak Basmati Ordinary	Thai Fragrant 100%
2011	565	577	505	549	1008	1054
2010	518	510	416	492	881	1045
2009	587	545	432	555	937	954
2008	695	782	614	682	1077	914
2007	335	436	313	325	677	550
2006	311	394	266	307	516	470
2005	291	319	255	289	473	404
2004	244	372	224	238	468	443
2003	201	284	183	198	357	449
2002	197	207	187	193	366	306

Source: FAO Rice Market Monitor, June 2007 & Jan 2012
*Data from 2002-2006 are collected from Thai Rice Exporters Association (USD/MT, F.O.B.)

Table2. Export quantity and value of Thai rice

Year	Quantity ('000 tons)		% of Jasmine	Value (million Bahts)		% of Jasmine
	Jasmine	Total		Jasmine	Total	
2011	2,358.96	10,706.23	22.03	63,584.10	196,117.05	32.42
2010	2,358.23	8,939.63	26.38	63,520.76	168,193.06	37.77
2009	2,631.13	8,619.87	30.52	68,577.67	172,207.65	39.82
2008	2,515.93	10,216.13	24.63	60,281.85	203,219.08	29.66
2007	3,067.57	9,192.52	33.37	47,921.45	119,215.43	40.20
2006	2,599.29	7,494.14	34.68	40,341.86	98,179.00	41.09
2005	2,311.07	7,495.90	30.83	34,904.35	92,993.72	37.53
2004	2,259.83	9,976.59	22.65	35,555.04	108,328.33	32.82
2003	2,202.80	7,346.27	29.99	31,304.75	76,700.72	40.81
2002	1,493.00	7,334.45	20.36	19,038.62	70,064.61	27.17

Source: Office of Agricultural Economics of Thailand, 2012.

Basmati rice is the major rice exports of India. The export values and quantities of Basmati rice are accounted for almost all rice exports from India (Table 4). The major export markets of Indian Basmati rice are Saudi Arabia, United Arab Emirates (UAE) and Iran. The exports of Basmati rice to these three countries accounted for more than 70% of total Basmati exports from India (Table 5). Though exports of Basmati rice from India to Saudi Arabia, UAE, the U.K. and the U.S. have decreased during the past few years, exports to Iran, Kuwait, Yemen Republic, Iraq, Jordan, and Netherland increased dramatically. This implies that not only the Middle Eastern countries have preferences towards Basmati rice, but the preferences seem to increase in the recent years.

Table 3. Value and growth rate of Jasmine rice exports from Thailand by destination, 2007-2011

Country	Value (million USD)						Export Share (%)	Growth Rate 07-11 (%)
	2007	2008	2009	2010	2011	Average		
The U.S.	200.27	301.38	340.77	406.48	451.73	340.12	22.70	125.56
Hong Kong	125.31	149.31	166.32	166.02	165.01	154.39	10.30	31.68
China	132.80	119.50	108.58	126.47	110.13	119.50	7.98	-17.07
Singapore	70.97	91.95	100.86	103.41	106.87	94.81	6.33	50.58
Côte d'Ivoire	64.54	57.61	141.70	116.25	84.83	92.99	6.21	31.43
Gana	46.43	79.63	67.42	83.01	124.52	80.20	5.35	168.19
Canada	40.11	66.21	70.46	83.59	82.36	68.55	4.58	105.34
Malaysia	58.13	80.12	88.86	53.99	36.34	63.49	4.24	-37.48
Australia	31.29	58.23	65.33	69.72	66.92	58.30	3.89	113.87
France	24.53	37.65	42.17	43.43	41.11	37.78	2.52	67.59
Others	290.93	375.94	418.44	434.20	421.15	388.13	25.91	44.76
Total	1,085	1,417	1,610	1,686	1,690	1,498	100	55.80

Source: ESAAN Center for Business and Economics Research, 2012

Table 4. Quantity and value of rice exports from India, 2008/09-2010/11

Year	Quantity ('000 tons)		% Basmati	Value (million USD)		% Basmati
	Basmati	Total		Basmati	Total	
2008/09	1,556.41	2,488.29	62.55	2,060.68	2,427.57	84.89
2009/10	2,016.77	2,156.32	93.53	2,297.30	2,374.38	96.75
2010/11	2,183.50	2,282.79	95.65	2,320.86	2,369.60	97.94

Source: APEDA, 2012

Table 5. Value of Basmati rice exports from India by destination, 2008/09-2010/11

Country	Value (million USD)				Share of Exports (%)	Growth Rate 08-11 (%)
	2008/09	2009/10	2010/11	Average		
Saudi Arabia	674.67	695.25	636.50	668.81	30.04	-5.66
United Arab Emirates	605.83	652.88	597.99	618.90	27.80	-1.29
Iran	213.26	433.14	416.63	354.34	15.92	95.36
Kuwait	159.59	217.33	223.18	200.03	8.99	39.85
The U.K.	93.72	41.33	70.95	68.67	3.08	-24.30
Yemen Republic	38.09	62.34	57.77	52.73	2.37	51.67
The U.S.	59.27	32.38	48.74	46.80	2.10	-17.77
Iraq	7.50	7.57	30.73	15.27	0.69	309.73
Jordan	5.32	10.53	22.50	12.78	0.57	322.93
Netherland	14.20	4.99	21.92	13.70	0.62	54.37
Others	189.23	139.56	193.95	174.25	7.83	2.49
Total	2060.68	2297.30	2320.86	2226.28	100.00	12.63

Source: APEDA, 2012

Table 6. Quantity and value of Basmati rice exports from Pakistan by country, 2009/10-2011/12

Country	July 2009/June 2010		July 2011/May 2012	
	Quantity ('000 MT)	Value (million USD)	Quantity ('000 MT)	Value (million USD)
United Arab Emirates	233.45	206.83	209.99	194.07
Iran	171.38	105.34	127.21	73.56
Oman	58.51	56.68	73.81	77.63
Yemen	70.42	58.41	57.40	53.31
Saudi Arabia	91.78	77.06	56.59	49.37
Qatar	52.97	45.32	48.45	47.51
United Kingdom	59.00	48.44	39.55	34.66
Turkey	4.62	4.08	31.19	15.97
Bahrain	31.19	30.01	17.90	18.02
Australia	20.84	18.94	17.10	17.27
Others	255.88	215.56	199.75	199.75
Total Basmati	1,050.05	866.66	878.94	761.64
Total Non-Basmati	3,557.50	1,399.15	2,608.31	1,169.89
% Basmati	22.79	38.25	25.20	39.43

Source: prepared from REAP, 2012

In 2009/10 crop year, Basmati rice represents about 1,050 thousand tons (22.8%) in quantity and about 867 million USD (38.2%) in value of all rice export from Pakistan. The main markets of Basmati rice from Pakistan are United Arab Emirates, Iran, Oman, Yemen, Saudi Arabia, Qatar and the United Kingdom in recent years (Table 6). Overall, aromatic rice is traded at about 10% in the world market.

3 Distribution of aromatic rice

Rice maybe classified into six groups based on allelic combinations at 14 isozyme loci (Glaszmann, 1987). A few cultivars belonging to group I (indica) and group VI (japonica) are aromatic while most of cultivars in group V are aromatic. Table 7 summarizes the distribution of aromatic cultivars of different taxonomy by country of origin. Most of aromatic rice cultivars are in group I, V, and VI. Jasmine rice belongs to group I whereas Basmati rice belongs to group V. Most of landraces aromatic rice is native to Asia. Only a few of them are found in the Middle Eastern countries, and the U.S.

Though there are several aromatic cultivars, only a few of them have made it to the world market. One of the reasons is because traditional aromatic rice has low yield and susceptible to diseases and insects. Basmati rice, for example, is susceptible to blast, bacterial leaf blight, stem borer and white backed plant hopper. Jasmine rice is also susceptible to brown plant hopper, blast, and bacterial leaf blight. Both traditional Basmati rice and Jasmine rice are photosensitive. They require short day length during flowering; thus, the harvest season is limited to only one crop per annum. Another important reason is because the market of aromatic rice is highly competitive; import regulations and technical trade barriers have made it difficult for newly developed aromatic rice.

4 Aromatic rice standards

Since Jasmine rice and Basmati rice are two most important aromatic rice cultivars in the world. This section will emphasize their standards and regulations in international market.

Table 7. Distribution of aromatic rice belonging to different taxonomy groups, by country

Country	I	II	V	VI	*	Total
India	11	7	62	21	32	133
Pakistan	–	1	60	–	4	65
Indonesia	19	–	1	24	4	48
Thailand	29	–	–	4	1	34
Bangladesh	3	3	17	7	3	33
Malaysia	9	–	1	9	2	21
Iran	–	–	17	–	1	18
Nepal	1	2	6	1	6	16
Vietnam	6	–	–	2	7	15
Philippines	1	–	–	11	–	12
China	3	–	–	8	–	11
Myanmar	4	–	4	–	–	8
Laos	–	–	1	2	–	3
Sri Lanka	–	2	1	–	–	3
Korea	–	–	–	2	–	2
The U.S.	–	–	–	1	–	1
Japan	–	–	–	1	–	1
Afghanistan	–	–	1	–	–	1
Total	86	15	171	93	60	425

Source: Singh, 2000 p. 143
* does not belong to any groups

4.1 Jasmine rice standard of Thailand

The National Bureau of Agricultural Commodity and Food Standards of Thailand have set separate standards for Thai aromatic rice for general aromatic cultivars, and Thai Hom Mali (Jasmine) rice. *Thai aromatic rice standard*, TAS 4001-2008, is declared as the Notification of the National Committee on Agricultural Commodity and Food Standards, Thai Aromatic Rice B.E. 2551 (2008). It covers both non-glutinous aromatic rice and glutinous aromatic rice from *Oryza sativa L.,* of the genus *Gramineae* or *Poaceae* which contain a natural fragrance. The standard is voluntary. Several varieties are classified into groups as in Table 8 (National Bureau of Agricultural Commodity and Food Standards, 2008). The use of certification mark for Thai aromatic rice shall be in compliance with the provisions and conditions established by the Committee on Agricultural Standards. In case the varietal name is intended to be specified on the package, at least 90% by weight has to be the specified variety. The procedure to test for aroma is simply, boiling in 10% salt solution for three minutes, cooling down, and smelling.

Thai Hom Mali Rice (or Jasmine) rice standard, TAS 4000-2003, was announced in November 2003. It applies to Jasmine rice produced from *Oryza sativa L.* which including paddy, brown rice and white rice derived from the paddy of the fragrant non-glutinous rice varieties which are photoperiod sensitive and cultivated as a main crop in Thailand. The Department of Agriculture, Ministry of Agriculture and Cooperatives, has certified only two Jasmine rice varieties: Khao Dawk Mali 105 (KDML105) and RD15 (National Bureau of Agricultural Commodity and Food Standards, 2003). The standard is also voluntary. KDML105 was locally screened and registered in 1959. Its grains contain a natural fragrance depending on its age, and when cooked retains a soft texture.

The paddy of qualified Thai Jasmine rice shall be in compliance with several requirements. Among them, it has to contain no less than 95% of Thai Jasmine rice. The official certification mark shall be in compliance with the provisions and conditions of inspection or certification agencies recognized by the Ministry of Agriculture and Cooperatives or other regulatory. The alkaline spreading is used as a method for analysis contaminant of rice varieties other than Thai Jasmine rice. The alkaline spreading value between one and five is considered not Thai Jasmine rice.

Since 2005 the Department of Foreign Trade of Thailand certifies "Thai Hom Mali Rice" for exports by using a certification mark (Figure 1). It says "Thai Hom Mali Rice•Originated in Thailand•Department of Foreign Trade" around a picture of rice plant with a word in Thai stating "ข้าวหอมมะลิไทย". The qualified products have to meet the Jasmine rice standard and contain at least 92% of Jasmine rice (Office of Commodity Standard, 2012). As of September 2011, there were 178 exporters who received the license to use the "Thai Hom Mali Rice" certification mark.

The Ministry of Commerce of Thailand defines the criteria for Thai Hom Mali Rice commodity standards in 2002, but not until 2006 that the DNA-based test is mentioned for alternative test for adulterant level of Jasmine rice. In 2007, the Office of Commodity Standard of Thailand is made responsible for the test of authentication of Jasmine rice. The cost of DNA inspection at the Biotechnology Research and Development Office (Department of Agriculture) is 1,500 THB (about 48 USD) while at the DNA Technology Laboratory (Kasetsart University at Kampangsaen) is 2,500-3,500 THB (about 80-112 USD) depending on the coverage of the analysis (UNESCAP, 2010).

Table 8. Authorized Thailand's Aromatic Rice Varieties

Category	Variety	Year of Registration	Photoperiod Sensitivity
Covered in Thai Hom Mali (Jasmine) Rice Standards[2]			
Soft Non-Glutinous Aromatic Rice	KDML 105	1959	yes
	RD 15	1978	yes
Covered in Thai Aromatic Rice Standards[1]			
Soft Non-Glutinous Aromatic Rice	Khao Jow Hom Khlong Luang 1	1997	no
	Khao Jow Hom Suphan Buri	1997	no
	Khao Jow Hom Pitsanuloke1	1998	yes
	Pathum Thani 1	2000	no
	RD33 (Hom Ubon80)	2007	no
Loose Non-glutinous Aromatic Rice	Nhang Mon S-4	1965	yes
	Dok Pa-yom	1979	yes
Hard Non-glutinous Aromatic Rice	Pathum Thani 60	1987	yes
	Chai Nat 2	2004	no
White Glutinous Aromatic Rice	RD 6	1977	yes
	Khao Pong Krai	1987	yes
	R 258	1987	no
	Sakon Nakorn	2000	no

Source: [1]National Bureau of Agricultural Commodity and Food Standards, 2008
[2]National Bureau of Agricultural Commodity and Food Standards, 2003

Figure 1. Jasmine rice (Thai Hom Mali Rice) certification mark

Source: Office of Commodity Standard, Department of Foreign Trade, Thailand.

4.2 Basmati rice standards

Basmati rice has special characteristics. Though specific to India and Pakistan location, there are several new bred varieties derived from historic land race varieties. European countries are major export destinations of Basmati rice following the Middle Eastern countries. The import regulations of Basmati rice in the U.K. and in the European Union are considered important for Basmati rice exports due to expanding market demand.

The imports of Basmati rice varieties from India and Pakistan into the European Community is eligible for zero duty. The eligible Basmati varieties are listed in Table 10. The regulation is applied to husked Basmati rice. The authentic certificate of these varieties must be verified by authorized body of each country via DNA-base variety test. In the context of random checks or checks targeted at operations entailing a risk of fraud, EC member states shall take representative samples to be sent to the competent body in the country of origin, as listed in Table 10, for a DNA-based variety test, and the member states may also carry out variety tests on the same sample in a Community laboratory (EUROPA, 2006).

The British Retail Consortium, the Rice Association, and British Rice Millers Association in consultation with Local Authorities Coordinators of Regulatory Services (LACORS) and Association of public Analysts (APA) has made the *Code of Practice on Basmati rice*. The Code of Practice is restricted to the labelling of Basmati rice, and is voluntary. The minimum specifications for Basmati rice (Oryza sativa L.) sold in the U.K. are certain varieties of rice that are grown exclusively in specific areas of Indo Gangeric Plains, which currently includes the Punjab (on both sides of the Indian and Pakistani border), Jammu, Haryana, Uttaranchal, and Western Uttar Pradesh in India (British Retail Consortium, 2005). Varieties listed in Table 11 are certified varieties of Basmati rice, that at least one parent is Historic Land Race variety, and having unique properties specified in Table 12.

The labelling of "Basmati rice" requires that the adulterant level must not exceed 7% of Basmati varieties. If the variety is labelled with a variety name, at least 97% of that variety is constituted. Furthermore, if the country of origin is marked, at least 97% of grains must originate from the referred country. The certified Basmati rice varieties are the same as ones eligible for zero import duty under European Commission regulation, and include other varieties originally approved by India and Pakistan. It is mandatory that all imported Basmati consignments must have the authentication certificate based on DNA test. In India, a joint Agricultural Processed Food Products Export Developmental Authority (APEDA)-Center for DNA Fingerprinting and Diagnostics (CDFD) performs DNA testing and certification of Basmati exports. The protocol tests are capillary electrophoresis based microsatellite DNA profiling protocol which can rapidly detect adulteration from 1% upward with an accuracy of ±1.5%, and currently are pending for US patents (Siddiq *et al.*, 2012).

Evidently leading exporters of aromatic rice attempt to make the varieties a trademark in the world market so that they have less competition from other new aromatic rice producers. At the same time, the imports of aromatic rice into major large countries such as the EU, and the U.S. are not without restriction. Basmati rice exported to the EU and the U.K. and Jasmine rice exported to the U.S., for examples, need to authenticate the varieties, and as a result incur high cost of testing, particularly when genetic-base test is used.

Though India, Pakistan, and Thailand continue to be leading producers and exporters of aromatic rice, recent developments of aromatic rice varieties are starting to come from emerging countries like the U.S., Myanmar, and Cambodia.

Table 10. Certified Basmati Rice Varieties and Authorized Body under European Commission Regulation*

Exporting country	Certified variety	Authorized body to issue authenticy certificates
India	Basmati 370 Basmati 386 Type-3 (Dhradun) Taraori Basmati (HBC-19) Basmati 217 Ranbir Basmati Pusa Basmati Super Basmati	Export Inspection Council (Ministry of Commerce, Government of India)
Pakistan	Kernel (Basmati) Basmati 370 Pusa Basmati Super Basmati	Trading Corporation of Pakistan (Pvt) Ltd

Source: EUROPA, 2006
* Commission Regulation (EC) No 972/2006 of 29 June 2006

Table 11. Certified Basmati Rice Varieties under the U.K. Labeling Regulation

Country of Origin	Basmati rice varieties eligible for a zero import duty under Regulation (EC) 1549/2004	Other Basmati rice varieties approved by India and Pakistan
India	Basmati 217 Basmati 370 Basmati 386 Type-3 (Dhradun) Taraori Basmati (HBC-19 Karnal Local) Ranbir Basmati (IET 11348) Pusa Basmati Super Basmati	Kasturi (IET 8580) Mahi Suganda Haryana Basmati (HKR 228/IET 10367) Punjab Basmati (Bauni Basmati)
Pakistan	Kernel Basmati (Basmati Pakistan) Basmati 370 Pusa Basmati Super Basmati	Basmati 198 Basmati 385

Source: British Retail Consortium, 2005

Table 12. Minimum Characteristics for Basmati Rice Varieties (milled raw) under the U.K. Regulation

Minimum elongation ratio on cooking	1.7
Minimum average pre-cooked length	6.5 mm
Amylose content	Intermediate 19-26%
Length/breadth ratio	greater than 3.5
Gel Length	60-100 mm
Alkali spreading value	4-5
Typical Basmati Aroma	Present

5 Recent innovations in aromatic rice

Thailand, India, and Pakistan are competitive producers and developers of aromatic rice in the world. However, many of farmers in these countries grow specific varieties mainly for export markets. One of the reasons is the limitation in aromatic rice production is yield improvement. The first high-yielding Basmati rice cultivars are Pusa Basmati1 and Kasturi; they yield 4.5 and 4.0 ton/ha (about 1.5 and 1.0 tons/ha) higher than traditional Basmati varieties (Bhattacharjee *et al.*, 2002). Pusa Basmati 1, the world's first high yielding semi-dwarf Basmati and being good quality, was released in 1989. Until 2007, it was accounted for 40-60% of Basmati rice exports from India (Siddiq *et al.*, 2012). Hybridization technology has been used in several high-yielding grains breeding including rice. It could provide a much higher yield than conventional inbred breeding yet challenging because Basmati quality shall not be much compromised. The first hybrid Basmati rice was developed by Indian Agricultural Research Institute. It gave 20-25% higher yield than the best yielding Basmati rice ((Bhattacharjee *et al.*, 2002). Pusa RH10 was the world's first superfine grain aromatic rice hybrid was released in 2001. Though high-yielding Basmati rice exists, none of them could match popular Basmati varieties in cooking and eating quality. Thus, the Union Government of India distinguish the different between traditional and hybrid Basmati varieties under the Seed Act. This resulted in a significant price differential between two categories. Indian and Pakistan approved Basmati varieties that did not meet E.C. zero duty (Table 11) are evolved Basmati, and several of them are high-yielding varieties i.e. Kasturi, Haryana Basmati, and Punjab Basmati. Details of Basmati quality rice varieties released in India until 2008 could be found in Siddiq *et al.* (2012).

As of Jasmine rice, Table 8 above shows registered aromatic and Jasmine rice by the Rice Department. Although recent aromatic rice developments aim to improve the resistance to biotic and abiotic stresses as well as quality and photoperiod sensitivity, success cultivars are not registered as Jasmine, but aromatic rice instead. A good example of success non-photoperiod sensitive breeding of aromatic rice in Thailand is Pathum Thani 1 in 2000; however, due to its inferior quality, it is not considered as Jasmine rice. Pathum Thani production is concentrated in irrigated Central areas of Thailand, and because it is non-photoperiod sensitive, it became popular among farmers. This somewhat created problems in the export markets as it got mixed with Jasmine rice. Other registered aromatic rice, particularly non-glutinous varieties are genetically close to Jasmine rice. RD33, for example, was released in 2007. It has good cooking quality close to KDML105, non-photoperiod sensitive, early maturity, and resistant to blast, but does not covered by Jasmine rice standard. This somewhat limit the potentials of Jasmine rice production.

Conventional breeding has been important tool in aromatic rice breeding, but new breeding programs are engaging in molecular breeding such as marker-aided selection (MAS) and genetic engineering. *Indica* rice genome sequencing was completed in 2002 by China though the genome sequencing of *Japonica* rice was completed in 2004 by International Rice

Genome Sequencing Project (IRGSP). The members of the IRGSP include Japan, China, Taiwan, Korea, India, Thailand, France, Brazil, the U.S. and the U.K. Understanding the pathway of the biosynthesis of 2AP is the key information in aromatic rice breeding. As genome sequencing became available to IRGSP countries, this makes molecular breeding more competitive.

MAS has been increasingly used in rice breeding; it fastens the process of screening for desired traits. *Betain aldehyde dehydrogenase (BADH2)* or *fgr* locus was found to be the fragrance causing gene in aromatic rice (Shi *et al.*, 2008). In June 2008, the National Science and Technology Development Agency of Thailand received the U.S. patent for "*transgenic rice plants with reduced expression of Os2AP and elevated levels of 2-acetyl-1-pyroline*". This is patent is claimed to be the discovery of genes controlling the 2AP of Jasmine rice using genetic engineering technology (US Patent and Trademark Office, 2008). However, the first commercial transgenic aromatic rice was *Tarom molaii+cry1 ab*. This improved aromatic rice variety was developed by Agricultural Biotech Research Institute of Iran to integrate insect resistant gene using genetic engineering technology, and was commercially released in 2005 (ISAAA, 2011).

Aside from traditional aromatic rice producing countries, the U.S. is among the emerging aromatic rice breeding countries. This is mainly because over 10% of rice consumption in the U.S. is imported, and the majority of them is Jasmine rice from Thailand. Because aromatic rice, particularly Jasmine rice, takes a large share in rice imports, and because Asian American consumers prefer it more than domestic produce, the U.S. is becoming more interested in aromatic rice breeding to compete with imports from Asia. The standard of aromatic rice defined by the U.S. Department of Agriculture (USDA) is given as "special varieties of rice (*Oryza sativa L.* scented) that have a distinctive and characteristic aroma; e.g., Basmati and Jasmine rice" (USDA, 2009).

The first adapted aromatic rice release in the U.S. was *Jasmine 85*, the cultivar derived from International Rice Research Institute (IRRI), in 1989. Due to its off-white grain color, creamy grain appearance, weak aroma and flavor, it was not popular among U.S. consumers. The breeding of aromatic rice suitable for U.S. temperate climatic conditions continue, mostly done by the public university research centers in Southern states such as Arkansas, Louisiana, and Florida, and California. Early successful public developments of aromatic rice in the U.S. were contributed to American long grains (Table 13). The U.S. Department of Agriculture (USDA) also makes a large contribution in terms of joint collaborator and funder. USDA's "Stepwise Program for Improvement of Jasmine Rice" was initiated to breed Jasmine-type rice for U.S. in 1999. The collaboration between Everglades Research and Education Center of University of Florida and Research and Extension Center of University of Arkansas obtained Jasmine rice germplasm from IRRI, and successfully introduced two important Jasmine-type characteristics via gamma radiation. Semi-dwarf which is preferred for combine harvesting and non-photoperiod sensitive which expand the cropping period are prominent traits. The program released Jasmine-type rice, *JES*, which became available to farmers in 2010 (University of Arkansas, 2009).

Table 13. US Long grain aromatic rice varieties and developers

Developer		US Basmati	US Jasmine	American long grain
Public	USDA, Agricultural Research Service	Sierra (2002)	Jasmine85 (1989)	Lotus (2002)
	LSU Agricultural Center		Jazzman (2009) Jazzman-2 (2011)	Della (1973) Dellmont (1992) Dellrose (1995) Dellmati (1999) Della-2 (2012)
	California Cooperative Rice Research Foundation, Inc.	Calmati201 (1999) Calmati202 (2009)		A201 (1997)
	University of Arkansas, University of Florida, USDA		JES (2010)	
Private	Rice Tec, Inc.	Texmati (1977) Kasmati (1994)	Jasmati (1993)	

Source: USA Rice Federation, 2010 and USDA 2005, and others.
numbers in parentheses are years of release

Though successfully bred, American long grain aromatic rice was not popular among U.S. consumers. Until recently *Jazzman* is released by LSU AgCenter. It is believed to be close to Jasmine rice of Thailand. The marketing of *Jazzman* by Jazzmen Rice, LLC in 2010 makes it becomes more recognized by using Louis Armstrong logo. LSU AgCenter continues to release *Jazzman-2* in 2011. It has higher aromatic fragrant than Thai Jasmine rice, and also has other characteristics such as color and softness as close as Thai Jasmine rice, and is expected not only to substitute imported Jasmine rice, but also to reach the export markets.

The private company, Rice Tec, Inc., was previously more active in aromatic rice breeding. However, it has been targeted in several biopiracy cases by the Indian government. Rice Tec Inc. was granted varietal patent for aromatic rices grown outside India and Pakistan as Basmati by U.S Patent and Trademarks Office (USPTO) in September 1997. Twenty claims of novel and superior varieties of *Texamati, Kasmati,* and *Jasmati* than traditional Basmati rices of India and Pakistan in quality and that they can be grown outside sub Himalayas region were included in the patent (Siddiq *et al.,* 2012). Later, USPTO disallowed 15 out of 20 claims, and amended the title from *'Basmati Lines and Grains*' to *Rice Lines Bas 267, RT 1117,* and *RT 1121.*

6 Geographical indication of aromatic rice

Goodwin *et al.* (1996a) found that Asian American, particularly Southeast Asian consumers in Texas prefer Jasmine-type rice that demand higher price than typical American long grain varieties. Similarly, Goodwin *et al*. (1996b) found that Filipino and Southeast Asian consumers in the U.S. are strongly willing to pay more for Thai aromatic rice while Taiwanese consumers are willing to pay less. The surveyed and estimated prices of rice imported from Thailand are higher than American varieties, including Jasmine 85. The inverted U-shaped curves of Jasmine 85 and Thai Jasmine rice in terms of aroma attribute imply that both varieties were beyond maximum desire—wrong aroma or too much of the right one, but the combination of traits such as flavor and texture or color and texture are desire traits in Thai imported rice. In the study by Suwannaporn and Linnemann (2008a) of Jasmine rice preferences, they found that consumers in non-rice eating countries are not concerned about the country of origin. However, it is shown that consumers of not the same country of origin prefer rice from Thailand the most (31% of respondents), followed by India (11%). Other major exporters such as U.S., Vietnam, China and Pakistan are not highly recognized. Suwannaporn and Linnemann (2008b) show that Jasmine rice is highly differentiated between consumers who prefer and do not prefer it. Aroma is also a desirable attribute for those who specifically prefer Jasmine rice. These studies reveal that consumers do have specific preferences towards specific aromatic rice varieties.

It is known that the best quality of aromatic rice is location specific. Jasmine rice is grown solely in Thailand, and the highest quality Jasmine rice is produced in Thung Kula Ronghai Plain--literally translated to "rice from plateau of crying Kulas – ancient minority tribe-- in Northeast Thailand. The plain includes Roi Et, Maha Sarakham, Sisa Ket, Yasothon and Surin provinces. Its arid and salinity and climatic condition makes aromatic and other good traits of Jasmine rice more prominent. Basmati rice is grown in West Punjab and Baluchistan of Pakistan, East Punjab, Uttar Pradesh, Haryana, and Bihar state in India. Among these areas, Haryana is known to produce supreme quality of Basmati (Bhattacharjee et al., 2002). Aroma in Basmati rice is vastly developed when grown in cooler temperature at maturity. Increasing in climatic temperature also decreases AC which in turn decrease translucency of the grains. Furthermore, temperature at the time of ripening affects grain elongation during cooking, which is a distinct characteristic of Basmati rice. The temperature of 25/21 Celsius (day/night) at ripening has a positive effect on grain elongation of Basmati rice. Therefore, Basmati rice is grown at about the same latitude in India, Pakistan, and the U.S. Thus climatic and soil conditions of the Punjab of Pakistan, Haryana, Punjab and western Uttar Pradesh of India are most suitable for expression of aroma and other quality traits of Basmati rice (Bhattacharjee et al., 2002). This is important because Basmati rice grown outside Punjab region in Pakistan may not be aromatic.

At present, aromatic rice is recognized as high valued than normal rice in the world market. While the supply of aromatic rice does not meet its demand, consumers cherish it from paying the premium. Traditional aromatic rice producers, namely India, Pakistan, and India, continue to be leading developers of new evolved aromatic rice, and the best quality of traditional Basmati and Jasmine rice cultivars are attributed by their geographical origins. There are several new evolved aromatic rice varieties as discussed above. Several of these new aromatic rice varieties possess traits to cope with production stress and to increase yield while maintaining aromatic and other cooking characteristics. Though Basmati and Jasmine rice are preferred among consumers that have specific taste form them, recent innovations of aromatic rice varieties, particularly in the U.S., are getting closer to match with the cooking quality of traditional cultivars. Furthermore, recently developed aromatic rice varieties have diminished production limitations in non-traditional climatic and environmental conditions. Currently organic Basmati rice from Italy is already sold in the European market (Giraud, 2008). This creates threats to traditional aromatic rice producing countries.

Evidently, in order to protect aromatic rice varieties produced from developing countries such as Jasmine rice from Thailand and Basmati rice from India and, it is important that the country of origin must be recognized as a quality trademark. Under WTO Trade-Related Aspects of Intellectual Property Rights (TRIPS), Geographical Indication (GI) is defined as '*indications which identify a good as originating in the territory of a member, or a region or locality in that territory, where a given quality, reputation or other characteristics of the good is essentially attributable to its geographical origin*' (Article 22(1)) (WTO, 1994). GI does not protect a product like plant variety rights or other intellectual property rights, but identifies special characteristics, most frequently quality, of products associated with its origin. TRIPS agreement set aside that all parties must provide means to prevent the use of any indication which misleads the consumer as to the origin of goods, and any use which would constitute an act of unfair competition. However, names that have already become generic are exempted. Furthermore, *'there will be no obligation under this agreement to protect geographical indications which are not or cease to be protected in their country of origin'* (Article 24) (WTO, 1994). GI would make it possible for traditional aromatic rice varieties for not being mistaken as generic products from competing countries, but only if the country of original embraces GI registration domestically.

Though GI became into effected in 1995, Rice Tec did receive a patent titled '*Basmati rice lines and grains*' on September 2, 1997 from the United States Patent and Trademark Office (USPTO). Claims 15-17 out of 20 were for rice grains without any limit to GI of Basmati (Mulik and Crespi, 2011). Furthermore, Rice Tec applied a trademark registration for *'Texmati'* and marketed as *'American Basmati*' with the U.K. Trademark Registry in 1997. The opposition by Indian government resulted in a withdraw of trademark application though the company tried to convinced that Basmati did not imply any GI for rice grown in the Indian sub-continent. It appeared that Rice Tec patent and trademark of *'Texmati'* were threatening Indian and Pakistan Basmati rice exports. This is contributed mainly by the fact that India and Pakistan did not register GI for Basmati in their countries at the time. In response to Rice Tec Basmati rice patent, Indian government through Indian Agricultural and Processed Food Products Export Development Authority (APEDA) filed a petition to with the USPTO in 2000. The Indian government eventually won the case against Rice Tec; no patent on Basmati rice is granted, and the term 'Basmati' is prohibited.

In India, the Geographical Indications of Goods Act was passed in 1999. GI is defined as *'an indication which identifies such goods as agricultural goods, natural goods or manufactured goods as originating, or manufactured in the territory of a country, where a given quality, reputation or other characteristic of such goods is essentially attributable to its geographical origin'*, and is precisely of TRIPS GI definition (Marie-Vivien, 2008). The GI Act of India emphasizes the objective of protecting traditional knowledge which essentially what has been used against Rice Tec's Basmati patent along with protecting genetic resources. APEDA was designated by Indian government to be the legitimate applicant for Basmati GI in January 2003. However, as of now APEDA has not applied for GI registration. However, the attempt to register GI Basmati rice was initiated by NGO 'The Heritage' in August 2004. The application is still pending.

In Pakistan, the GI is protected under the Trade Mark Law as of April 2005. GI is defined as '*Geographical indication is in relation of goods originating in a particular country or in a region or locality of that country means a mark recognized in that country as a mark indicating that the goods- (a) originated in that country, region or locality; and (b) have a quality, reputation or other characteristic attributable in the geographical region'* (Marie-Vivien, 2008). Unlike TRIPS or GI Act of India, GI of Pakistan does not emphasize quality attributable to geographical origin. One of the reasons that India and Pakistan are reluctant to register GI Basmati is due to debatable definition of Basmati varieties and the geographical areas to be covered by GI. As traditional Basmati growing area involved both Pakistan and India, the GI registration of Basmati requires that both countries comply on the same protection. The EU granted zero duty exemption to certain traditional varieties of Basmati rice from India and Pakistan to ensure best quality rice imports. However, India and Pakistan negotiated to include two evolved varieties, *Pusa Basmati* and *Super Basmati*, on the list. These varieties, to scientists, are not legitimate landrace or traditional Basmati, whereas the pressure of high export demand put Ministry of Commerce of India to notify *Improved Pusa Basmati-1* under Seed Act 1966, the Act that defines legitimate Basmati rice in India. In December 2007, India defined '*newly evolved Basmati varieties'* as *'through direct parentage or having the characteristics and the genes of the traditional Basmati such as aroma, length* *and elongation in cooking to comply with the expanded definition'*. Eventually for the benefits of farmers, scientists support the expansion of Basmati definition. Furthermore, in May 2006, India notified the approved Super Basmati as evolved variety for export purpose; the variety was in fact developed and was only cultivated in Pakistan. The tension between two countries from this incidence will continue to make GI Basmati difficult.

With current technology, it is possible that to identify geographical location where Basmati rice is produced by employing isotopic and multi-element analyses. The ratio of carbon 13/12 and oxygen 18/6, concentration of certain trace elements and isotopes of samples are compared with those of Basmati rice grown in India and Pakistan, the U.S. and Europe to distinguish the country of origin (Siddiq *et al.,* 2012). It is costly and suspected to be difficult to employ in the importing countries without GI system in exporting countries.

Thailand has passed Act on Geographical Indications Protection in 2003. Under this Act, Thung Kula Ronghai Khao Hom Mali Rice is the first registered GI rice in 2007. As of August, 2012, There are five other rice varieties under Thailand's GI protection; none are aromatic rice varieties. In 2012, Thung Kula Ronghai Khao Hom Mali Rice GI registration changes the specific locations to be only five provinces in the Thung Kula Ronghai (Department of Intellectual Property, 2012). Thailand attempted to register GI Jasmine rice with the EU in 2011. Five countries including the UK, France, Italy, the Netherlands and Belgium cited that Thailand could not use the phrase "Khao Hom Mali", and questioned whether the rice was packed in a specific area. Thus, at the present, Khao Hom Mali Thung Kula Ronghai failed to gain protection and recognition in the EU market.

7 Evidences from economic aspects of GI rice

The study by Mulik and Crespi (2011) used residual inverse demand curve—the same concept of Lerner index--to determine whether price premium of Basmati rice existed in four selected countries, and whether they diminished after Rice Tec's Basmati-type rice are available in the market. Their findings revealed that price premium of Basmati existed in the U.K. and Kuwait, but not in Canada and the U.S. After the introduction of Rice Tec Basmati-type varieties, product differentiation as determined by price premium of Basmati rice dropped. This implies a negative impact of Basmati substitute in major export markets.

GI was hypothesized to protect small farmers in developing countries, particularly to protect traditional knowledge, specific to geographical area from competing nations. Jena and Grote (2012) found that rice farmers in Uttarakhand state of Northern India were got more profits from growing Basmati rice than other rice varieties. Thus, for rice farmers located in traditional aromatic rice growing areas could be better off growing traditional varieties, and even more so if the varieties are protected by GI.

In reality, competing crops and other factors could influence farmers' decision of growing aromatic rice variety in traditional aromatic rice producing area. Jena and Grote (2012) found that important factors contributing to allocating more land to Basmati varieties are off-farm income and attending Basmati production training program from NGO, and because Basmati rice production is labor intensive, large family allocate more land to Basmati varieties than other normal rice. However, since sugarcane is a competing crop for its much higher yield and net income than rice, those who are intensively cultivate sugarcane in this area are less participated in Basmati rice production. Ngokkuen and Grote (2012) also found that rice farmers in Thung Kula Rong Hai who have access to information about the GI certification and are member of famer's cooperative are more probable to cultivate GI Jasmine rice. Their study implies that the GI can be complicated and created more transaction cost i.e. transportation to GI certified buyers so the social activities that promoting GI certification should be embraced for GI system to function. Furthermore, because Jasmine rice receives high price even without GI certification, Jasmine rice farmers may choose alternative buyers who pay high price to avoid the GI burden.

8 Discussion and Conclusion

Though aromatic rice contributes to a small share in the world market, but is valued at the highest price among all types of rice. The demand for aromatic rice is not expected to decrease if not increase by consumers who have specific taste for them. Because traditional aromatic rice varieties are susceptible to diseases and limited to abiotic stresses, they generate relatively low yield compared to other varieties. Though aromatic rice is mostly originated in Asia, Thailand, India, and Pakistan are predominantly leading producers and exporters of high quality aromatic rice. Nevertheless, recent success developments of new aromatic rice emerge from countries outside Asian continent such as the U.S. as well as other Asian countries. For instance, at the 3rd World Rice Conference in 2011, Myanmar aromatic Pearl Paw San rice won the *World's Best Tasting Rice* over Thailand's Jasmine rice, and Hom Mali rice from China came in fourth. It is the first time that Thai Jasmine rice did not win this contest. Myanmar Pearl Paw San rice is photosensitive variety grown in the Ayeyarwaddy region that has fertile soil. This shows that breeding of new aromatic rice will be increasingly more competitive as Myanmar and China are involved in aromatic rice breeding.

While scientists in Thailand, India, and Pakistan continuously research in evolved aromatic varieties that have improved traits, their innovations to increase yield shall not be compromised with quality as a threat from losing their competitive advantage in aromatic rice production will soon to be realized. Unless Thailand's Jasmine rice and Basmati rice of India and Pakistan could maintain their quality and being recognized in the world market, it will be a challenge for them to maintain their reputation without GI. GI is still new in developing countries and the system can be costly and complex, and the benefits of GI protection under TRIPS may be underestimated by these countries. It will be difficult for farmers who have alternatives of cultivating non-GI rice or other more profitable crops when the participation in GM system does not cover their transaction cost. This implies that even if GI may protect developing countries from losing their traditional knowledge and competitiveness of producing aromatic rice, getting certify GI continue to be a challenge. Currently there is no Basmati rice registered as GI, neither in India or Pakistan whilst Jasmine rice is registered as GI Thung Kula Rong Hai Khow Hom Mali in Thailand. These countries should reexamine whether GI certification is worth to protection their farmers, and pursue that their quality aromatic rice is GI protected in major importing countries as well.

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A Stepwise Innovation toward Viable Educational Services in Agriculture: Evidence from Japan

Yasuo Ohe

Annotation: Although the educational function in agriculture is attracting growing attention as a kind of multifunctionality in agriculture, these services are not yet provided as a viable farm product. This paper explores how the educational externality could be internalized to establish a viable market for these services. We focused on educational dairy farms in Japan and used a questionnaire survey to quantitatively evaluate the attitudes of operators toward establishing viable services. First, a conceptual framework was presented to express operators' orientation toward an economically viable service by incorporating a stepwise internalization process of positive externalities with the help of a social learning network. Then, empirically, statistical tests were conducted and factors that determined this orientation, a viable service determinant function, were explored by the ordered logit model. The result showed that, first, the higher the number of visitors to the farm, the more operators were oriented toward a viable service while no connection with ordinary dairy production was shown. Second, social learning was effective for initiating the internalization process. Third, marketing skills became more important for upgrading the internalization level. Consequently, it is important to create opportunities for those farmers who want to provide consumers with educational services to learn a new role for agriculture and to establish a new income source in a stepwise fashion.

Key words: educational tourism; educational function in agriculture; multifunctionality; rural tourism; farm diversification; product innovation; externality

1 Introduction

Conventional innovation in farm management has been mainly focused on the improvement of technical efficiency in the processes of farm production such as mechanization of farm operation, utilization of chemicals, and creation of high-yield or input-saving varieties. In this respect, hardware process innovation in farm production has been a major target in rural areas. Product innovation in the creation of high-yield or high-quality varieties has been generated from agricultural research and exogenously introduced into rural areas. This is to comply with food demand, which is a basic and permanent mission of the agricultural sector.

In contrast, the aim of this paper is to explore how endogenous product innovation in rural areas can be attained and to support measures for that purpose. This type of innovation is different from conventional innovation in agriculture and the differences set up many hurdles to achieving a new rural innovation.

First, this innovation creates a new demand. Many consumers do not know about new products/services so it is often difficult to expect high profitability in the initial stage.

Second, new products are often provided as new services that utilize not only conventional farm inputs, i.e., land, capital, and labour, but also ecosystem services based on the rural resources. In this sense, these new products are soft innovations, which are intangible. Third, externalities that are accompanied by agricultural production such as multifunctionality, play a crucial role in creation of this type of services. Conventional marketing of farm products does not appropriately express the value of these new products and the market failure of farm resource allocation causes them to be in short supply. Thus, it is necessary to internalize these externalities for a new income source through social-optimal resource allocation. Finally, however, it is quite common for ordinary rural areas to face severe shortages of human resources with enough skills to overcome these difficulties. In those cases, in addition to self-sustaining efforts, additional policy support measures should be undertaken in rural areas.

In short, new rural product innovation requires a new perspective that differs from conventional hardware innovation in farm production technology. This requirement poses many challenges for the farming sector.

Thus, it is necessary to explore how to attain endogenous product innovation for the sustainable evolution of rural economies, but there has been no full-fledged study on this point conceptually or empirically. Therefore, this paper focuses on newly emerging educational services provided by dairy farmers in Japan and presents a stepwise internalization hypothesis to explore a desirable way to achieve a new product innovation.

It is now widely recognized that agriculture has multifunctionality (OECD, 2001, 2003, 2005; van Huylenbroeck and Durand, 2003; Japan Science Council, 2001), or positive externalities to society, in addition to food production. One of the sub-functions of the multifunctionality that has been little investigated is the educational function that enables people to learn about farm life and how food production is conducted, which are often forgotten in modern urban life (Ohe, 2011b). In this respect, educational tourism in agriculture has been attracting growing attention as a newly emerging activity along with the bourgeoning demand for experience-oriented tourism. Examples of such activities that have already been implemented are the FACE (farming and countryside education) program in the UK (Graham, 2004; for more recent developments, Gatward, 2007), Ferme Pédagogique in France, Fattorie Didattiche in Emilia-Romagna in Italy (Canavari et al., 2009; children's gardening in the USA (Moore, 1995) and educational dairy farms (hereafter EDFs) in Japan (Ohe, 2007).

One problem with these educational services is that their activities have yet to become economically viable (Ohe, 2011a). For this reason, rural and farm experience services have often been studied together with rural and agritourism (for Japanese, Sato, 2010; Ohe, 2010 and for Italian, Ohe and Ciani, 2011). Nevertheless, with the increasing demand for these educational services and, on the other hand, with the mounting competitive pressure in the market for farm products as well as constant price volatility, it is time to focus on clarifying the conditions under which viable educational services can be established as a new income generating farm activity rather than remaining as a simple generator of externality to society without any compensation. This issue has not been fully addressed through an economic approach, although case studies were sporadically conducted (for instance, Sato, 2008; Yamada, 2008).

In response to this need, this paper approaches this issue with a perspective on farm diversification by internalizing the externality of these educational services. First, I present a conceptual model under the framework that the internalization process of educational externality is attained through stepwise innovation. I consider on-farm and off-farm factors that stipulate that stepwise process, especially looking at the role of social learning network organizations. Second, by an empirical approach, I focus on Educational Dairy Farms in Japan, which is a network organization that provides a pioneering framework for the provision of educational services in agriculture in this country and I quantitatively examine the relationship between the operators' orientation toward viable educational service activity and factors related to farm activity by statistical tests. Subsequently, I estimate an orientation determinant model of viable educational services and explore factors to determine that orientation. Finally, policy recommendations are presented for more effective support measures to attain the viability of educational tourism services.

2 Literature Review

In the arena of agriculture, since the classic work by T. W. Schultz (for instance, Schultz, 1971) on education as an investment in human capital, the education of farmers has been considered as essential for the diffusion and adaptation of new technology in agriculture in developing countries (Foster and Rosenzweig, 1995). This is basically the same in the tourism industry except for one thing, that is, the addition of the importance of service management due to the characteristic of service goods that tourism has. The importance of raising human capital that serves its own industry has not changed in any industry, as producer education that aims at those who serve the industry (Airey and Tribe, 2005; Fidgeon, 2010). Nevertheless, what this paper addresses is in the area of consumer education rather than producer education. As far as the author knows, Shichinohe et al. (1990) was the earliest to point out the existence of the educational function in agriculture as consumer education; this was then followed by sporadic case studies as already mentioned.

Issues on the diffusion of agricultural technology were taken up as a good example of social learning (Goyal, 2007). Leeuwis and Pyburn (2002) conducted comprehensive studies on the social learning network in agriculture. Sociological approaches were mainly used in social learning in agriculture as follows: technological innovation in genetically-modified crops (Oreszczyn et al., 2010), farmers' markets (Hinrichs et al., 2004), organic farmers network (Kroma, 2006), and sustainable or environmentally friendly agriculture (Nerbonne and Lentz, 2003; Andrew, 2003; Naiper and Tucker 2001; Ingram, 2010). With social learning in environmental research, issues on environmental education and raising awareness of the environment have been studied (Measham, 2006; Raymond et al., 2010). In agricultural and development economics, social learning studies are concentrated on technology transfer in developing countries (Conley and Udry, 2001; Munshi, 2004; Yamauchi, 2007). On the contrary, in tourism research, Fisher (2004) explored the demonstration effect from the perspective of imitation and social learning and Koutsouris (2009) dealt with social learning related to sustainable tourism; however, these two studies were descriptive. Studies on social learning issues are very limited in tourism research compared with agricultural research where quantitative analyses with economic frameworks have been conducted actively.

On topics of farm diversification, van der Ploeg et al. (2009) conducted a sociological investigation and Sharpley and Vass (2006) examined the connection of rural tourism with farm diversification. As to rural tourism studies under an economic framework, OECD (2005) explored the issues of internalization of externality generated by multifunctionality in agriculture, including rural tourism. In comparison with a wide range of econometric tourism research in general (for instance, Barros (2005) and Barros and Machado (2010)), although econometric analyses of rural tourism are increasing (Tchetchik et al. (2008) on rural tourism market evaluation and simulation, Vanslenbrouck et al. (2005) and Ohe and Ciani (2011) on hedonic pricing, Ohe (2011a) on measuring labour productivity of rural tourism), econometric research papers on rural tourism have not been accumulated enough and these papers did not focus on farm educational services per se.

Finally, regarding our aim of empirical economic studies on educational services and travel in agriculture, Ohe (2007, 2011b) took a stance on the internalization of the educational externality by presenting an economic framework and conducted empirical evaluations of EDFs. Although it is crucial to clarify the conditions for viable educational services, from what is described above, no study has thus far answered the questions of social learning and stepwise innovation of educational services and tourism in agriculture. Therefore, this paper throws light on the topics that remain to be explored and tries to further the establishment of viable educational services.

3 Conceptual Framework: Stepwise Internalization Process of Educational Externality in EDF services

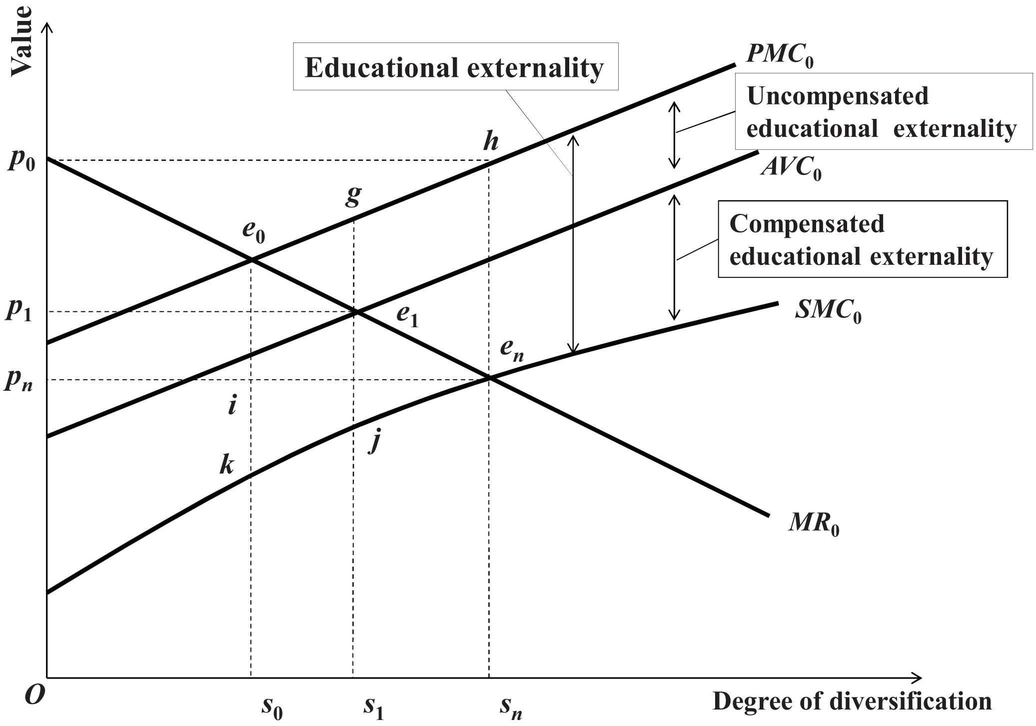

Figure 1. Internalization process of educational externality

Here, I present a conceptual framework of a stepwise internalization process to establish a basis for the empirical examination in the latter half of this paper. Figure 1 depicts an operator's subjective equilibrium in the provision of educational experience services by vertically measuring values and the level of farm activity horizontally. Out of three right upward lines, there are two marginal cost curves depicted because farm activity including the operation of EDF activity generates positive externality as a multifunctionality of agriculture. The private marginal cost curve PMC is indicated by the upper right upward line and the social marginal cost curve SMC is indicated by the lower line. The vertical distance between the two curves indicates the educational externality. The reason why the two marginal cost curves have different forms is that the educational externality depends on the level of diversification, which determines the shape of the SMC curve (Ohe, 2011b). The middle right upward line is the average variable cost curve AVC because AVC curve always comes under PMC curve in the diminishing return area that we consider here.

The right downward curve illustrates the operator's marginal revenue curve of educational experience services, MR0. If there is no externality at all, then the ordinary subjective equilibrium, or the private optimal point, is attained at point e0 where the PMC curve meets MR0. Nevertheless, the subjective equilibrium points vary from one operator to another, actually depending on the attitudes and managerial efforts as to where the operator positions the educational experience services in the farm activity. In this respect, I consider three main cases that represent the stepwise process toward the internalization of the externality as described below to simplify the discussion, although I asked more than three questions on attitudes in the questionnaire survey as mentioned later.

The first phase is the case wherein the operator provides educational experience services on the SMC curve. In this case, the operator does not fully recognize the existence of the educational positive externality that he/she generates, or provides these services as a volunteer, even if the operator recognizes that externality. This means that internalization of the educational externality is not conducted at all. Thus, this subjective equilibrium point is attained as the private optimal at e0 and educational experience services are offered to Os0, shorter than the social optimal supply level Osn.

The second phase is the case whereby the operator does not act to recover the social marginal cost that equals the amount of externality the operator generates, but only to recover at least the material cost although the operator recognizes the externality. In that case, the operator provides the services as a semi-volunteer and only the average cost is recovered. Thus, the operator's subjective equilibrium is attained as the average cost optimal at e1 where the average variable cost AVC0 meets MR0 with providing service Os1. The operator can partially recover the externality, i.e. e1j out of gj and ge1 is left uncompensated. This means that the social optimal resource allocation is not achieved as an economic activity and thus the orientation toward a viable economic activity is not established yet.

In the last phase, the operator charges for every educational experience service as a result of managerial efforts, meaning that the externality is completely internalized. The social optimal is attained on SMC curve at en where we can say that the complete internalization of the externality is achieved because the operator takes into account the social cost that should be compensated. Also, the two marginal cost lines, PMC and SMC curves, are overlapped at least at the point of en due to the downward shift of the PMC curve. I assume that this downward shift of the PMC is caused by stepwise innovation starting from e0 to en through e1. This is the stepwise process of the educational internalization. At the last phase, the orientation toward a viable economic activity is firmly established.

The next empirical questions are to clarify what and how factors inside and outside of farms stipulate the operators' behavior that enables them to cause stepwise innovation or the downward shift of the PMC curve to the SMC curve.

4 Hypothesis: Significance of Network Organizations

As one of the factors that generate the stepwise innovation, I focus on the social learning effect among operators in the network organizations in addition to on-farm factors. To explore the significance of network organizations, I characterize the two contrasting types of network organizations that undertake new activities in rural areas (Table 1). The second column shows various factors related to traditional network organizations in rural areas. A typical example is the hamlet organization, which originates from the banding together of members of the local community and acts as a body to organize and perform the collective work in the hamlet. Further, these network organizations are now expected to act as a body to undertake new village businesses such as rural tourism. Rural community-based activity is the root of this type of organization, so that these organizations are basically constituted of community members. In this context, entry and exit of members from outside of the community are not easy. Thus, that type of organization is closed rather than open to those outside of the local community and I term this type a 'closed network organization'. Because of this characteristic, it is easy to suppose that the optimal size would not be large. This optimal size will remain relatively small and therefore an organization limited to local residents will be a suitable size for this type of organization.

Table 1. Features and roles of network organizations in rural areas		
Type	**Closed Network Organization**	**Open Network Organization**
Origin	Club of local community	Club of like-minded individuals
Characteristic	Territorial	Personal
Entry/exit	Difficult	Easy
Territorial limitation	Yes	No
Optimal size	Small	Large
Effective areas	Traditional collective work in the hamlet, rural business activity	Social learning of new activity, new market formation
Examples	Conventional hamlet bodies	Educational dairy farms, open dairy farms

Now I look at the open network organization (third column). This type of organization has the following features in contrast to the closed network type. This open network type is based on like-minded relationships or personal relationships or connections. Therefore, the membership is not limited territorially, so that entry and exit are easier than in the former type. This type has an advantage in sharing and acquiring information and developing ideas based on such shared information; thus, it is suitable for activities by independent individuals rather than those acting as a body for conducting business that needs strict decision-making. Thus, the Educational Dairy Farms and Open Dairy Farms that are mentioned below are typical examples of these types of network organizations.

Innovation in the way of utilization of local tangible and intangible resources will cause a reduction in management costs by a downward shift in the cost of resource utilization. Such innovations in utilization of local resources are not always hardware related, but are more often software related, which are also difficult to generate (Ohe, 2011a). Thus, as the conceptual framework, it is realistic to assume empirically that this downward shift will occur in a stepwise manner rather than occurring all at once.

Although the conventional agricultural organization has been mostly a closed network organization, which is closer to the Coleman type of network, the open network, which is closer to the Burt type network, has not been well investigated (Coleman, 1988; Burt, 2001). Social learning among people concerned is expected to work on the stepwise downward shift in the cost of resource unitization. Since the social learning effects have not been tested in the case of new rural services, such as educational experience services, in agriculture and rural tourism, this paper will try to fill this gap in research.

5 Two Social Learning Organizations for Operation of an Educational Dairy Farm

To be an associate of Educational Dairy Farms, a farmer must attend a course on principles, safety and hygiene, and communication skills as well as presentation of a case study provided by Japan Dairy Council, which is a national dairy farmers' organization. The Council administers the certification for recognition as an Educational Dairy Farm and presents various capacity building courses for those with certification as an Educational Dairy Farm as well as dairy farmers at large in Japan.

In addition to the Educational Dairy Farms organization, we need to look at another organization, which is called Open Dairy Farms. It was established in 2000 and is a nationwide organization of dairy farmers who conduct an open-door policy to visitors from outside of the community. Although also supported by the Japan Dairy Council as a secretariat, membership is voluntary with no requirement of a technical course. Open Dairy Farms is autonomous, having its own board and consisting of six regional branches comprised of member farmers. This organization has played an important role for its member farmers by providing a forum for sharing experiences, information, and ideas and also in shaping a long-term vision and philosophy for open-door farm activity, e.g., by often conducting dairy events at local and national festivals. Although its main purpose is not to provide an educational service, Open Dairy Farms has supported the evolution of educational dairy farms as a banner of the open-door policy of dairy farms. In this regard, Educational Dairy Farms has developed together with Open Dairy Farms. Interestingly, Educational Dairy Farms and Open Dairy Farms have the common feature of a typical open network organization. In reality, these two networks have overlapping memberships as shown in Table 2.

It is considered that the two networks, through which member farmers exchange information and strengthen networking among members formally and informally, have worked complementarily as social learning places, which generate a network externality that leads to a downward shift of the SMC curve. This complementary relationship then generates the stepwise innovation of internalizing externalities by enabling members to firstly recognize a new role for agriculture and then to come up with an orientation for internalizing educational externalities. This is our working hypothesis, which we test empirically below.

6 Data

Data are based on a survey on the attitudes of members of the organization, Educational Dairy Farms. The author conducted this survey to gain an understanding of the operation, problems related to educational activities and the operators' attitudes, and the survey was sent to all of 257 Educational Dairy Farm members by surface mail from October 1st to December 31st 2009. The response rate was 79.4% (204 farms). Other farm data related to EDF activities were also used. These data were provided by the Japan Dairy Council, which is an administrative body of the Educational Dairy Farm program. Information was obtained on milk production (as of 2009), acreage of forage and pasture (as of 2009), number of milk cows (as of 2009), the year the operators received certification as an Educational Dairy Farm, and the number of visitors (as of 2008).

7 Results of Statistical Tests

First, the experience services offered by the EDFs are summarized in Table 3. A short lecture by the farmer, milking and feeding cattle are the three major services, which shows that experiences related to operation of a dairy farm are more popular than food cultural experiences such as butter making and ice cream making. This is because the main activity of these farms is not tourism, but milk production.

Table 4 contrasts the present attitudes toward EDF activity and future intentions. Among the present attitudes, 'cost covering' and 'volunteer' account for 60% of responses, which would indicate a non-profit activity or that respondents have no orientation toward viability of the educational experience services indicating that those operators provided educational services at the private optimal or the average cost optimal. On the other hand, those who expressed 'marketing' and 'aiming at viable activity' only accounted for one fourth of the total responses, and these respondents are supposed to have an orientation toward viable services indicating that those operators aimed at the social optimal. Now turning to future intentions, those with no orientation toward viability dropped to about 40% while nearly 50% of operators expressed their intention to seek viability. Thus, it is safe to say that many operators intend to establish viability of educational services in the long run.

Table 3. Offered educational dairy farm services

Experience services	No. farms
Lecture by farmer	185
Milking	156
Feeding	154
Giving bottle to calves	143
Cleaning barn	112
Brushing animals	95
Field work	68
Tour of farmyard	183
Horseback riding	33
Butter making	133
Cheese making	37
Ice cream making	54
Ham/sausage making	14
Cutting sheep wool	15

Notes: Data source as for Table 2.

Table 4. Attitudes toward educational experience services (present and future)

Items	Present		Future	
	Percentage	Sample size	Percentage	Sample size
Volunteer	28.4	58	17.2	35
Cost covering	31.9	65	24.0	49
Measure of marketing	7.4	15	23.0	47
Aiming at viable activity	16.7	34	24.0	49
Nothing in particular	7.8	16	—	
Decrease/quit	—	—	1.0	2
Don't know	—	—	2.5	5
Others	5.4	11	5.4	11
No answer	2.5	5	2.9	6
Total	100.0	204	100.0	204

Note: Data source as for Table 2.

Table 5. Connection between orientation to viable activity of educational diary farm (EDF) and farm attributes (%)

Items	Orientation of viable EDF activity		Test results
	No	Yes	
Labour size for dairy activity (real term)	3.7	3.3	En.s.
Milk production (year/ton)	471.5	553.5	Nn.s.
No. milk cows	130.7	307.9	Nn.s.
Acreage of feed production (ha)	34.0	31.2	Nn.s.
No. activities	2.1	2.9	N***
No. visitors on farm in 2008	1150.7	2993.8	E**
No. times EDF activity in 2008	47.2	171.3	N*
More than 1 1times (%)	51.9	69.8	***
More than 100 visitors (%)	58.3	78.1	***
More than 300 visitors (%)	33.3	63.5	***
Main person of EDF activity :Female (%)	30.6	39.6	+
Kanto area (%)	13.0	26.0	**
Member of Open Dairy Farms (%)	88.9	96.9	**

Notes: Data as for Table 2. In area above the broken line, t test was used while Chi-square test was used below the line. Fisher's Exact test was employed when sample size of a cell was less than 5. E=equal variance, N=unequal variance, ***,**,*,+ show 1%, 5%, 10%, 20% (reference) significance level and no significance shown by -. Labour size in real terms was calibrated in each activity by the following criteria: full-time labor and mainly responsible for the operation=1, full time and supplementarily responsible=0.5, part-time and mainly responsible=0.5, part-time and supplementarily responsible=0.25.

Table 6. Connection between orientation to viable activity of educational dairy farm and farm attributes(2) (%)

Items	Orientation of viable EDF activity		Test results
	No	Yes	
Type of ownership			
Family	64.8	55.2	+
Family (corporate)	11.1	24.0	**
Joint ownership	1.9	3.1	n.s.
Agricultural cooperatives	0.9	5.2	+
Private sector	2.8	4.2	n.s.
Public sector	3.7	2.1	n.s.
Third sector	1.9	2.1	n.s.
Others	7.4	4.2	n.s.
Total	100.0	100.0	-
Activity (multiple answers)			
Milk production	90.7	91.7	n.s.
Processing milk products	15.7	50.5	***
Raising beef cows	2.8	11.6	**
Lodging facility	7.4	12.6	n.s.
Restaurant	9.3	20.0	**
Direct selling	12.0	34.7	***

Notes: Data are as for Table 2. Chi-square test was used and Fisher's exact test was employed when sample size of a cell was less than 5. E=equal variance, N=unequal variance, ***,**,*,+ show 1%, 5%, 10%, 20% (reference) significance level and no significance shown by -.

Table 7. Connection between orientation toward viable activity of educational dairy farm (EDF) and farm attributes(3) (%)			
Items	Orientation of viable EDF activity		Test results
	No	Yes	
Type of menu of experience services			
Individual	42.6	28.1	**
Set menu	16.7	22.9	n.s.
Both	27.8	31.3	n.s.
Total	100.0	100.0	-
Targeted area			
Neighbouring municipality	62.0	44.8	**
Neighbouring prefecture	9.3	14.6	n.s.
No limitation	19.4	29.2	+
Case by case	6.5	5.2	n.s.
Others	2.8	4.2	n.s.
Total	100.0	100.0	-
Changes in consciousness after starting EDF (multiple answers)			
Teaching	80.6	84.4	n.s.
Exchange with people	89.8	88.5	n.s.
Value of local resources	80.6	83.3	n.s.
Self-confidence/local pride	76.9	83.3	n.s.
A new role	82.4	90.6	*
Connection to local community	77.8	83.3	n.s.
Discovery of material for EDF services	61.1	77.1	**
Extension of network beyond local boundary	65.7	76.0	+
Revenue source	13.9	53.1	***
Direct selling of dairy products	21.3	57.3	***
New viable activity	21.3	51.0	***

Notes: Data are as for Table 2. Chi-square test was used and Fisher's exact test was employed when sample size of a cell was less than 5. E=equal variance, N=unequal variance, ***,**,*,+ show 1%, 5%, 10%, 20% (reference) significance level and no significance shown by -.

Table 8. Connection between orientation toward viable activity of educational dairy farm (EDF) and farm attributes(4) (%)			
Items	Orientation of viable EDF activity		Test results
	No	Yes	
Charging for experience services			
Every service	10.2	38.5	***
A part of service	24.1	29.2	n.s.
No charge	46.3	15.6	***
Depending on where visitors come from	7.4	11.5	n.s.
Others	8.3	4.2	n.s.
Total	100.0	100.0	-
Future direction (multiple answers)			
Using travel agency	15.7	42.7	***
Extension of types of visitors	25.9	51.0	***
Food combined services	27.8	61.5	***
Healing/welfare	51.9	61.5	+
Collaboration with other local farmers	38.9	64.6	***
Lodging facility	18.5	36.5	***
Restaurant	8.3	38.5	***
Direct selling facility	24.1	62.5	***
Collaboration with local community	55.6	74.0	***
Nothing in particular	6.5	2.1	+

Notes: Data are as for Table 2. Chi-square test was used and Fisher's exact test was employed when sample size of a cell was less than 5. E=equal variance, N=unequal variance, ***,**,*,+ show 1%, 5%, 10%, 20% (reference) significance level and no significance shown by -.

From the results shown in Table 4, I classified the attitudes toward the EDF activity into the two groups: ‘a means of marketing dairy products’ and ‘aiming for viable activity’ went into a group with orientation toward viability while ‘volunteer’, ‘cost covering’ and others went into a group with no orientation toward viability. With this criterion, I conducted statistical tests on the conditions and activity of dairy farming, the behavior as a member of Educational Dairy Farms and attitude toward viability.

Table 5 shows results related to conditions and activity of the dairy farm; there was no statistical connection between the two groups with regard to farm size indicated by such factors as labour size, acreage for forage and pasture, number of milk cows and milk production, which are the input and output factors of ordinary dairy production activity. Additional tests were also conducted to see if there was a relationship between these dairy production indicators and indicators of EDF activity. I found no statistical connection between the number of visitors and times visitors were accommodated with dairy production indicators, indicating no connection between ordinary dairy production activity and EDF activity. In contrast, there were statistically significant differences between the two groups in the number of on-farm activities, which is an indicator of farm diversification, and the number of visitors (especially over 100 and 300 visitors) and times of visits (especially over 11 times) in terms of EDF activity. Thus, those with an orientation toward viable educational activity expressed a higher ratio for these variables than those who did not (from 10% to 1% significance). Those operators located in the Kanto area have an orientation toward viability due to closeness to the most densely populated area in this country. I could also confirm our working hypothesis statistically because the result shows the complementary relationship between Open Dairy Farm members and a positive orientation toward viability (5% significance). Although other network-related variables such as the number of members of each branch of the Open Dairy Farms organization and the year of the membership were also tested, no statistically significant connection was found. This means that belonging to a nationwide network is more effective for a connection with an orientation toward viability than a regional network.

As to the type of farm ownership (Table 6), family farms are the most common type followed by family corporate farms. Taken together, family corporate farms and family farms had a higher ratio of orientation toward viability (5% significance). Activity-wise, a significantly higher percentage of operators with an orientation toward viability conducted activities in addition to milk production than those with no such orientation (50.5%, processed milk products; 34.7%, direct selling; 20%, restaurant), which shows that those operators oriented toward viable EDF activity engage in more diversified farm activity than those not so oriented.

As to the type of menu of educational experience services (Table 7), operators with a viability orientation provided these services less in the form of individual service than those with no such orientation (5% significance). As to the area targeted in offering educational experience services, also shown in Table 7, a lower percentage of operators with a viability orientation targeted visitors only from their municipality than those without such orientation (5% significance), suggesting that they targeted a wider area for their services. With respect to the changes in operators’ consciousness after EDF activity, those with a viability orientation had more positive attitudes toward the utilization of local resources and profit-seeking activity, such as selling of dairy products, than those without that orientation (Table 7).

Table 8 shows to what extent charges were made for educational experience services. More operators with the viability orientation charged for every service than those without the viability orientation; also, fewer of the former operators provided services at no charge (1% significance). Finally, in connection with the future direction, those with a viability orientation expressed their willingness to conduct many activities in order to provide viable services (Table 8).

To summarize, first, the members of Open Dairy Farms had a positive connection with the viability orientation of educational experience services. Second, the more visitors EDF operators accommodate, the more positive is their attitude toward the viability orientation. Third, there were no correlations between the number of visitors or the viability orientation and indicators of farm size such as forage and pasture acreage, number of milk cows and milk production. To put it another way, there is no economy of scale in terms of EDF activity in relation to dairy production.

8 Estimation of Viability Orientation Determinant Model

Bearing in mind the findings above, here I estimate a viability orientation determinant model to clarify the factors that determine the viability orientation of the educational experience services and the degree of influence of these factors by taking into account on-farm present and future factors, and off-farm factors. Thus, the analytical model is described as equation (1) and an estimation model with actual variables is given as equation (2).

H=F (on-farm present, on-farm future, off-farm) (1)

Where, on-farm=vector of on-farm present factors, on-farm future=vector of on-farm planned factors and off-farm=vector of off-farm factors

H=F (NUM, FMALE, CHANGE, AREA, KANTO, TAGENT, DIRECT, FOOD, SL, ε) (2)

Where, H=Level of viability orientation (5-point scale)

NUM=More than 101 visitors (model 1), or more than 301 visitors (model 2)

FMALE=Main person performing EDF activity (female: yes=1, no=0)

CHANGE=Attitude change after starting EDF: (discovery of material: yes=1, no=0)

AREA=Targeted area (neighbouring municipalities: yes=1, no=0)

KANTO=Location of farm (Kanto area: yes=1, no=0)

TAGENT=Future direction 1 (using travel agency: yes=1, no=0)

DIRECT=Future direction 2 (direct selling: yes=1, no=0)

FOOD=Future direction 3 (food combined service: yes=1, no=0)

SL=Social learning effect (member of Open Dairy Farms: yes=1, no=0)

ε =Stochastic error

As the explained variables, based on the hypothesis of the stepwise process, the variable H represents orientation on a scale of 0 to 4 for viable educational activity: unanswered, shrinking or quitting, and undecided=0, volunteer=1, recovering cost=2, a measure of marketing of farm products=3, and aiming at viable activity=4. Among the explanatory variables, as on-farm variables the current practices and future contemplated activities were taken up. First, as on-farm present factors the variable NUM represents the activity level of educational services by considering two cases: more than 101 visitors (yes=1, no=0) in model 1 or more than 301 visitors (yes=1, no=0) in model 2. The variable FMALE expressed who was responsible for the activity, as that person is not only important for the service activity but is supposed to be influential in the viability orientation; especially, females are better adopted for this activity (female mainly responsible of EDF activity: yes=1, no=0).

The variable CHANGE represents changes in consciousness of operators after starting the EDF activity. Specifically, I tested whether an operator discovered material for EDF services from the local resources surrounding the farmyard and obtained a wider perspective not only for management of his/her own farm, but also to local resource management. If so, we can expect further extension of EDF activity (discovery of material for EDF services: yes=1, no=0). The variable AREA expresses how large a target area as a demand potential operators assume, which indicates the market area. I use this variable to test the differences in the sizes of targeted areas on the viability orientation (neighbouring municipalities: yes=1, no=0). The variable KANTO expressed the location of the farm, and it is assumed that the Kanto area, which includes a densely populated metropolitan area, indicates a favourable spatial condition in terms of easy access for people to visit farms (located in Kanto area: yes=1, no=0).

With respect to future contemplated directions, three market related variables that would affect the viability orientation were considered. First, the variable TAGENT represents how to ensure stable demand, which is a crucial factor for the establishment of viable EDF activity. For this purpose, the intention to use a travel agency is tested (using travel agency: yes=1, no=0). A second aspect deals with the sales channel, which is also important for viability, so doing or extending direct selling is taken up as the variable DIRECT (direct selling: yes=1, no=0). A third variable is the content of the EDF service; hence, the variable FOOD denotes the intention of providing services in combination with food (yes=1, no=0). These three factors are supposed to work positively on the viability orientation.

As an off-farm variable, the variable SL connotes the social learning effect that an open network organization can generate (member of Open Dairy Farms: yes=1, no=0). Further, this variable is interpreted as a proxy variable for family farms as well because the member farms are mainly family farms whether corporate or not. Ordered logit model was employed due to the ordered explained variable.

The results of estimation are tabulated in Table 9. The ordered logit model does not give any information on multicollinearity and heteroscedasticity, so I referred to an estimation result by OLS. The OLS result indicated that no heteroscedasticity was observed and the maximum vif was 1.31, indicating no multicollinearity. As a reference, I showed the robust estimate of variance in addition to the standard estimate of variance. There was no distinctive difference between the standard and robust estimates in terms of parameters and significance levels. From these results I accept the results of logit estimation to interpret parameters.

Every estimated parameter had statistical significance, which shows no contradiction with the results of the preceding statistical tests. Results were similar to models 1 and 2. Now let us consider the estimation results in Table 9.

The parameters of the number of visitors in the two models have positive signs implying that operators with at least over 100 visitors have an orientation toward a viable EDF activity. The parameter of the female being mainly responsible was positive, indicating that this factor raises the viability orientation. Since the discovery of materials from surrounding local resources was positive, I can say that this widening perspective on local resources beyond the individual farmyard will raise the possibility of realizing the viability of EDF services. On the other hand, the parameter of a small targeted area or market area was negative, indicating that the market area should be widened for viability. The location parameter of the Kanto area was positive, indicating that easy access to farms works positively in raising the viability orientation.

Table 9. Estimation results of an orientation determinant model of viable educational services (Ordered logit model)				
Model	# 1		# 2	
Estimate of Variance	Standard	Robust	Standard	Robust
Explanatory variables	Parameter			
More than 101 visitors (yes=1, no=0)	0.6561** (2.22)	0.6561** (2.00)	—	—
More than 301 visitors (yes=1, no=0)	—	—	0.6493** (2.31)	0.6493** (2.21)
Main person for EDF activity: Female (yes=1, no=0)	0.5411* (1.90)	0.5411* (1.90)	0.6152** (2.13)	0.6152** (2.11)
Attitude change after starting EDF: Discovery of material (yes=1, no=0)	0.6451** (2.23)	0.6451** (2.38)	0.7055** (2.44)	0.7055*** (2.60)
Targeting area: Neighbouring municipality (yes=1, no=0)	-0.6486** (-2.36)	-0.6496** (-2.36)	-0.6324** (-2.30)	-0.6324** (-2.27)
Location of farm: Kanto area (yes=1, no=0)	0.6609* (1.85)	0.6619* (1.65)	0.7111** (1.99)	0.7111* (1.78)
Future direction 1: Using travel agency (yes=1, no=0)	1.1393*** (3.43)	1.1393*** (3.46)	1.0245*** (3.04)	1.0245*** (2.99)
Future direction 2: Doing direct selling (yes=1, no=0)	1.1175*** (3.83)	1.1185*** (3.66)	1.0662*** (3.65)	1.0662*** (3.53)
Future direction 3: Food combined service (yes=1, no=0)	0.6074** (2.07)	0.6074** (2.02)	0.6239** (2.14)	0.6239** (2.12)
Member of open dairy farms (yes=1, no=0)	1.0711** (2.11)	1.0711** (2.16)	0.9593* (1.88)	0.9593* (1.85)
Sample size	204	204	204	204
Log likelihood ratio	-267.1786	-267.1786	-266.9749	-266.9749
LR Chi-square	91.8***	—	92.21***	—
Wald Chi-square	—	79.17***	—	79.98***

Notes: Data are same as Table 2. ***,**,* show 1%, 5%, 10% significance level. LR=likelihood ratio.

Now, turning to the parameters on the future contemplated direction, the parameters of using a travel agency and direct selling were both positive with 1% significance, which means a strong connection with an orientation toward viability. Another parameter of the contemplated directions on the services being combined with food was positive, suggesting that the combination of food and farm experiences will play a role in the realization of viable EDF services. Thus, it is safe to say that market conscious attitudes and skills are crucial for viable educational services.

Finally, regarding the parameters of off-farm factors, the social learning effect of the open network organization was confirmed and, interestingly, the parameter of model 1 with 5% significance is larger than that of model 2 with 10% significance. This indicates that the social learning effect is more effective at the level up to 300 visitors or when there are not a large number of visitors.

To summarize the estimation results, it is safe to say that not only on-farm, but also off-farm, perspectives on resource management are important in operators raising the viability of EDF services. Specific to this point, I compared the degree of influence of variables affecting the degree of the orientation. Table 10 summarizes simulated expected probabilities for each variable from the parameters with standard variance in models 1 and 2 (more than 301 visitors). Expected probabilities over 30% are shown in bold in the table. Among these probabilities that are highlighted, the highest influential variables were in the following order using a travel agency (50.5%), direct selling (40.1%), food combined service (37.5%), Kanto area (36.1%), over 300 visitors (35.2%), the reverse effect of a narrow range of the targeted area or wider target areas (32.9%), and female initiative (31.9%). These expected probabilities show that factors related to marketing conditions become more important in a higher orientation toward a viable EDF activity. I also cannot ignore the other factors because raising the orientation is a stepwise process and, especially, the estimation results revealed the significance of the social learning effect among the operator's network, which generates the network externality to initiate the downward shift of the PMC curve. In this context, the social learning effect initiates the stepwise innovation for internalizing the educational externality that they produce.

Table 10. Predicted probability of the five attitudes based on the estimation result (%)

Variables	Yes/no	Don't know	Volunteer	Cost covering	Marketing	Viable activity
More than 101 visitors	Yes	4.1	17.4	22.9	26.0	29.6
	No	10.9	31.0	24.6	19.1	14.4
More than 301 visitors	Yes	3.0	14.1	20.7	26.9	**35.2**
	No	9.3	28.7	25.8	21.1	15.1
Main person of EDF activity: Female	Yes	4.1	16.8	21.5	25.7	**31.9**
	No	7.5	24.5	24.5	22.7	20.8
Targeting area: Neighbouring municipality	Yes	8.7	26.9	24.9	21.8	17.7
	No	3.5	15.9	21.8	26.0	**32.9**
Location of farm: Kanto area	Yes	2.7	13.3	20.7	27.2	**36.1**
	No	7.2	23.8	24.1	22.9	22.0
Attitude change after starting EDF: Discovery of material	Yes	4.6	18.1	22.8	25.9	28.7
	No	10.1	30.1	24.9	19.2	15.7
Future direction 1: Using travel agency	Yes	0.9	6.1	14.3	28.2	**50.5**
	No	8.5	28.1	27.1	22.0	14.4
Future direction 2: Doing direct selling	Yes	20.2	10.7	18.9	28.3	**40.1**
	No	8.9	28.6	26.2	21.0	15.3
Future direction 3: Food combined service	Yes	2.3	11.9	19.9	28.3	**37.5**
	No	9.4	29.5	26.2	20.2	14.7
Member of Open Dairy Farms	Yes	5.6	20.7	23.4	24.4	26.0
	No	15.3	36.0	24.6	15.8	8.3
Total	-	6.3	21.8	23.4	23.8	24.7

Notes: Data were as for Table 2. Expected probabilities were simulated from parameters with standard variance of model 1 and model 2 (more than 301 visitors). Bold numbers are over 30% of expected probability.

9 Conclusions

Although education services in agriculture are attracting growing attention, one problem of these open-door farm policy services is that a viable market has not yet been established. Therefore, it is necessary to clarify on- and off-farm conditions. Based on a survey to Educational Dairy Farms in Japan and from a perspective of exploring a product innovation, this paper examined the operators' attitudes toward the establishment of viable educational services. The main findings and conclusions are as follows.

First, the higher the number of visitors, the greater was the operator's orientation toward a viable service while there was no statistical connection between the input-output factors of ordinary dairy production and the educational activity. Second, the operators that had a human network with a social learning effect beyond the traditional closed communal organizations were more positive toward a viable market orientation than those without such a network. This suggests the significance of social learning effects for operators who participated in the open network organization at the initial process of establishment of viable educational services.

Third, the involvement of women rather than men and services combined with food experiences rather than simple farming experience services per se were factors that raised the viability of educational services.

Fourth, the importance of marketing activities was revealed, such as direct selling of dairy products in the farmyard and the use of a travel agency, which had positive connections with a higher orientation toward the viability of educational services.

In conclusion, making educational services viable does not simply mean that those farms should become tourism ranches. Rather, the balance between the educational function and the economic viability of services should be attained for the exploration of a new social role of agriculture and the creation of a new market. In this respect, public support will be effective in building the capacity of those operators, especially in taking into account the stepwise process of a new market establishing innovation. Finally, further research is needed on the relationship between rural entrepreneurship and this stepwise innovation process.

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Induced Innovation in Canadian Agriculture

J.S. Clark, Lukas Cechura and S.J. Thompson

Annotation: The study re-examines the induced innovation hypothesis from 1958-2006 in Canadian agriculture for two regions in Canada: Central Canada (Provinces of Ontario and Quebec) and Western Canada (Provinces of Alberta Saskatchewan and Manitoba). There is broadly consistent support for the induced innovations hypothesis for Canadian agriculture, especially for Western Canadian Agriculture. In addition, there is support for the notion the US as well as Canadian research expenditures are important to the explanation of input ratio movements in Canadian Agriculture in the long run. This could indicate the existence of spillover effects that run from US agricultural research to Canadian Agriculture.

Key words: Induced Innovation; factor substitution; spillover effects; non-stationarity; cointegration

1 Introduction

Technical change is important in global agriculture and it is widely studied and prescribed by policy makers. A related issue is induced innovation, a concept first introduced by Hicks (1932), refined by Hayami and Ruttan (1971), Ahmad (1966), and de Janvry et al. (1989).

> "Changes in relative prices of factors are expected to induce development and implementation of new technology to save the relatively more expensive inputs" (Liu & Shumway, 2009)

By 1990, it had become a stylized fact in the US that technical change was consistent with the induced innovation hypothesis (IIH). In Canada, a 1990 paper by Karagiannis and Furtan also found support for this hypothesis.

However, recently the induced innovation hypothesis has come under challenge. Omstead and Rhode's research (1993 and 1998) suggested that the IIH should be reconsidered for US agriculture. Lambert and Shonkwiler (1995) and Thirtle et al. (2002) found support for the IHH in US agriculture. Lin (1998) rejected the hypothesis as did Machado (1995), Tiffin and Dawson (1995) and Liu and Shumway (2009).

It has been almost a quarter of a century since the publication of the Karagiannis and Furtan study of induced innovation in Canadian agriculture. A re-examination of this topic for Canadian agriculture seems timely. Our study updates the Karagiannis and Furtan study by:

- Extending the time series from 1985 to 2006
- Adding research expenditures as well as a time trend as a proxy for technical change
- Updating the econometric technique to use modern time series analysis
- Estimating the two state CES model
- Adding US research expenditures to examine spillover effects

2 Discussion of Theoretical Model and Empirical Implications of the Induced Innovations Hypothesis

The model used by Karagiannis and Furtan (1990), Thirtle et al. (2002) and Liu and Shumway (2009) is the two stage CES function. This function assumes the machinery/labour input pair is separable from land/fertilizer input pair and that the overall function is homogeneous of degree one. This leads to a long run specification of the two equations:

$ln(M_t /L_t) = \beta_0 -\sigma_1 \, ln(P_{M\,t} /P_{L\,t}) +(1- \sigma_1) \, ln(E_t)$, (1) and

$ln(F_t /A_t) = \alpha_0 - \sigma_2 \, ln(P_{F\,t} /P_{A\,t}) +(1- \sigma_2) \, ln(E_t)$, (2)

where σ_1 is the elasticity of substitution between machinery and labour, σ_2 is the elasticity of substitution between fertilizer and land, M_t is the quantity of machinery, L_t is the quantity of labour, F_t is the quantity of fertilizer, A_t is the quantity of land, P_{Mt} is the price of machinery, P_{Lt} is the price of labour, P_{Ft} is the price of fertilizer, P_{At} is the price of land and E_t is technological progress.

According to Liu and Shumway (2009) and Thritle et al. (2002), the induced innovations hypothesis implies the following empirical implications associated with equations (1) and (2):

1) All variables in the system are balanced. Assuming the variables in model are integrated, then this implies that the variables are I(1);

2) There are two cointegrating vectors given the stochastic variables in the system. There is one cointegrating vector for the machinery/labour equation and one cointegrating vector for the fertilizer/land equation;

3) Factor prices and quantities are negatively correlated over the long run;

4) Current factor prices do not completely explain factor substitution; and

5) Causality runs from prices to quantities but not quantities to prices.

In addition to empirically testing these five implications of the IIH for Canadian data, this study tests three additional implications of the model. The first relates to the choice of the two stage CES function. Karagiannis and Furtan (1990), Thirtle et al. (2002) and Liu and Shumway (2009) all maintain the two stage CES functional form to study the IIH. The unrestricted two long run equations studied are:

$ln(M_t /L_t) = \beta_0 + \beta_1 \, ln(P_{M\,t} /P_{L\,t}) + \beta_2 \, ln(P_{F\,t} /P_{A\,t}) + \beta_3 \, ln(E_{ct}) +\beta_4 \, ln(E_{USt}) + \beta_5 t$, (3) and

$ln(F_t /A_t) = \alpha_0 + \alpha_1 \, ln(P_{M\,t} /P_{L\,t}) + \alpha_2 \, ln(P_{F\,t} /P_{A\,t}) + \alpha_3 \, ln(E_{ct}) +\alpha_4 \, ln(E_{USt}) + \alpha_4 t.$ (4)

Comparing equation (1) with equation (3) and equation (2) with equation (4), then the following restrictions are implied:

$\beta_1 + \beta_3 = -1, \beta_2 = 0, \text{ and } \beta_3 = \beta_4.$ (5)
$\alpha_2 = 0, \alpha_2 + \alpha_3 = -1, \text{ and } \alpha_3 = \alpha_4.$ (6)

This will be called empirical implication 6.

Also, this study is different than previous studies in the both Canadian as well as US research expenditures are used as a proxy for technological progress. Therefore, the fact that US research expenditures matter in equations (3) and (4) implies the test $\beta_4 = \alpha_4 = 0$ will be implemented.

This will be called empirical implication 7.

A final test of the IIH that will be undertaken that is not discussed by previous authors is an additional causality test than the test where prices cause quantities (implication (3) above). Since research expenditures are used as a proxy for technological change and the IIH assumes that prices induce innovations, it seems reasonable the prices cause research expenditures.

This will be called empirical implication 8.

3 Data and Results

3.1 Discussion of Data

The data on prices and quantities from 1935-85 are taken from Karagiannis and Furtan (1990). The original dataset contains annual observations from 1935 to 1985, for price and expenditure on land, machinery, fertilizers and chemicals and labour (Statistics Canada, 2009 and various years). The data from 1985-2006 were taken from a study by Clark et al. (2012) who updated the Karagiannis and Furtan data to study cost and distance functions. The data for research Canadian research expenditures (1956-2007) were compiled from Statistics Canada data sources. United States research expenditures from 1890-1990 are taken from Thirtle et al. (2002) and updated to 2006 from their US data sources. The longest overlapping time period for all data was 1958-2006. All data were normalized by the 2006 observation (therefore 2006=1.0).

3.1 Discussion of Results

Recall that empirical implication (1) implies that all the stochastic variables in the system are required to be I(1). This implication is tested using an augmented Dickey – Fuller (1979) (ADF) test. Table 1 presents the results of performing an ADF test on the stochastic variables in the system.

Table 1: Augmented Dickey Fuller Tests on Data (1958-2006)

Variable	Deterministic Variables included in Dickey Fuller Regression			
	Western Canada		Central Canada	
	Intercept	Intercept, trend	Intercept	Intercept, trend
Natural log of M/L	-1.29	-1.16	-2.28	-2.98
	(1)	(1)	(2)	(2)
Natural log of F/A	-2.09	-1.77	-3.40	-1.19
	(1)	(1)	(0)	(0)
Natural log of P_M/P_L	-1.43	-0.67	-2.40	-1.59
	(1)	(1)	(1)	(1)
Natural log of P_F/P_A	-1.84	-0.04	-2.32	-1.09
	(0)	(0)	(0)	(0)
	Western Canada & Central Canada			
	Intercept		Intercept, trend	
Natural log of RES_C	-1.82		-0.23	
	(0)		(0)	
Natural log of RES_{US}	-1.11		-1.60	
	(0)		(0)	

Note: (1) M=Machinery, L=Labor, F=Fertilizer, A=Land, P_M=Price of Machinery, P_L=Price of Labor, P_F=Price of Fertilizer, P_A=Price of Land, RES_C=Agriculture Research Expenditure in Canada, RES_{US}=Agriculture Research Expenditure in United State. (2) Value in parentheses is number of lagged first differences included in Dickey-Fuller regression.
Source: own calculations

The table indicates that for all cases, a unit root in the series cannot be rejected at the 5% level of significance. Furthermore, the conclusion that all series contain a unit root is invariant to the inclusion of only an intercept in the Dickey-Fuller regression or the inclusion of both an intercept and a time trend in the Dickey-Fuller regression. These results imply that there is strong support for empirical implication (1) for both Central and Western Canadian agriculture.

Table 2 provides results of variable addition tests (Park (1992)) for Western and Central Canadian agriculture. This test is based on the Park (1990) canonical cointegrating regression (CCR) estimator of model parameters. Two CCR model specifications are estimated. The first includes both the $\ln(P_M/P_L)$ and $\ln(P_F/P_A)$ in the CCR specification of the ln(M/L) and ln(F/A) equations (the specification given in equations (3) and (4)). The second does not include $\ln(P_F/P_A)$ in the ln(M/L) equation and does not include $\ln(P_F/P_A)$ in the ln(F/A) equation (the specification given in equations (1) and (2)) .

Table 2: Park (1992) Variable Addition test for cointegration for Western and Central Canadian Agriculture (1958-2006)

Superfluous Regressors	Central Canada			
	without other price		with other price	
	M/L	F/A	M/L	F/A
t^2	0.680	0.300	0.089	0.811
	(0.40)	(0.58)	(0.77)	(0.37)
t^2t^3	8.390	1.930	6.720	1.460
	(0.015)	(0.37)	(0.035)	(0.48)
$t^2t^3t^4$	9.440	4.700	6.750	2.560
	(0.024)	(0.19)	(0.080)	(0.46)
	Western Canada			
	without other price		with other price	
	M/L	F/A	M/L	F/A
t^2	0.33	0.069	1.33	0.056
	(0.56)	(0.79)	(0.66)	(0.81)
t^2t^3	0.36	1.33	4.04	0.424
	(0.83)	(0.51)	(0.13)	(0.81)
$t^2t^3t^4$	1.22	1.51	5.12	1.73
	(0.75)	(0.68)	(0.16)	(0.62)

Note: Value in parentheses is probability value.
Source: own calculations

Strictly speaking, as equation (1) and (2) indicate, only own price (and not other price) should be included. However, other authors (e.g. Thirtle et al. (2002) and Liu and Shumway (2009)) undertake tests for cointegration with both prices included in the long run specification of the factor ratios.

The table indicates that cointegration cannot be rejected for either the ln(M/L) equation or the ln(F/A) for either Central or Western Canadian agriculture when all prices are included in the long run specification of the model. A conclusion of cointegration among variables is reached for Western Canadian agriculture when other price is dropped from the cointegrating regression. For Central Canada, cointegration is rejected for the ln(M/L) equation when other price is dropped from the CCR and is not rejected for the ln(F/A) equation. These results indicate that Western Canadian agriculture is consistent with empirical implication (2) but there is evidence against implication (2) for Central Canada, particularly for the ln(M/L) equation when other prices is dropped for the CCR specification.

Table 3 presents results of imposing two types of restrictions on the long-run specification of the ln(M/L) and ln(F/A) for Central and Western Canadian agriculture using the maximum likelihood estimator of Johansen (1991) with structural modelling approach developed by Pesaran and Shin (2002). Tests using lag lengths of two, three, four and five are presented (the Schwartz criterion minimized at lag length five for both regions, based on an unrestricted vector autoregression).

Table 3: Restricted maximum likelihood estimates of two stage CES parameters.

	Central Canada		Western Canada			
	Lag length=2		Lag length=3		Lag length=5	
Natural log of	M/L	F/A	M/L	F/A	M/L	F/A
Intercept	1.03	-1.38	0.906	-1.79	0.876	-1.854
Trend	-0.025	0.031	-0.021	0.041	-0.02	0.045
Natural log of P_M/P_L	-1.11		-1.197		-1.211	
Natural log of P_F/P_A		-0.80		-1.059		-1.042
Natural log of RES_C	0.11	-0.20	0.197	0.059	0.211	0.042
Natural log of RES_{US}	0.11	-0.20	0.197	0.059	0.211	0.042

Source: own calculations

Both of these tests assume there are two cointegrating relationships for input ratios both regions. Given the results of the previous table, this may not be a plausible conclusion for Central Canadian agriculture, especially for long run movements in the Machinery/Labour factor ratio. The first is a test that US research expenditures do not affect factor ratios for either region. The second is a test that all of the restrictions implied by the choice of the two stage CES given by equations (5) and (6).

The table indicates that the hypothesis that US research expenditures do not affect Canadian factor price ratios is rejected at the 5% level of significance at all lag lengths for Western Canadian agriculture and at all lag lengths except lag length two for Central Canada. Based on these results, we find evidence in support of empirical implication 6 in these data, or that US research expenditures are found to be important in the explanation of the long run movements of factor input ratios for Central and, especially for, Western Canadian agriculture.

The second part of the table presents tests of restrictions implied by the choice of the two stage CES function. Here the restrictions implied by the two stage CES function are not rejected for lag length two for Central Canadian agriculture and for lag lengths three and five for Western Canadian agriculture. Given that the Schwartz criterion minimizes at lag length five for both regions, the results of the tests seems most plausible for Western Canadian agriculture. Therefore, empirical implication 7 seems finds the most support in Western Canadian agriculture.

Table 4 presents the results of maximum likelihood estimates of parameters imposing the restrictions implied by the two stage CES function when likelihood ratio tests are not rejected from table (3) (i.e. lag length two for Central Canadian agriculture and lag length three and five for Western Canadian agriculture). From these results, implication (3), that of negative correlation between factor input ratios and own factor prices can be examined.

Table 4: Likelihood ratio tests of long run CES parameters.

Lag-Length	Central Canada		Western Canada	
	US Expenditures=0	CES	US Expenditures=0	CES
2	6.25	12.00	12.16	36.85
	(0.04)	(0.06)	(0.00)	(0.00)
3	27.40	26.68	15.72	1.77
	(0.00)	(0.00)	(0.00)	(0.94)
4	21.30	27.40	80.12	31.57
	(0.00)	(0.00)	(0.00)	(0.00)
5	108.17	57.09	43.00	5.41
	(0.00)	(0.00)	(0.00)	(0.49)

Note: Value in parentheses is probability value.
Source: own calculations

The table indicates that parameter elasticity estimates are consistent with the IIH for both regions because in all cases the own price coefficient is negative. For Central Canadian agriculture, the estimated long-run elasticity of substitution between machinery and labour is 1.11 and for fertilizer and land 0.80. The long run elasticity for research expenditures is 0.11 for the machinery/labour factor ratio and -0.20 for the fertilizer/land factor ratio. For Western Canadian agriculture, there is very little difference of elasticity estimates between the lag length three and lag length five estimates. The elasticity of substitution between machinery labour is 1.197 for lag length three and 1.21 for lag length five and the elasticity of substitution between fertilizer and land is 1.059 for lag length three and 1.042 for lag length five. The corresponding lag length three and lag length five elasticities for research expenditures for the machinery/labour factor ratio is 0.197 and 0.211 respectively and for the fertilizer/land factor ratio is 0.059 and 0.042 respectively.

The final set of results that will be presented relate to implication 5, that causality runs from input prices to quantities and not from input quantities to prices and empirical implication 7, that causality runs from prices to research expenditures. These implications are tested using Granger (1969) tests based on an unrestricted vector autoregression with a lag length of five (based on the minimization of the Schwartz criterion). These results are presented in table 6.

Table 5: Granger Causality Results.

Region	Result	F Statistic	Probability Value
Western Canada	P Granger Causes Q	2.14	0.008
	Q Granger Causes P	1.08	0.032
	P Granger Cause Research Expenditures	1.27	0.21
Central Canada	P Granger Causes Q	1.92	0.021
	Q Granger Causes P	1.43	0.13
	P Granger Causes Research Expenditures	1.44	0.18

Source: own calculations

Table 5 indicates that empirical implication 5, that causality runs from price ratios to input quantity ratios but not from input quantity ratios to input price ratios, is supported in the data from Central Canadian agriculture and mildly supported for Western Canadian agriculture. The hypothesis that price do not Granger cause quantities is rejected at the 1% level of significance for Western Canada and the 5% level of significance for Central Canada. In contrast, the hypothesis that quantities do not Granger cause prices is not rejected for Central Canada at the 10% level of significance but only the 1% level of significance for Western Canada

Granger causality tests for factor price to research expenditures are not supported by the data in either region. For Central Canada, the hypothesis that prices do not Granger cause research expenditures is not rejected to the 10% level of significance for both Central Canadian agriculture and Western Canadian agriculture.

4 Conclusion

Our results are summarized below:

Empirical Implication	Central Canada	Western Canada
All variables in the system are balanced. Assuming the variables in model are integrated, then this implies that the variables are I(1)	Cannot reject	Cannot reject
There are two cointegrating vectors given the stochastic variables in the system. There is one cointegrating vector for the machinery/labour equation and one cointegrating vector for the fertilizer/land equation	Cannot reject when all prices included Reject when other price is dropped	Cannot reject when all prices included Cannot reject when other price is dropped
Factor prices and quantities are negatively correlated over the long run	Cannot reject	Cannot reject
Current factor prices do not completely explain factor substitution	Not tested directly	Not tested directly
Causality runs from prices to quantities but not quantities to prices	Cannot reject	Cannot reject
CES specification holds	Cannot reject for lag 2 If fix at 5, then reject	Cannot reject for lag 3 and 5 If fix at 5, cannot reject
Research expenditures in US do not spillover to Canada	Cannot reject for lag length 2 Reject for all other lag lengths	Reject for all lag lengths
Prices cause research expenditures	Cannot reject at all lag lengths except length 2	Cannot reject at all lag lengths

We conclude that there is broadly consistent support for the induced innovations hypothesis for Canadian agriculture, especially for Western Canadian Agriculture. This is consistent with Karagiannis and Furtan (1990) for Canadian Agriculture and Thirtle et al. (2002) for US agriculture, but not with a more recent study by Liu and Schmway (2009) on US Agriculture.

In addition, there is support for the notion the US as well as Canadian research expenditures are important to the explanation of input ratio movements in Canadian Agriculture in the long run. This could indicate the existence of spillover effects that run from US agricultural research to Canadian Agriculture.

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Who gains and who loses from China's growth?

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Annotation: Recent trade evolutions credit China with a large and growing market potential, and explain the increasing attractiveness of the Chinese market to foreign producers. In 2007 one tenth of internationally traded products were shipped to China. The present paper aims to determine the countries that profit and suffer the most from the recent expansion of the Chinese market. We use an econometric shift-share methodology that permits to identify for each trade flow the share of growth arising from the capacity to target the products and markets with the highest increase in demand, and the share due exclusively to exporter's performance. Export dynamics specific to each country (exporter) are estimated for the Chinese market and compared to those of the global market, for all internationally traded products and agri-food products alone. We estimate the contribution of countries' geographical and sectoral structure, and their export performance to the evolution of their market shares, and differentiate between changes in export volumes and prices.

Key words: International trade, Export performance, Market shares, Shift-Share, China.

1 Introduction

One of the most remarkable features that characterized international trade over the last two decades is the transformation of China into the world's largest exporter. In the early 1990s, Chinese products accounted for less than 5% of the world market; by the end of the 2000s, more than one sixth of the value of merchandises traded worldwide originates from China. This impressive market share gain was achieved at the extend of losses experienced by other exporters, especially the ones from the developed world. At the same time, the rising Chinese share in world exports sustained the expansion of the country's domestic and import demand. Two factors lie at the heart of China becoming a major outlet for world production. On one hand, due to increasing outsourcing of world production to China, the country's exports incorporate a large share of imported inputs. Parts and components represent one third of China's imports, compared to less that 20% at the global level. On the other hand, the rapid growth of Chinese exports has increased the purchasing power of domestic consumers and their demand for foreign produced goods. Both trends led to a strong increase in China's import capacity. Unsurprisingly, selling to the Chinese market has become a priority for most countries and large exporting firms, and the Chinese market is often referred to as the new driver of the world economy.

Exporting to China can be very different from exporting to the rest of the global market or traditional trade partners and therefore very challenging. Which countries have profited the most which the less from this increase in the size of the Chinese market? Are the best performers on the Chinese market also the ones that cope the best with the global competition? Which products sell the best on the Chinese relative to the global market? This paper aims at answering these questions by identifying recent changes in specialization and market shares of leading world exporters.

We use an econometric shift-share analysis that allows us to identify for each country the share of export growth arising from the capacity to target the products and markets with the

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highest increase in demand, and the share due exclusively to its exporting performance. This methodology applies only to the intensive margin of trade, i.e. the same products exchanged between the same partners in two different years, as growth rates can be computed only for these trade flows. Symmetrically, the extensive margin is the net value of appearing and disappearing trade flows. While a rapid turnover of trade flows can be observed in a world matrix mostly ``filled'' with zeros, the largest contribution to the growth of trade on both global and Chinese markets was the intensive margin.[2]

Using an econometric shift-share analysis, we compute for each exporting country the amount of growth that can be imputed to the geographical and sectoral composition of its exports and the amount owed to its proper efforts, i.e. export performance. These intrinsic export growths differ from the overall growth rates of exports for the corresponding categories (country, partner, or product) due to composition terms. Thus, only part of the growth rate of European exports reflects the efforts undertaken by exporting countries. Some of the growth comes from the above world average increase in the import demand of EU partner countries, and some is due to the above world average increase in the world demand for products exported by the EU. In the end, the intrinsic export growth attributable to the EU may be even negative.

Similar export dynamics specific to each country (exporter) and product are estimated for the Chinese market and compared to those of the global market. For that, we perform a shift-share analysis of exports to China alone. Accordingly, we are able to separate the evolution of the `pure' Chinese import demand from the growth rate of the Chinese market. To simplify the comparison across countries and import markets, all terms are expressed as percentage shifts of initial (1995) market shares.

The rest of the paper is organized as follows. Section 2 shows the redistribution of global and Chinese market shares among exporters and sectors over the 1995-2007 period, and the trade dynamics of the global and Chinese markets. In section 3, we discuss the decomposition of changes in countries' market shares obtained with the shift-share methodology, the contribution of price fluctuations and volume changes, and evolutions in terms of value-added (i.e. after correcting for the foreign content of exports). Concluding remarks are formulated in section 4.

2 Methods

Table 1 summarizes the recent changes in world market shares. I consider all exchanged products, i.e. the primary and the manufacturing sectors, with the exception of mineral products, notably oil, as well as some specific and non classified sectors. Intra-EU27 trade flows are excluded to allow the comparison of European countries with other exporters.[3] The first column gives the share of the global market in 2007 of largest world exporters.[4] The second column shows the percentage point changes in market shares over the 1995-2007 period. The last two columns display similar figures for the Chinese market. Similar evolutions for trade in agri-food products, corresponding to HS2 chapters 1 to 24, are displayed in Table 2.

The most remarkable evolution in Table 1 is that China has almost tripled its world market share since the mid-1990s, becoming a trade giant, second only behind the EU27. The EU market share has been fairly affected by the ten-point rise of China over the same period. In

[2] Hereafter the Chinese market designates the sum of Chinese imports, or the sum of trade flows having China as destination.

[3] See Appendix \ref{sec data} for details.

[4] For the simplicity of the exposal only countries and group of countries that account for at least 1% of world trade in all years from 1995 to 2007 are shown. Data on other countries can be provided upon request.

contrast, Japan and the US have lost over five percentage points of market shares each. Evolutions were less spectacular for developing countries given their smaller shares in world exports. Most of them managed to increase their exports at a pace at least equal to the growth rate of global trade.

Table 1: The distribution of export market shares over 1995-2007, all products

	The global market		*The Chinese market*	
	2007 share, %	1995-2007 Δ, p.p.	2007 share, %	1995-2007 Δ, p.p.
EU27	19.4	*-1.22*	16.2	*-2.53*
France	2.3	*-0.54*	2.0	*-0.96*
Germany	5.5	*-0.09*	5.8	*0.96*
Italy	2.3	*-0.41*	1.7	*-1.27*
United Kingdom	2.0	*-0.79*	1.5	*-0.98*
United States of America	13.0	*-5.25*	10.3	*-2.09*
Japan	8.9	*-5.31*	17.8	*-4.30*
Canada	3.8	*-1.42*	1.2	*-0.72*
Switzerland	2.3	*-0.56*	1.2	*-0.51*
China	15.5	*9.22*		
Brazil	1.7	*0.27*	0.9	*0.25*
India	1.7	*0.62*	1.4	*0.43*
Indonesia	1.2	*0.06*	1.1	*-0.33*
Korea	4.4	*0.57*	11.6	*3.57*
Malaysia	2.1	*-0.28*	3.1	*0.33*
Mexico	2.8	*0.59*	0.3	*0.01*
Taiwan	3.6	*-0.12*	15.9	*2.18*
Singapore	2.0	*-0.75*	4.7	*0.07*
Thailand	1.9	*0.14*	3.1	*1.00*
Middle East and North Africa	4.0	*1.54*	1.6	*0.32*
Sub-Saharan Africa	1.6	*0.10*	0.8	*-0.15*
Rest of the World	9.9	*1.80*	8.8	*2.48*

Notes: Author's calculations. Oil and intra-EU 27 trade are excluded. The change in market shares is given in percentage points (p.p.).

Another important dynamic over the 1995-2007 period is the transformation of China also into a large importer. In 2007 9.7% of the goods traded internationally were shipped to China. Combined with the two-digit growth rate of Chinese production, this makes China a very attractive market. Its capacity to drive world trade and economic growth was confirmed during the 2008-2009 crisis and is being tested again as many industrialized countries are threatened by a deep economic recession.

If we consider the Chinese market alone, only Germany and a few large Asian exporters (Korea, Taiwan, Thailand) succeeded to increase substantially their market shares. For the US, Japan and Canada, their losses on the Chinese market were smaller than on the extra-Chinese market. This reveals their capacity to sell better domestic production to China than to the global market. Differently, the position of most European countries deteriorated more on the Chinese market.

Next, we focus on the contribution of different factors to the growth of exports. We focus exclusively on the intensive margin of trade, i.e. on trade flows that involve the same partners and traded products in at least two consecutive years from 1995 to 2007. We ignore trade flows created or disappeared throughout the period, for which one cannot compute growth rates. This does not affect much our results, since at our level of disaggregation the bulk of the growth in world trade comes from a larger volume of goods being exchanged via previously established trade partnerships. We decompose the intensive margin of exports using an econometric shift-share methodology, and analyze the export growth specific to each exporter and product category on the global and the Chinese markets.

Table 2: The distribution of export market shares over 1995-2007, agri-food products

	The global market		*The Chinese market*	
	2007 share, %	1995-2007 Δ, p.p.	2007 share, %	1995-2007 Δ, p.p.
EU27	15.3	*-2.45*	9.4	*-6.02*
France	2.7	*-0.52*	2.6	*-1.87*
Germany	1.8	*-0.46*	0.9	*-1.44*
Italy	1.6	*0.16*	0.5	*0.18*
United Kingdom	1.3	*-0.81*	1.0	*-2.11*
United States of America	14.4	*-5.08*	19.6	*-2.93*
Japan	0.6	*-0.20*	2.8	*-1.17*
Canada	6.9	*2.57*	3.6	*-6.49*
Switzerland	0.7	*-0.59*	0.2	*-0.14*
China	5.1	*0.08*		
Brazil	0.9	*0.02*	11.6	*6.69*
India	5.7	*1.17*	1.5	*0.58*
Indonesia	2.3	*0.32*	5.2	*2.51*
Korea	2.8	*0.87*	1.5	*-0.60*
Malaysia	0.6	*-0.46*	8.3	*2.15*
Mexico	2.6	*0.29*	0.3	*0.12*
Taiwan	2.4	*0.41*	0.9	*-0.56*
Singapore	0.4	*-1.02*	1.7	*-1.89*
Thailand	2.9	*-0.54*	4.6	*-3.79*
Middle East and North Africa	5.1	*1.29*	1.1	*0.69*
Sub-Saharan Africa	4.2	*-0.29*	1.5	*0.48*
Rest of the World	27.1	*3.61*	26.3	*10.38*

Notes: Author's calculations. Intra-EU 27 trade are excluded. The change in market shares is given in percentage points (p.p.).

In the field of international trade, the traditional shift-share analysis, also known as the *constant market share analysis*, aims to measure the contribution of countries' geographical and sectoral specialization to the growth of their exports (Tyszynski, 1951; Richardson, 1971a, 1971b; Fagerberg, 1988). The method simply aims at computing the contribution of the initial geographical and sectoral composition of exports to changes in market shares. The remaining part of the change is attributed to pure performance (i.e. price and non-price competitiveness).

Departing from this traditional analysis, we rely here on an econometric shift-share methodology developed by Cheptea et al. (2012) and Cheptea (2012). Rather than using a simple balance-sheet decomposition of growth rates into structural and competitiveness effects, we use a weighted variance analysis. Firstly, structural and performance contributions to export growth rates, expressed as changes in logarithms, are estimated from highly disaggregated data with weighted OLS. Secondly, estimated exporter, importer and product effects are aggregated into country-specific structural and performance effects. The resulting decomposition of export growth rates (in logarithmic form) is then transposed into a decomposition of changes in global market shares. Finally, we switch from log-linearized growth rates to true growth rates in order to obtain results comparable with previous ones. To use the information on time variations in the data, we focus on the sum of annual growths of each trade flow rather than on the increase in its value between the first and last years of a period. Therefore, our method is constrained by the observation of the same flow in two consecutive years (necessary for computing annual growth rates), i.e. it applies only to the intensive margin of trade.[5]

We regress export growths on country, partner and sector (HS 2-digit) fixed effects. Normalized estimated effects α_i^t, β_j^t and γ_k^t give the intrinsic contribution of each exporter (*i*), importer (*j*) and product category (*k*) to the growth of exports on the global market in time *t*:

$$d\ln X_i^t = \alpha_i^t + \Sigma_j \left(\frac{w_{ij}^t}{w_i^t}\right)\beta_j^t + \Sigma_k \left(\frac{w_{ik}^t}{w_i^t}\right)\gamma_k^t. \quad (1)$$

In equation (1) $d\ln X_.^t$ and $w_.^t$ stand for the growth of exports towards all world partners in time period *t* and, respectively, the average weight of flows in global trade. We choose to express the growth rate of country *i*'s exports as a Törnqvist index of growth rates of disaggregated trade flows, i.e. as a weighted average of the logarithmic change in its exports of each product *k* to each partner *j*:

$$d\ln X_i^t = \Sigma_{jk}\left(\frac{w_{ijk}^t}{w_i^t}\right)\ln\frac{X_{ijk}^t}{X_{ijk}^{t-1}} = \Sigma_{jk}\left(\frac{w_{ijk}^t}{w_i^t}\right)d\ln X_{ijk}^t. \quad (2)$$

Similar effects, except for importers, (α_{iJ}^t and c_{kJ}^t) are estimated for shipments towards China (*J*):

$$d\ln X_{iJ}^t = \alpha_{iJ}^t + \Sigma_k\left(\frac{w_{iJk}^t}{w_{iJ}^t}\right)c_{kJ}^t. \quad (3)$$

Figure 1 pictures the annual growth rates of exports towards the global and Chinese markets. The evolution of the import capacity of both markets followed more or less the same peaks and downturns. However, in the middle of the period (from 2000 to 2004) exports to China grew much more rapidly. This resulted in an overall increase in Chinese imports from 1995 to 2007 of 247%, while world trade grew by only 151%. Differently, the intrinsic growth of China's import demand, corresponding to parameter β_J^t, was considerably lower: 69% for the entire 1995-2007 period. Still, this figure is largely above the trade dynamics of most other import markets. Among the twenty-two countries and groups of countries listed in Table 1, only India's intrinsic import demand grew faster. The large gaps between the increase of the intrinsic Chinese demand and the overall growth of Chinese imports reveal the fact that a significant part of the expansion the Chinese market was driven by the strong export dynamics of its trade partners and the strong demand for products they exchange with China. In other words, China imported a lot from countries with the best export performances and in products with the most rapidly growing global demand.

[5] In the context of the recent economic crisis this type of analysis gained interest among economists: Brenton and Newfarmer (2007), Cafiso (2009), ECB (2005), Amador and Cabral (2008), Jimenez and Martin (2010), Panagiotis et al. (2010), Finicelli et al. (2011).

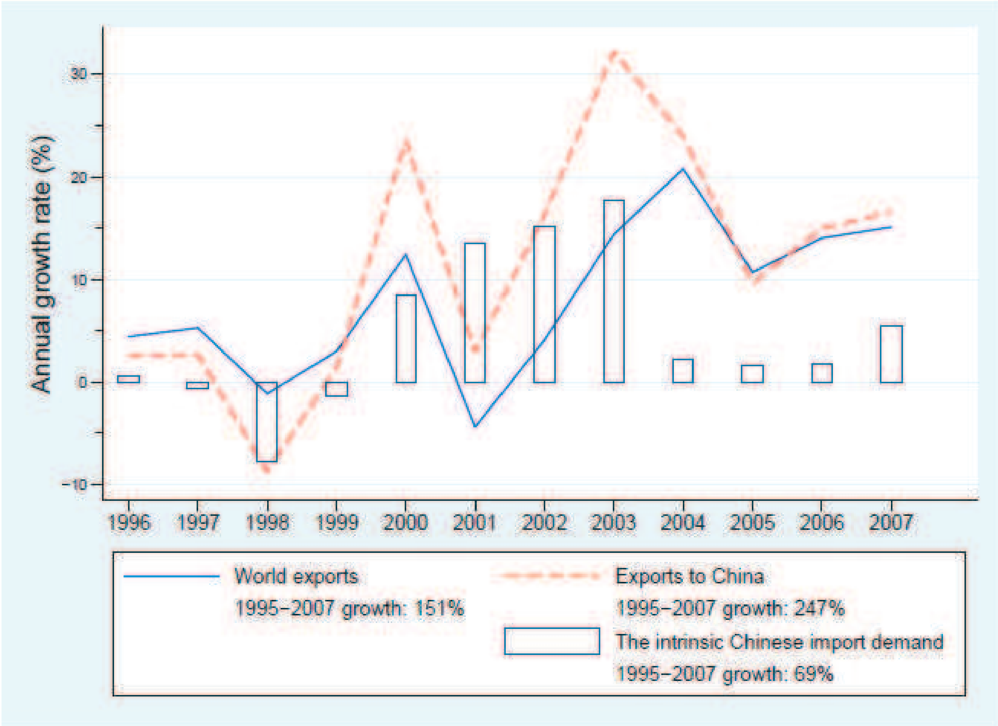

Fig. 1: Exports growth on the global and Chinese markets, 1995-2007

3 Results and Discussion

The present section is dedicated to the decomposition of changes in countries' shares of the global and Chinese markets, at the intensive margin, into export performance and structure effects. We compute the latter using exporter-, importer- and product-specific effects discussed in section 2. Our objective is to identify the countries with the best and the poorest resilience in terms of their global and Chinese market shares. We focus here only on the intensive margin of exports, which reflects 97.2% of growth in world exports and 99.9% of the increase in exports having China as destination. Therefore, the conclusions reached for this component of exports' growth can be safely generalized.

Table 3 displays the evolution of global market shares of main exporters between 1995 and 2007 and its decomposition into exporter-specific performance, geographic and sectoral structure effects:

$$g_i = \exp\left(\sum_t d\ln\left(\frac{X_i^t}{X^t}\right)\right) - 1 = [1 + PERF_i] * [1 + GEO_i] * [1 + SECT_i] - 1. \quad (4)$$

The *export performance* ($PERF_i$) is the change in a country's market share driven by country-specific factors. This is the increase in market shares one would observe in the absence of any differences in the product composition and the geographical orientation of country's exports and world trade. Structural effects (GEO_i and $SECT_i$) reflect the contributions of the country's exports structure by partner and product to the overall growth of its exports. A large positive (negative) structure effect corresponds to a share of country' exports in products and to import markets with strongly growing demand higher (lower) than the world average. More precisely, we define:

$$PERF_i = \exp\left(\sum_t (\alpha_i^t - d\ln X^t)\right) - 1; \quad (5)$$

$$GEO_i = \exp\left(\sum_t \sum_j \left(\frac{w_{ij}^t}{w_i^t}\right)\beta_j^t\right) - 1; \tag{6}$$

$$SECT_i = \exp\left(\sum_t \sum_k \left(\frac{w_{ik}^t}{w_i^t}\right)\gamma_k^t\right) - 1. \tag{7}$$

The decomposition is obtained for each country and year within the considered period, and, since growth rates are computed as changes in logarithms, country-level *export performance*, *geographic* and *sectoral structure* effects for the entire period are obtained by summing up the corresponding annual effects.

Table 3: Decomposition of changes in world market shares, 1995-2007, all products

	Change in market share (%)	Contribution of:		
		Performance	Structure effects	
			Geographic	Sectoral
	(1)	(2)	(3)	(4)
EU27	-5.0	-17.3	6.0	8.4
France	-19.0	-31.7	5.2	12.9
Germany	-0.6	-15.3	4.8	11.9
Italy	-14.9	-16.1	8.2	-6.3
United Kingdom	-29.6	-39.2	1.0	14.5
United States of America	-28.1	-36.2	4.4	8.0
Japan	-37.7	-43.3	-1.6	11.6
Canada	-26.0	-16.8	-14.4	3.9
Switzerland	-15.7	-26.4	1.4	13.0
China	155.2	264.8	-12.2	-20.4
Brazil	24.3	49.9	-1.7	-15.7
India	59.2	88.4	4.7	-19.3
Indonesia	8.0	49.2	-7.4	-21.9
Korea	16.7	12.2	3.4	0.6
Malaysia	-11.5	-0.4	-9.9	-1.4
Mexico	29.0	47.5	-14.2	1.9
Taiwan	-6.1	-10.6	8.0	-2.8
Singapore	-24.3	-28.3	-1.0	6.6
Thailand	11.0	35.1	-8.3	-10.5
Middle East and North Africa	50.6	53.2	10.5	-11.0
Sub-Saharan Africa	0.8	16.2	-2.6	-11.0
Rest of the World	12.9	24.1	3.7	-12.2

Notes: Author's calculations. The estimation is performed at the 2-digit level of the HS and explain the annual growth of all trade flows existing in any two consecutive years in the period 1995-2007. The following identity between columns holds: ln((1)=100+1) = ln((2)=100 + 1) + ln((3)=100 + 1) + ln((4)=100 + 1).

According to Table 3, the 5% loss of EU's share of the global market on the intensive margin is mainly due to its poor export performance (-17.3%), partially compensated by favorable geographic (6.0%) and sectoral (8.4%) structure effects. Market share losses suffered by developed economies, already documented in section 2, were the result of their poor global export performances. The good positioning in terms of best selling products and most dynamic trade partners only hindered the contraction of these countries' shares of the global market. On the opposite, emerging economies reinforced their positions as world exporters by increasing the overall competitiveness of their exports and despite the adverse sectoral and geographic structure effects.

Table 4: Decomposition of changes in Chinese market shares, 1995-2007, all products

	Change in market share (%)	Contribution of:		Contribution of:	
		Perfor-mance	Sectoral structure	*Price* evolutions	*Volume* evolutions
	(1)	(2)	(3)	(4)	(5)
EU27	-14.5	-18.3	4.7	11.9	-23.6
France	-35.5	-46.8	21.2	-31.7	-5.6
Germany	19.2	7.6	10.7	12.7	5.8
Italy	-43.2	-28.2	-20.9	20.7	-52.9
United Kingdom	-40.2	-41.6	2.4	37.0	-56.3
United States of America	-17.9	-23.9	7.9	-1.8	-16.4
Japan	-19.5	-25.3	7.7	7.7	-25.3
Canada	-39.4	-28.6	-15.1	37.7	-56.0
Switzerland	-30.5	1.2	-31.4	-1.3	-29.6
Brazil	35.7	27.6	6.4	4.3	30.0
India	47.4	108.8	-29.4	-3.0	52.0
Indonesia	-23.2	-12.9	-11.8	-11.0	-13.7
Korea	43.8	53.2	-6.1	35.9	5.8
Malaysia	11.5	5.0	6.2	66.3	-33.0
Mexico	24.4	16.3	7.0	73.2	-28.2
Taiwan	16.0	17.0	-0.9	-37.9	86.8
Singapore	1.0	-12.4	15.3	-43.3	78.1
Thailand	57.9	106.7	-23.6	9.4	44.3
Middle East and North Africa	28.8	49.6	-13.9	25.9	2.3
Sub-Saharan Africa	-16.6	11.3	-25.1	109.4	-60.2
Rest of the World	44.2	66.1	-13.2	66.3	-13.3

Notes: Author's calculations. The estimation is performed at the 2-digit level of the HS and explain the annual growth of all trade flows existing in any two consecutive years in the period 1995-2007. Columns (4) and (5) give the contribution of the evolution of prices and volumes to changes in shares of the Chinese market. The following identities between the different columns hold: ln((1)=100 + 1) = ln((2)=100 + 1) + ln((3)=100 + 1) and ln((1)=100 + 1) = ln((4)=100 + 1) + ln((5)=100 + 1).

In Table 4, we report the decomposition of changes in exporters' shares of the Chinese market. Columns 2 and 3 of the table reflect the contribution of exporter-specific performance and sectoral structure effects:

$$g_{iJ} = \exp\left(\sum_t d\ln\left(\frac{x_{iJ}^t}{x_J^t}\right)\right) - 1 = [1+PERF_{iJ}] * [1+SECT_{iJ}] - 1. \quad (8)$$

where $PERF_{iJ}$ and $SECT_{iJ}$ are computed similarly to $PERF_i$ and $SECT_i$:

$$PERF_{iJ} = \exp\left(\sum_t \left(\alpha_{iJ}^t - d\ln X_J^t\right)\right) - 1; \quad (9)$$

$$SECT_{iJ} = \exp\left(\sum_t \sum_k \left(\frac{w_{iJk}^t}{w_{iJ}^t}\right) c_{kJ}^t\right) - 1. \quad (10)$$

The last two columns of Table 4 correspond to shifts in market shares induced by changes in prices and volumes. To obtain market share evolutions in terms of volumes, we deflate all trade values expressed in current USD, X_{ijk}^{t}, with trade indices computed for each exporter × importer × HS2 relationship. The procedure is similar to Fontagne et al. (2008) and relies exclusively on trade values and unit values available in the BACI database. Trade indices for each pair of countries and HS2 chapter are computed as chained Tornqvist indices of unit value ratios of traded HS 6-digit products within the chapter. The year 2000 is taken as reference, meaning that 2000 trade flows in constant and current/volume terms are equal. The difference between the evolution of trade expressed in current and constant/volume terms is attributed to price fluctuations.

Table 5: Decomposition of changes in world market shares, agri-food products, 1995-2007

	Change in market share (%)	Contribution of:		
		Performance	Structure effects	
			Geographic	Sectoral
	(1)	(2)	(3)	(4)
EU27	-3.2	-8.4	0.6	5.1
France	-21.0	-26.5	0.5	6.8
Germany	8.7	5.3	2.5	0.7
Italy	4.1	-3.9	-4.2	13.0
United Kingdom	-34.7	-46.3	10.6	10.1
United States of America	-24.8	-29.4	6.0	0.6
Japan	-65.1	-44.9	-37.6	1.4
Canada	10.4	10.0	1.7	-1.3
Switzerland	-4.2	-6.5	-2.4	5.0
China	36.4	90.6	-25.0	-4.6
Brazil	81.1	99.5	1.3	-10.4
India	22.9	37.6	4.2	-14.3
Indonesia	57.4	70.0	0.7	-8.0
Korea	-48.0	-31.9	-24.4	1.0
Malaysia	17.4	9.8	12.9	-5.3
Mexico	27.1	14.0	8.1	3.2
Taiwan	-77.7	-68.2	-25.2	-6.4
Singapore	-47.3	-48.4	-2.6	5.0
Thailand	-15.6	-7.0	-5.1	-4.4
Middle East and North Africa	10.9	9.2	2.6	-1.0
Sub-Saharan Africa	-6.5	-2.5	5.9	-9.4
Rest of the World	11.3	17.5	-0.4	-4.9

Notes: Author's calculations. The estimation is performed at the 2-digit level of the HS and explain the annual growth of all trade flows existing in any two consecutive years in the period 1995-2007. The following identity between columns holds: ln((1)=100+1) = ln((2)=100 + 1) + ln((3)=100 + 1) + ln((4)=100 + 1).

Overall, the role of performance and structure effects in explaining changes is shares of the Chinese market are similar to country-level evolutions observed at the global level. The position of industrialized countries weakens although they export the products mostly demanded by Chinese firms and consumers. The only exception is Germany who increased in twelve years its share of the Chinese market by 19%, corresponding to 1 p.p. Other European countries, on the contrary, were much less performing that on the world market. In turn, developing countries benefited the most from the increasing size of the Chinese import demand. This is particularly the case of China's traditional trade partners (Korea, Taiwan, Malaysia, Thailand), but also that of Latin American countries (Brazil, Mexico, Argentina, Chile). The latter succeeded to expand their sales on the Chinese market by mainly targeting the products with fast growing demand.

If we ignore price evolutions, market share losses of most developed countries in China were even more pronounced. The increase in the unit value of products exported by these countries to Chinese partners (up to 38% for Canada) could not compensate for the contraction of Chinese demand for these products in volume (real) terms. The main exception to this trend are French exporters who lost shares of the Chinese market mainly because of the drop in the price of exported products. Price evolutions are very heterogeneous and even larger across developing countries. This is due to larger exchange rate appreciations/depreciations observed for these countries, a main element of price evolutions. For example, Malaysia and Mexico compensate their large market shares losses in real terms by an about 70% price increase in the price of exported goods. On the contrary, Singapore and Taiwan reinforced their positions on the Chinese market as their exports became around 40% cheaper.

Table 6: Decomposition of changes in Chinese market shares, agri-food products, 1995-2007

	Change in market share (%)	Contribution of:		Contribution of:	
		Perfor-mance	Sectoral structure	*Price* evolutions	*Volume* evolutions
	(1)	(2)	(3)	(4)	(5)
EU27	-53.0	-59.2	15.2	-35.1	-27.6
France	-58.7	-73.8	57.8	-31.7	-39.5
Germany	-64.6	-66.9	6.8	-21.1	-55.2
Italy	72.7	45.5	18.7	-21.8	120.8
United Kingdom	-75.7	-77.4	7.4	-24.6	-67.8
United States of America	-17.1	-35.1	27.7	-2.0	-15.4
Japan	-27.7	-35.6	12.3	-9.0	-20.5
Canada	-63.7	-17.9	-55.8	-7.7	-60.7
Switzerland	-45.3	-49.7	8.9	-58.2	31.0
Brazil	176.1	62.5	69.9	-43.5	388.5
India	88.1	29.3	45.5	-17.4	127.8
Indonesia	100.3	51.0	32.6	-16.2	139.0
Korea	-27.2	-4.7	-23.6	-21.6	-7.1
Malaysia	40.4	25.6	11.8	-14.1	63.4
Mexico	63.6	76.4	-7.2	-48.1	215.3
Taiwan	-39.7	-58.1	43.7	-51.7	24.9
Singapore	-49.4	-52.3	6.0	44.4	-65.0
Thailand	-42.0	35.8	-57.3	-22.5	-25.1
Middle East and North Africa	210.0	277.8	-18.0	-10.9	247.7
Sub-Saharan Africa	51.5	61.6	-6.3	-1.8	54.3
Rest of the World	88.4	91.7	-1.7	72.8	9.0

Notes: Author's calculations. The estimation is performed at the 2-digit level of the HS and explain the annual growth of all trade flows existing in any two consecutive years in the period 1995-2007. Columns (4) and (5) give the contribution of the evolution of prices and volumes to changes in shares of the Chinese market. The following identities between the different columns hold: ln((1)=100 + 1) = ln((2)=100 + 1) + ln((3)=100 + 1) and ln((1)=100 + 1) = ln((4)=100 + 1) + ln((5)=100 + 1).

Tables 5 and 6 show decomposition of countries' market shares evolution on the global and Chinese markets for agricultural and food products (HS2 chapters 1 to 24), according to equations (4) and (5), respectively.

Differences between the contribution of different factors, for developed and developing countries, are better visualized in a graphical representation of market share evolutions from Tables 4 and 6 (Figures 2 and 3 of Appendix B). To ease comparisons, evolutions are expressed in logarithms of shifts in exporters' shares of the Chinese demand. Performance and structure bars (log-effects) add up to give the logs of market share shifts. The same is true for price and volume bars (log-effects).

4 Conclusions

Emerging countries have been winning large market shares since the early 1990s. Among these, China stands out with the most remarkable performance: it almost tripled its world market share and has become a leading exporter, second only to EU~27. Recent evolutions also reveal the large and growing potential of the Chinese market and its increasing attractiveness to foreign producers. The present paper attempts to identify the countries that have profit the most from the expansion of the Chinese market.

To answer this question, an econometric shift-share methodology is employed. For each exporter the share of trade growth arising from the capacity to target the products and markets with the highest increase in demand, and the share due exclusively to the country's own export performance are identified. This methodology applies only to the intensive margin of trade, which captures in our case the bulk of the growth. Exporter, importer and product specific contributions to export growth rates are estimated from highly disaggregated data with a weighted variance analysis, and then aggregated into country-specific structural and performance effects. The resulting decomposition of export growth rates is then transposed into a decomposition of changes in market shares to obtain comparable results. We use detailed longitudinal trade data on an exhaustive basis from the BACI database. Shifts in shares of the global and Chinese market, expressed in percentage of the initial share, and their decomposition into performance and structural effects are computed for each exporting country.

We find that countries that profit the most from the expansion of the Chinese economy are its traditional trade partners (except Japan), Germany, and large Latin American countries (Brazil and Mexico). For the first group of countries, the main driving forces were the specificities of the bilateral relationship with China (geographical proximity, trade agreements, complementarity of production processes, etc.). The selection of most competitive exporting firms into suppliers of the Chinese market was at the origin of Germany's market share gains. Our results suggest that German firms selling to China were more competitive than average German exporting firms. Lastly, we acknowledge the capacity of Latin American exporters to adapt their product mix to the evolution of the Chinese demand.

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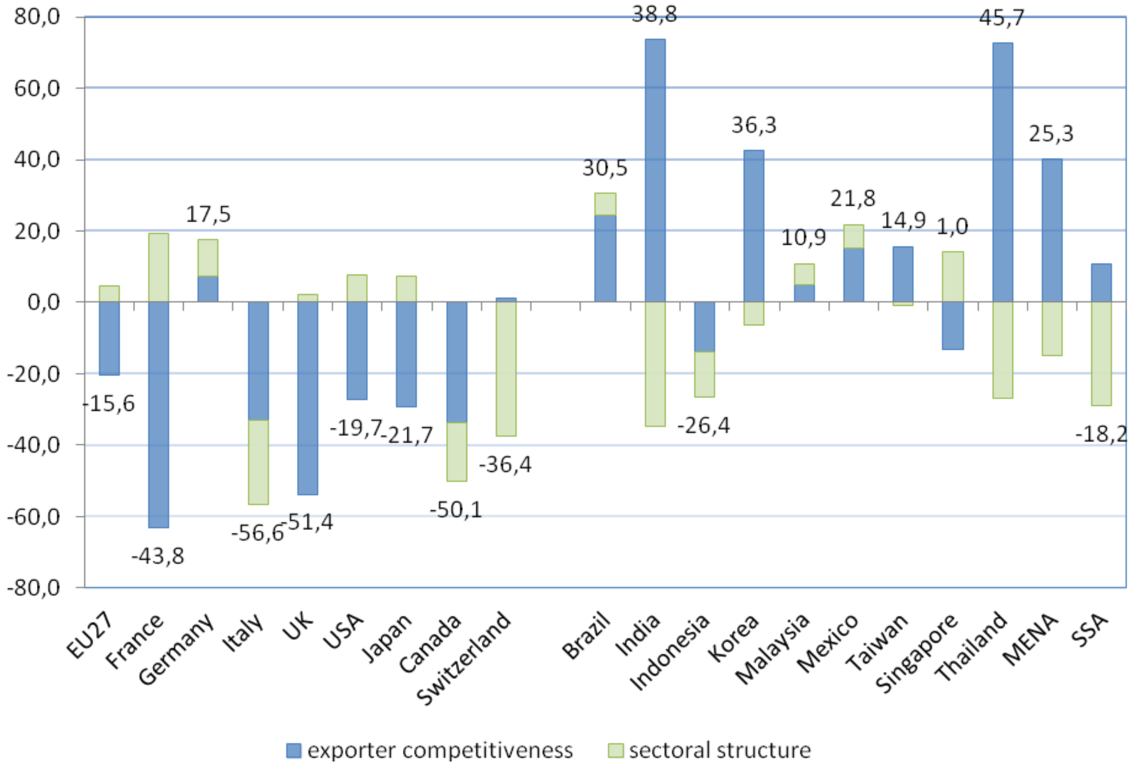
A Data description

Trade data used in this paper are from the BACI database, a new database for the analysis of international trade developed by Gaulier and Zignago (2010), available to COMTRADE users at: http://www.cepii.fr/anglaisgraph/bdd/baci.htm. BACI covers trade between more than 200 countries, in about the 5,000 products of the 6 digits Harmonized System (HS) classification. The present study excludes intra-EU 27 trade flows. This choice must be kept in mind when it comes to market shares and changes therein. We exclude also mineral products, specific, and non-classified products, corresponding to chapters 25, 26, 27 (mineral products), 97 (works of art, collectors' pieces and antiques), 98 and 99 (special classifications or transactions) of the Harmonized System. For the shift-share decomposition of the intensive margin of exports we also exclude trade flows inferior to USD 10,000 and non-independent territories and micro-countries. The motivation behind is to keep a larger share of trade flows in the intensive margin, the only component of the growth of trade discussed in that section. For export growths and the shift-share decomposition we also drop trade flows of a value lower than USD 10,000 or involving micro-states in order to avoid very large growth rates that would alter the explanatory power and the statistical significance of country, partner and product fixed-effect estimates. For this analysis we employ HS2 data obtained by aggregation of HS6 data.

B Export performance and structure effects



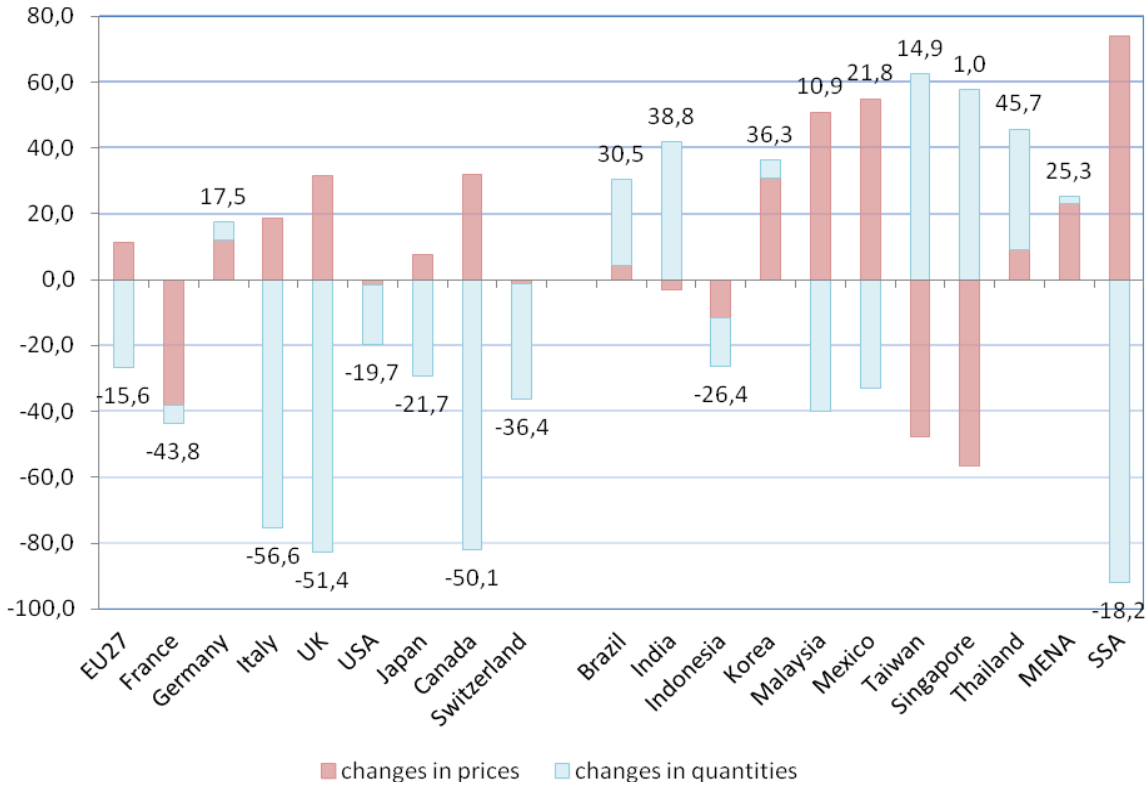


Fig. 2: Changes in shares of the Chinese import demand, all products, 1995-2007
Notes: Units on the vertical axis correspond to logarithmic changes (%) in 1995 market shares.

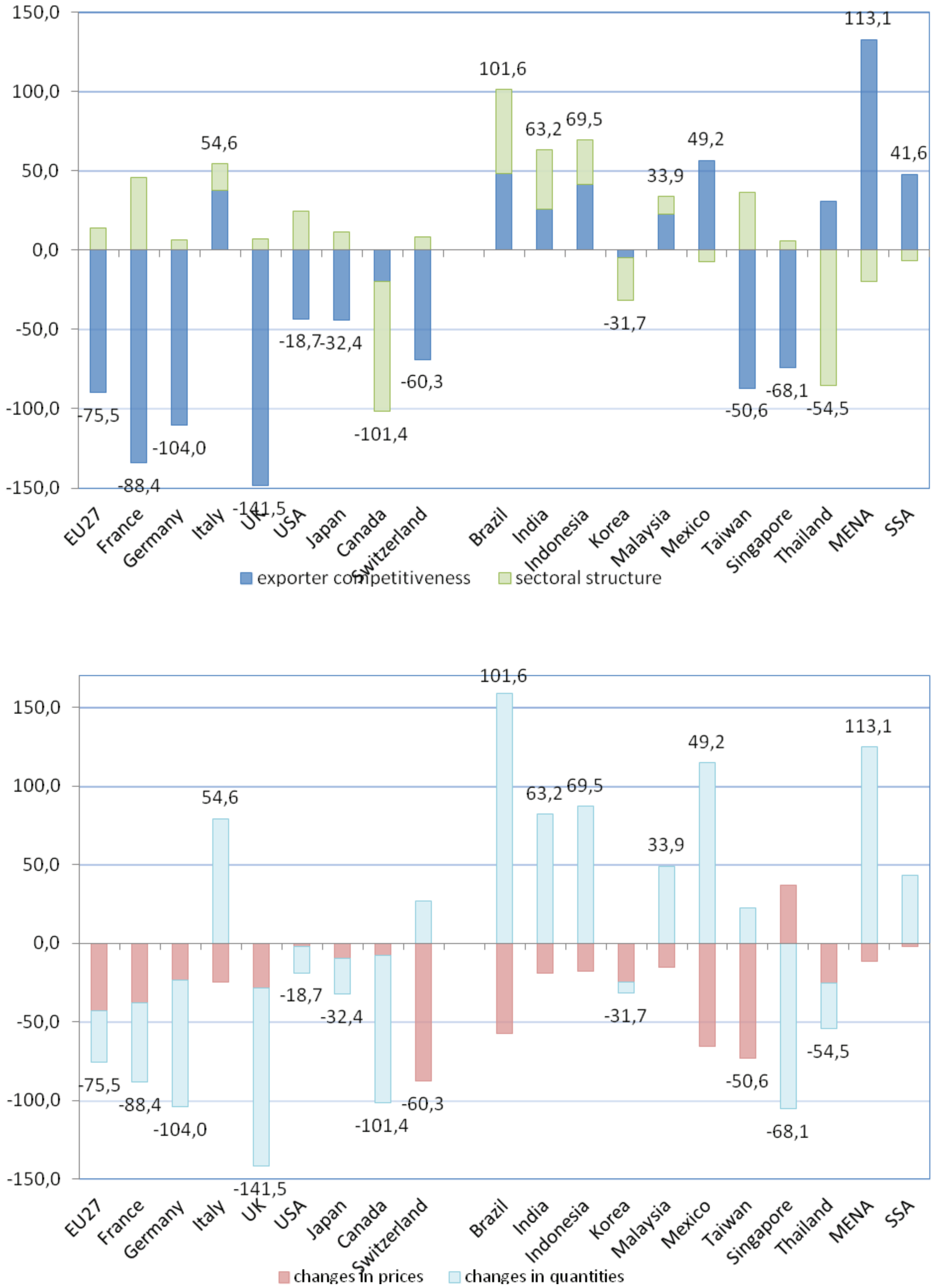


Fig. 3: Changes in shares of the Chinese agri-food import demand, 1995-2007
Notes: Units on the vertical axis correspond to logarithmic changes (%) in 1995 market shares.

Analysing agricultural innovation systems: a multilevel mixed methods approach

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Annotation: Innovations of agricultural suppliers, producers and retailers are directly or indirectly shaping sustainability within the agro food web. If sustainable innovations targeted at the key challenges agriculture is facing worldwide, such as food security, climate change, sustainable use of natural resources etc. should be promoted, knowledge about current innovation processes is needed to reveal mechanisms that allow for promoting sustainable agricultural innovations. In this paper we present the development of an analytical framework to study agricultural innovation systems. We divide the agricultural sector into four levels and expand the innovation system approach (Malerba 2002 and 2004, Koschatzky 2009) to study innovation processes. On the example of the role of farmers and extension services in agricultural innovation processes we demonstrate the adequateness of the approach and give detailed insight into the later stages of the innovation process, where barriers occur most in the German agricultural innovation system.

Key words: innovation system, precision farming, animal monitoring, energy in horticulture

1 Introduction

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Innovations by agricultural suppliers, producers and retailers are directly and indirectly shaping sustainability within the agro food web. In order to promote sustainable innovations targeted at the key challenges agriculture is facing worldwide such as food security, climate change, sustainable use of natural resources – (McIntyre et al 2009) more knowledge about current innovation processes is needed to reveal mechanisms enabling the creation and dissemination of such innovations.

The innovation system approach proposed by Malerba (2002, 2004) facilitates systematic analysis of national and sectoral innovation systems. It does not provide empirical guidance, however, but is rather intended to be adapted for research question-specific research designs. Moreover, innovation systems research has so far been linked only sporadically to knowledge and innovation systems (AKIS) research in agriculture (Dockés 2011).

Understanding of agricultural innovation systems has not primarily been conceived as a research framework in the strict sense, but rather as more of a political concept developed in the 1960s: a mental model for practically guiding actors within an agricultural system. Originating out of the aims of achieving food security and increasing production ("green revolution"), sectoral agricultural innovation systems involve specific actors compared to other branches, such as administrative structures and institutions of publicly funded agricultural R&D and extension services. These systems have since the 1990's undergone changes in terms of reduction of publicly funded actors and institutions (e.g. Alston 1999) and installment of new intermediate actors, e.g. technology- and knowledge-transfer offices or

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private consultancies (Klerx and Leuwis 2008). Simultaneously, agriculture has developed into an international agribusiness sector constituted of highly specialized value chains and production branches (e.g. in horticulture, see Bokelmann 2009), involving not only a specialized supplier industry with its own R&D activities, but also very many SMEs besides large corporations as pesticide suppliers and food trade. Hence, innovation processes cannot be assumed to follow a single and linear (research-based) logic; rather, value chains have to be understood as the action arena where innovations are developed in double feedback looped processes.

Research on innovation processes in the field of genetically modified plants has shown in an exemplary manner how societal and consumer expectations and entrepreneurial innovation interests lead to new constellations in comparison to mainly publicly funded innovation systems (Vanloqueren and Baret 2009). However, there are also other innovative technological paths that could potentially contribute towards mastering the challenges agriculture is facing. Examples of potentially globally successful production systems and technologies include innovations developed within the German agricultural system, such as precision farming, animal monitoring systems and low-energy greenhouse systems. Yet each innovation involves different actors and value chains.

From the foregoing we conclude that, for studying agricultural innovation systems and innovation mechanisms, an adapted research framework is required. The development of a consistent conceptual and methodological framework could contribute towards facilitating agricultural economic researchers in advising on ways of improving innovation processes and systems. The aim of this paper is to develop a conceptual synthesis and methodological approach for studying agricultural innovation systems based on the example of Germany. Given the diversity of national agricultural systems in the EU, we only seek here to provide a basis for further discussion and analysis by presenting empirical results from the German case in a way that we hope will demonstrate the validity of our approach.

A consistent conceptual and methodological framework has to be developed in order to respond to the current needs of advise on how to improve innovation processes and agricultural innovation systems. Our goal of explaining recent agricultural innovation in Germany based on a case study approach.. in order to answer the “HOW” and “WHY” of agricultural innovation, about which the researcher has little control, since the object of research consists of an ongoing real-world context (Yin 2003)

Nonetheless, according to the literature in innovation systems different levels of innovation analysis can be distinguished (e.g. Geels 2004: niches, trajectories and landcapes),, allowing the development of an adapted multi-level research framework to systematically localize an adequate level for conducting our case study research. Malerba (2002) and Koschatzky et al (2009) also propose that, prior to studying an innovation system, the level on which innovation occurs has to be identified. In our case, that turns out to be the value chain arena, which is embedded in the sectoral (whole agricultural sector) and subsectors as traditionally divided in the German sectoral nomenclature.

Our approach accordingly divided the agricultural sector into different levels. First, three main subsectors (animal husbandry, plant production and horticultural production) were distinguished from the general sector level (level 1), as the actors at the lower level (level 2) presumably do not have interlinkages in their innovation processes, because their production processes (e.g. pig farming – wheat production – ornamental plant production) are quite different in terms of actors, technologies, marketing channels and the like. Then, on level 3, which we call the “innovation field”, we located the value chains organized around a technology, product or a group of products and the corresponding actors and interactions that shape innovation. Only on this concrete level, it is possible to study innovation mechanisms as well as their supporting and hindering factors. Level 3 consists of a variety of single innovations, such as sensors, machinery components labels. By then distinguishing a fourth level (level 4), we were able to look deeper into single innovations, such as efficient light sources in horticultural production or special sensor technologies in animal production.

Malerba (2002 and 2004) and Koschatzky et al (2009) distinguish six elements characterizing innovation systems, analyzed at context-specific levels of abstraction. In order to answer the question HOW innovation occurs, our research team added a seventh element, called "innovation processes", which reveals interlinkages between system elements. The system elements can be described as follows:

1. **Agents and organizations** are actors involved in innovation processes and their characteristics.
2. **Interaction and intermediaries** includes the market and non-market relations and communication between actors with regard to innovation. Intermediaries are organizations or groups within organizations working with the goal of promoting innovation, e.g. at the interface between science and business, and aiming to promote sustainable networks (Dalziel 2010).
3. **Knowledge base and human capital** contains information regarding sector-specific and cross-sectoral knowledge, learning processes, knowledge accessibility as well as tacit and codified knowledge.
4. **Institutions and politics** includes the implicit and explicit rules of actors and organizations, such as norms, laws, rules as well as behavioral patterns and routines.
5. The analysis of existing **technologies**, products and services and the demand for them provides insight into development and future potentials or technological trends and problems that require innovative solutions.
6. The environment of **competition** surrounding the innovation system in question includes national and international aspects.
7. **Innovation processes** provides insight into the temporal aspects and "making of" of agricultural innovation by linking the other elements together in order to understand their systemic relations better.

2 Methods

In order to describe innovation processes in the German agricultural innovation system, and taking into account that this information can only be obtained on the value chain level (here called level 3 or innovation field), we designed a research framework allowing us to combine knowledge derived on different systemic levels. In this section, we describe our three-level mixed method research concept, which can be seen as a sequential qualitative–quantitative design (Kelle 2007, p. 285).

According to Johnson and Christensen, "[m]ixed methods research […] recognizes the importance of traditional quantitative and qualitative research but also offers a powerful third paradigm choice that often will provide the most informative, complete, balanced, and useful research results." (2007, p. 129)

Figure 1 shows the above described multi-level approach. Following that, the methods applied on the different levels along the innovation system elements will be described in further detail.

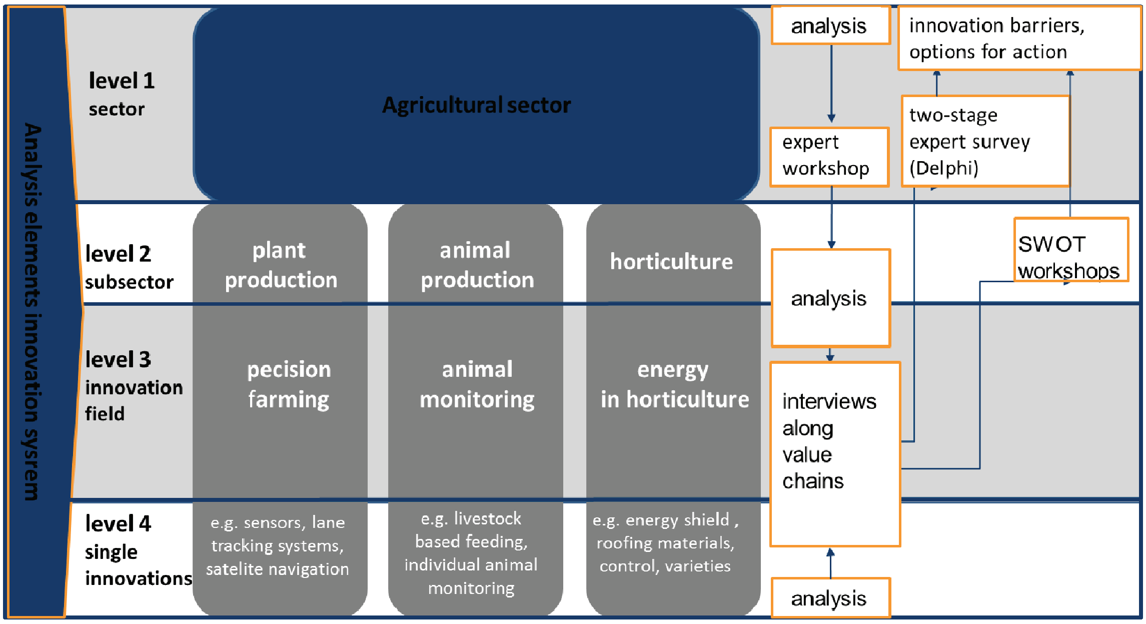

Fig. 1. research design (source: own figure)

Because the data sets usually used to generate innovation indicators either lack relevant data for our purposes or agricultural data cannot be separated from other branches, we designed a multi-level mixed methods approach. Furthermore, data alone provides no insights into innovation mechanisms. Therefore, as a first step, an expert[5] workshop was organized, focused on locating case studies where typical barriers and chances for innovation processes in agriculture could be studied. Then, having selected three exemplary cases, literature and secondary data analyses built the basis for semi-structured expert interviews along their value chains. Based on the data thus collected, already involved and newly identified experts with general knowledge for the subsector discussed the plausibility and transferability of results from the innovation examples to the wider agricultural sub-sectors to which they belong, namely: plant production, animal production and specialized horticultural production.

2.1 Literature and Data analysis

First, on a general sectoral level, a data-based innovation analysis was conducted (patents, publications etc.). The main purpose here was to obtain an overview and see if it were possible to relate innovation information about agriculture to those indicators typically used to analyse innovation systems of other sectors. We feel that this analysis strengthened our argument concerning the chosen multilevel research design with explicit data on the lack of innovation-related indicators for agriculture. At the same time, the analysis of statistics, market reports, publications, documents and websites also served as an entrance point for the case study research itself.

2.2 Semi-structured expert interviews

Experts in the case studies were identified according to their backgrounds and value chain involvement. In order to access their exclusive knowledge on innovation processes in agricultural value chains, interview guidlines were developed, serving as a red thread for our

[5] experts where defined in our study as actors with a special knowledge about agricultural innovation processes in terms of social processes, professional and practical action context (Gläser/ Laudel 2004)

expert interviews. The questionnaire we developed served as a common basis for comparison across the case studies. The openness of the interviews, despite their topically concrete focus, ensured that specific knowledge on innovation processes in each of the case studies could be obtained while also allowing for unexpected aspects to be discovered (Liebold and Trinczek 2002). For each case study, 15 interviews were conducted along the value chain, recorded, transcribed and analysed with qualitative content analysis, supported by the software MAXQDA. The fact that innovation-process knowledge is sensitive in terms of competitiveness was also taken into account.

2.3 Expert workshops

Workshops with selected experts were conducted at two stages of the research process as a means for deriving the "collective orientation" and tacit knowledge (Liebig and Nentwig-Gesemann 2002) of actors involved in agricultural innovation. The first workshop included experts from different fields (regional entrepreneurship, bioenergy, banking, farmmachinery, new fruit varieties, terra preta etc.) who were invited to discuss opportunities and hindering factors in agricultural innovation processes. According to criteria previously developed by the researchers and the funding organization of BMELV (see box), three topics for case studies were identified during the workshop.

Box 1: Criteria for case study selection formulated for the first workshop:

1. Best practise example in terms of mastering current challenges (environment and resources, market development, social trends and ethics, food security and safety, climate change…);
2. Supporting competitiveness of the sector (efficiency, cost reduction, new markets, niches…);
3. Relevance for employment and value creation (labor conditions, jobs in agriculture and supplier industries…);
4. Important actors in the innovation process are located in Germany; and
5. Systemic relevance (sustainability dimensions).

After the case studies had been conducted, their results were tested in three expert workshops. These workshops were to answer the following questions: Are the results from the case studies generalizable for the given subsector (animal monitoring -> animal production, precision farming -> plant production, energy in horticulture -> horticulture)? Are the critical factors identified by the analysis of system elements from other innovation fields in the subsectors (e.g. plant breeding, ergonomics, extension, farmer organizations, innovative entrepreneurs, experimental station representative). Actual workshops had six to eight participants each.

The research team developed a process concept for the workshop that first introduced the case study results to the participants and then discussed the relevance of the major results for the subsector. The most relevant critical factors for the subsector were selected by the experts and then SWOT and risk analyses were conducted for them. Resulting options for action were also discussed.

All workshops were moderated and visualized by a professional facilitator (Kühl 2002). According to participant feedback, the workshops fulfilled their functions of (1) providing the researchers with relevant information while also (2) spurring a learning process for the participants (Dreher and Dreher 1995).

2.4 Delphi survey

After the research topic had been opened up (expert workshop), and knowledge had been obtained in the three case studies, testing of generalizability of the results to the subsectoral level was conducted in SWOT workshops, while generalizability to the general sectoral level was tested with a Delphi survey, which also served to detect general technological trends. Generally, Delphi studies are used in innovation research as foresight instruments to collect different opinions and facilitate expert dialogue by presenting results of the first questionnaire in a second round (Cuhls 2009:207, Häder 2002, Meier et al 2005:65). In our case, the second round repeated the questions from round one, with the addition of a question that resulted from the SWOT Workshops on the presumed different roles of farmers within innovation processes. Again, the focus was laid on experts involved in innovation processes. In both rounds, 150 experts were contacted. In the first round 65 experts answered and 63 in the second round. The questions for the Delphi survey were developed according to the results of the case studies in the innovation system elements scheme and were refined through the results of the above-reported literature and general data analysis.

3 Results and Discussion

In this section, based on the example of the role of farmers and the role of extension, we demonstrate the advantages for generating knowledge with the chosen multi-level approach. We have chosen these two aspects because barriers in agricultural innovation processes have been reported as mainly occurring in later stages of the innovation process in the interviews as well the Delphi survey (see figure 2).

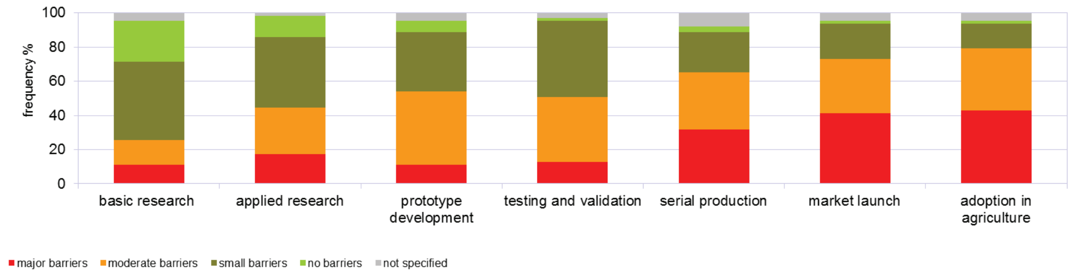

Fig. 2. In which stage of the innovation process do barriers occur most frequently? (Delphi 2, n=63)

Role of farmers in innovation processes. Besides industry and science, agricultural producers are an integral part of the triangle where innovation impulses occur most often in agriculture. The case study interviews revealed that the role of farmers in innovation processes is not restricted to ("passive") adoption. Rather, some farmers act as lead users, such as in research and development in precision farming. They provide qualified detailed feedback to suppliers and formulate needs that lead to new innovation processes. In the SWOT workshops, the role of farmers was discussed as a prominent critical factor that was revealed by the case studies. Although this is especially relevant for the plant production subsector, possible strategies of better integration of farmers in innovations processes were also addressed in animal husbandry and horticulture.

The experts in the plant production workshop estimated the number of farmers generally open to innovation, who are seen to be a strength for the subsector, to be up to 10%. A weakness with a moderatelikelihood and strongeffect is the phenomenon that farmers' own technological developments often remain singular solutions for their own farms. Three opportunities were identified. First, well-targeted funding would allow farmers to generate additional income from innovations. Second, changes in the organizational structures of farms would support the adoption of innovations (e.g. because they are only feasible from a certain farm size on). Similarly, third, a personnel and operational structural change will favour certain innovations. A weakness in the innovation system with a high likelihood and a strong effect is the possibility that funding schemes favor windfall gains.

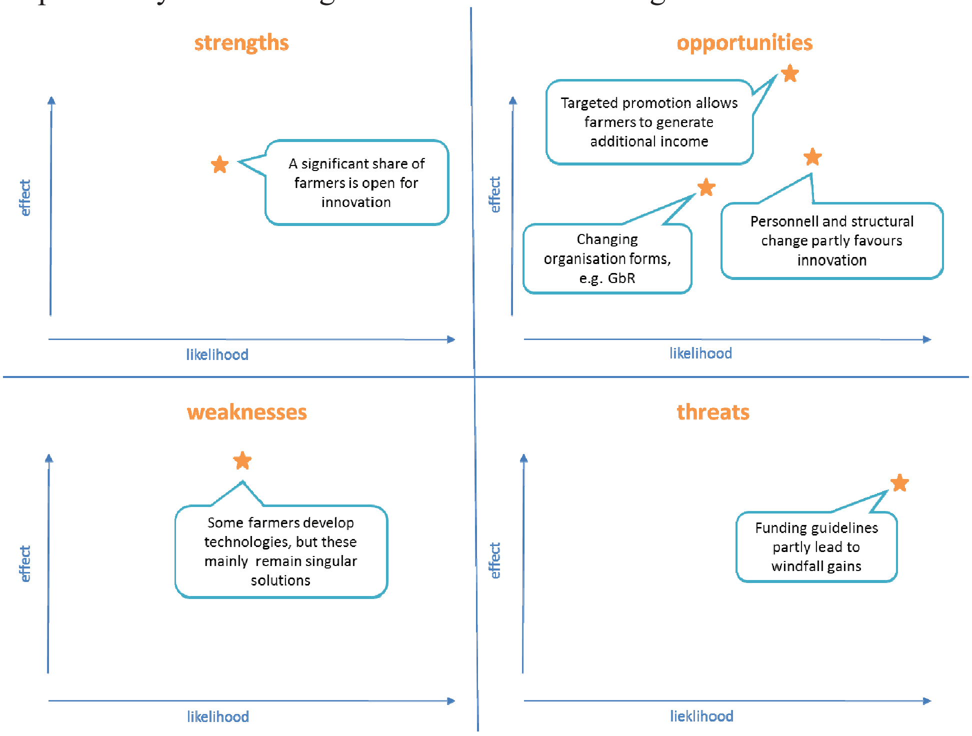

Fig. 3. The role of farmers in innovation processes in plant production: strengths, weaknesses, chances and risks – their likelihood and effect (SWOT workshop plant production)

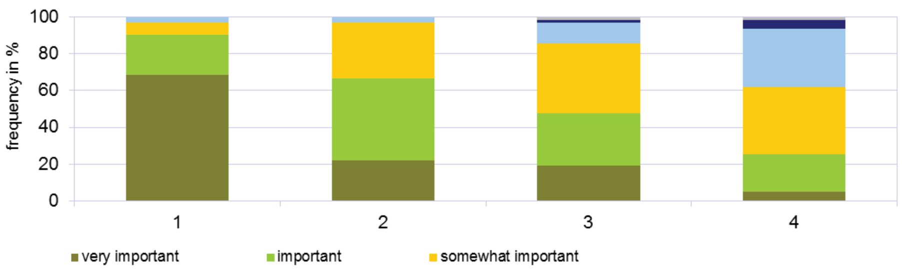

Fig. 4. The role of agricultural producers in innovation processes (1) User/ adopter, (2) initiator, giving impulses, (3) inventor, (4) entrepreneur (Delphi 2, n= 63)

Role of extension services in innovation processes. Extension services are ranked number five behind suppliers, agriculture, science/ research amd international competition as actors that give impulses to agricultural innovation. In the case studies on precision farming and energy in horticulture, a lack of neutral information about the benefits of innovations and information on their implementation was mentioned as a relevant gap, an issue of particular importance in the highly specialized horticultural subsector. Extension in horticulture is not only provided by extensionists, but also by experimental stations and their publications as well as internet platforms. Extensionists embedded in the work of experimental stations, were seen by experts as ideal knowledge brokers between science and the horticultural business.

Being heterogeneously distributed among the Federal states, and a with primarily regional range of extension, horticultural production faces uneven innovation preconditions in Germany, due to the federal organization of the extension system. Yet, in some cases, such as highly specialized and competitive market segments (e.g. asparagus production), extension is organized by geographical distance of the producers from each other. A current strength of horticultural extension with regard to innovation is its function as contact partner for producers. Due to its neutral function, extension allows networking and provides neutrally assessed knowledge on horticultural innovations for producers. Both factors will have a high likelihood and a high effect on the innovation system, according to the experts. A weakness is the limitation that extensionists do not always have knowledge of the whole pool of innovations potentially applicable for producers. Moreover, to provide neutrally assessed knowledge, expert knowledge is needed, but specialized extension is not sufficiently available in horticulture, which was also a finding from the interviews in the field of precision farming. Again, both factors were assessed with a high likelihood and a high effect on innovation in horticulture. Hence, an opportunity could be the continued funding of the currently basically well-functioning parts of the transfer system, but only a small likelihood with a high effect was estimated for this. On the contrary, pioneering horticultural entrepreneurs could serve as role models for others, with a high likelihood and a high effect. Yet, the manifestation of different extension services within the federal structure of Germany bears the risk of lack of equal competition conditions within the horticultural innovation subsystem, having a high effect with a high likelihood.

The Delphi analysis rounded out the study's insights into the role of farmers and extension services in the current agricultural innovation system in Germany. Agricultural production and extension are the two fields of employment in agriculture which the experts consider to be most lacking in personnel specially trained to foster innovation processes. As extension was described as one of the important actors after the top four (supplier industry, producers, science/ research, international competition), a lack of innovation (absorptive) capacity might be expected in the German agricultural innovation system due to inadequacies in this domain. Moreover, science is thought to lack personnel with sufficient understanding of and connection to practical concerns. This illustrates the need to further study and develop mechanisms of innovation production and diffusion, and the role of extension therein, and investigate whether new actors or applied research should take over some of the intermediating and knowledge- and technology-diffusing functions in a new mode.

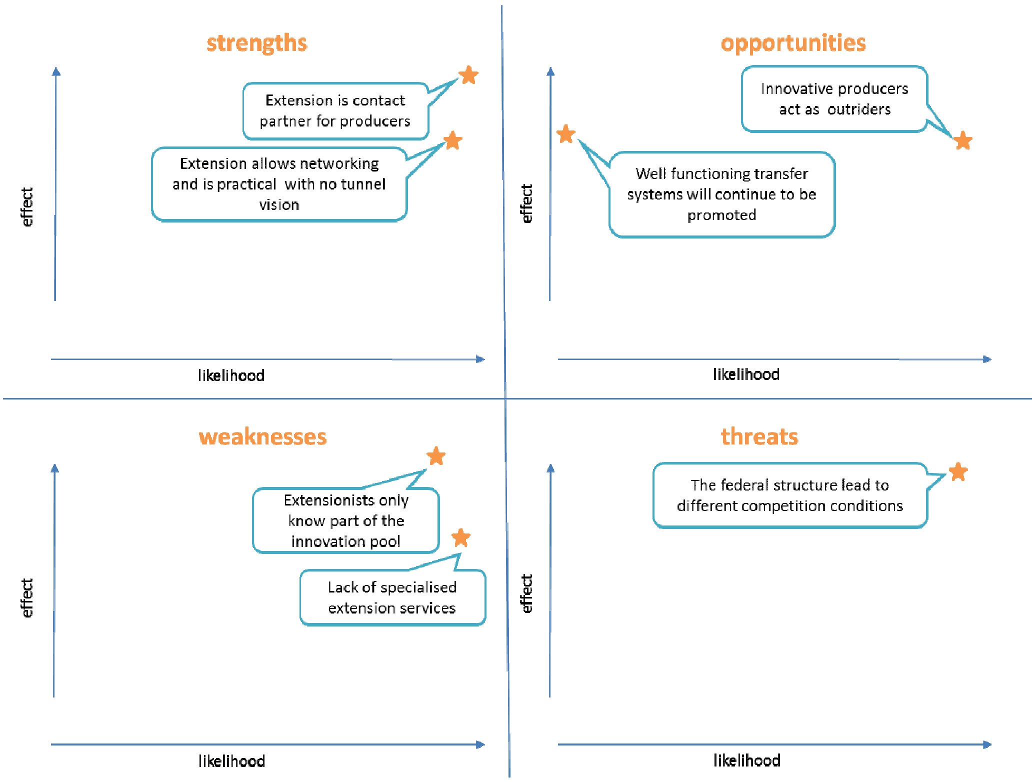

Fig. 5. The role of extension services in innovation processes in horticulture: strengths, weaknesses, chances and risks – their likelihood and effect (SWOT workshop horticulture)

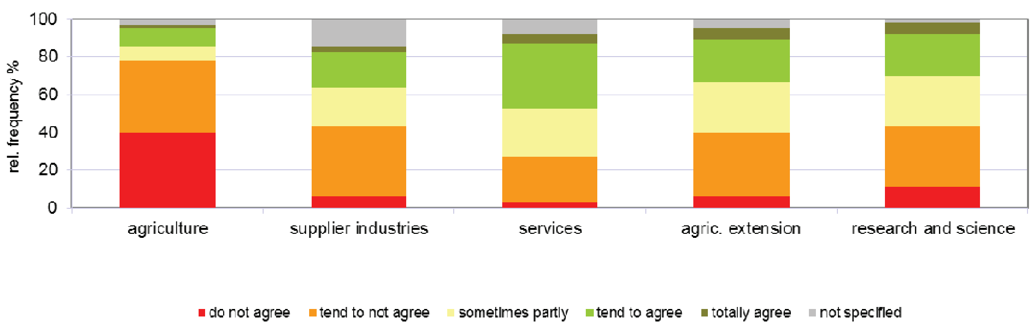

Fig. 6. Assessment of personnel: "The number of qualified personnel will be sufficient within the next 5-10 years" (Delphi round 2, n=63)

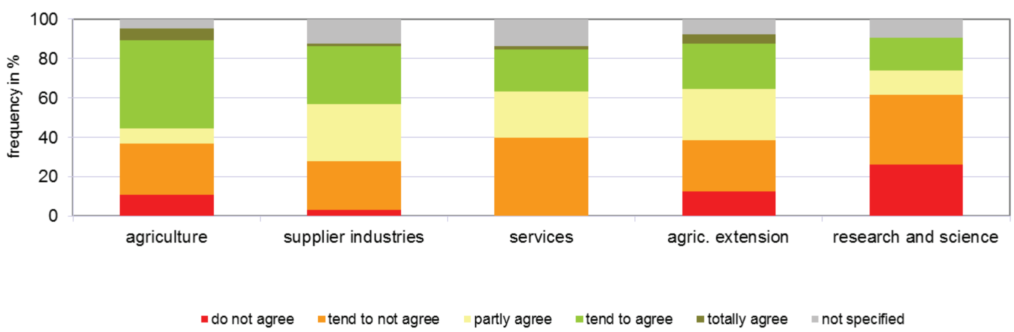

Fig. 7. Assessment of availability of personnel with practical knowledge and skills (Delphi round 1, n=65)

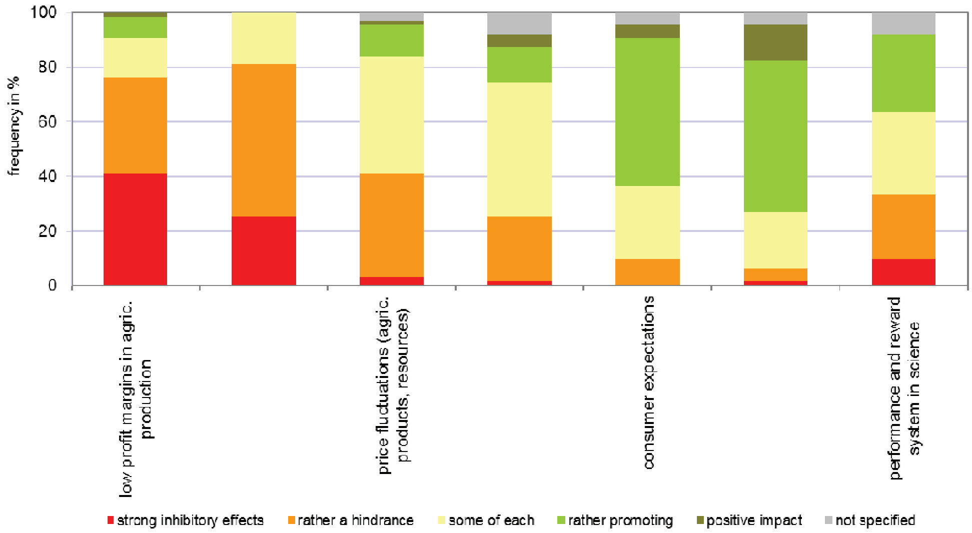

Fig. 8. Hindering and promoting factors for the innovative capacities of the German agricultural sector (Delphi round 2, n= 63)

4 Discussion and Conclusion

The aim of our paper has been to demonstrate the benefits in knowledge gained from using a multilevel mixed method approach, here used specifically for the analysis of the German agricultural innovation system through presenting results for two selected aspects. We have sought to demonstrate that different methods applied at different levels of an innovation system can enable more detailed insight into key barriers occurring in the later stages of the innovation process, which we feel is more than can be achieved with only indicator-based analyses. We have also sought to bring attention to the role of farmers and the ability of the system to enable farmers to participate more actively in innovation processes and to reasonably support adoption decisions, as this situation requires further attention from researchers, policy makers, administrators and by the actors themselves.

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A Systemic Policy Framework: The cases of Scottish and Dutch Agrifood Innovation Systems –Preliminary results

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Annotation: Innovation and knowledge exchange are receiving increased attention among policy makers as a means to address sustainable economic development challenges (European Commission, 2011). However, a range of factors such as inappropriate structures and institutional or capabilities barriers may negatively influence the spread or direction of processes of innovation and knowledge exchange (Klein-Woolthuis et al., 2005). These problems are often referred to as systemic weaknesses or failures, and highlight the need to focus on the innovation system (IS) as a whole (Smiths and Kuhlmann, 2004; Raven et al., 2010).

The purpose of the paper, using a comprehensive innovation systems failure framework, is to assess and he performance of agrifood innovation systems of Scotland and the Netherlands, through analysis of the key innovation actors (organisations, networks or influential individuals), and their key functions (research provider, intermediary etc), and those mechanisms that either facilitate or hinder the operation of the IS (known as inducing and blocking mechanisms, respectively). This framework was drawn up based on literature research and a series of semi-structured interviews and/or workshops with experts involved in the agrifood innovation systems in the two countries.

The findings confirm the appropriateness of considering actors, functions, inducing or blocking mechanisms and governance instruments as analytical tools to evaluate the performance of agrifood innovation systems. In both countries, blocking mechanisms in terms of actors' interactions and competencies as well as market and incentive structure were revealed. The proposed mix of governance mechanisms in each country offers actors a better chance to influence the direction and speed of innovation in agrifood systems.

Key words: national innovation system, IS failure matrix, Dutch, Scottish, agrifood

1 Introduction

It is argued that current pathways of economic development in the agricultural and rural sectors fail to serve balanced development in terms of competitiveness, sustainability and social-territorial cohesion (European Commission, 2011). Innovation and knowledge exchange are receiving increased attention among policy makers as a means to address this challenge, and develop an economy capable of mitigating climate change, whilst responding to the pressures arising from a growing demand for food, increasing energy-costs and resource scarcity (European Commission, 2011).

A systems approach to innovation has been recognised amongst academic researchers and policy makers as one of the most promising tools to understand and support processes underlying innovation, knowledge exchange and transformation of agricultural and food sectors (Spielman

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and Birner, 2008; World Bank, 2012). It indicates a paradigm shift in the justification of innovation policy intervention away from market failures towards system failures (Chaminade and Edquist, 2006; Jacobsson and Johnson, 2000; Smith, 2000). The strength of this approach is derived from rejecting the simplistic 'linear' or 'pipeline' model of technological knowledge transfer from research through extension services to farmers (Clark, 2002). The new interpretation recognises that (agricultural) innovation is the outcome of an interactive and co-evolutionary process (Smits and Kuhlmann, 2004), where a wider network of actors are engaged, with the speed and direction of innovation processes dramatically affected by the institutional and policy environment (Hall *et al*., 2006). Consequently, innovation combines not only technological but also social, organisational, economic and institutional changes (Klerkx et al., 2012; World Bank, 2006).

In line with this systemic approach to innovation, a need emerges for developing policy instruments that operate at the system level, instead of supporting the individual components of the system (which may be described as the neoclassical approach), and for going beyond traditional command-and-control measures (Jacob *et al*., 2006, OECD, 2001; Metcalfe, 1995). For example, the long-term and complex character of sustainability problems calls for systemic, integrative and participatory instruments for stimulating transition to sustainability-oriented innovation systems (Raven et al., 2010; Hekkert *et al.,* 2007). The innovation systems (ISs) approach has been instrumental in legitimising and designing research and policy interventions that enhance iterative and interactive learning processes among innovation agents, and their capacity to learn, change and innovate (Spielman and Birner, 2008; OECD, 2002; Lundvall, 1992). The focus is on the functionality of the whole system as an entity, rather than on its specific components (i.e. particular actors or institutions etc., Wieczorek and Hekkert, 2012), offering a better insight into coordination and alignment of system components e.g. whether institutions are complementary or conflicting.

The literature in the agricultural innovation domain is rich in empirical studies using the innovation systems approach, at different levels e.g. national, regional, sectoral or technological innovation systems. Yet, surprisingly very few studies (Amankwah *et al*., 2012; Gildermacher *et al.,* 2009) apply comprehensive frameworks to assess systemic failures. This paper aims to address this gap, by undertaking a comparative system analysis of the Dutch and Scottish Agri-food sector. The paper is organised as follows. In Section 2, a conceptual framework is presented, clarifying the particular analytical tools used describe the dynamics and performance of the the Scottish and Dutch agrifood innovation systems. Section 3 outlines the goal and research methods, and Section 4 focuses on presenting the results of the cross–country comparison analysis, and the paper closes with some concluding remarks summarised in Section 5.

2 Conceptual/Analytical framework

In innovation systems literature, both structural and functional analyses have been used to identify the determinants of varying rates of innovation, and to develop systemic innovation policies (Wieczorek and Hekkert, 2012). Originally, as suggested by its name, structural analysis served to study structural elements of innovation systems, including the actors, institutions (in terms of the 'rules of the game') and infrastructures (see for example Crawford and Ostrom, 1995; Edquist, 1997; Smith, 1997), but mostly it was used to analyse national innovation systems

(Schmoch *et al.,* 2006; Nelson, 1993). Functional analysis emerged to replace the structural focus with a process-oriented analysis, identifying different functions within an IS (such as funding research, knowledge creation etc.) and assessing the performance of the system on whether all the functions were being performed properly (Hekkert, *et al.,* 2007; Bergek*,* 2002; Johnson, 2001).

Regarding structural analysis, there has been a focus on identifying difficulties within innovation systems and different classifications of these systemic problems can be found in the literature. These are alternatively called systemic failures, weaknesses or blocking mechanisms (Chaminade and Edquist, 2010; Jacobsson and Johnson, 2000; Smith, 2000; OECD, 1997). Within this context Klein-Woolthuis et al. (2005), van Mierlo et al., (2010) and Weber and Rohracher (2012), propose an innovation system failure matrix, This places different actors against systemic failure categories. The initial work by Klein-Woolthuis et al. (2005) listed four categories, namely (physical, knowledge and financial) infrastructure, (formal/hard and informal/soft) institutions, interactions and problems with capabilities Van Mierlo et al., (2010) extended the matrix, by introducing the market structure failure. Weber and Rohracher (2012) advanced Klein-Woolthuis' work, and the policy framework's potential to deal with the strategic challenges of transformative change in systems of innovation, production and consumption (see Table 1 for details). They added failures of directionality, policy coordination, demand articulation and reflexivity.

Regarding functions, the most advanced typologies in literature are provided by Hekkert *et al*., (2007) and Bergek *et al*., (2008), with slight differences in their phrasing. For the purpose of this research, a list of functions is formed, based on combining insights from these two sources, and satisfying the purpose of being meaningful to interviewees. Nine processes are identified as important for innovation systems to perform well, and presented in Table 2.

Recent literature however, has argued that neither of these two separately-developed approaches (structural and functional) alone constitute a sufficient basis for analysis of ISs (Bergek et al., 2008). Wieczorek and Hekkert (2012) explain that structures make functions meaningful and vice versa, and argue that alteration of a structural element is always necessary for policies to enable or strengthen functions. Arguably, an integrated functional-structural analysis could provide a much more comprehensive overview of systems' operation and determinants in shaping innovation trajectories (Bergek et al., 2008; Wieczorek and Hekkert, 2012).

Table 1. Overview of innovation system failures

Categories of failures	Type of failure	Failure mechanism
Market failures	Information asymmetries	Uncertainty about outcomes and short time horizon of private investors lead to undersupply of funding for R&D.
	Knowledge spill-over	Public good character of knowledge and leakage of knowledge lead to socially sub-optimal investment in (basic) research and development.
	Externalization of costs	The possibility to externalize costs leads to innovations that can damage the environment or other social agents.
	Over-exploitation of commons	Public resources are over-used in the absence of institutional rules that limit their exploitation (tragedy of the commons).
Structural system failures	Infrastructural failure	Lack of physical and knowledge infrastructures due to large scale, long time horizon of operation and ultimately too low return on investment for private investors.
	Institutional failures	Hard institutional failure: Absence, excess or shortcomings of formal institutions such as laws, regulations, and standards (in particular regarding IPR and investment) create an unfavourable environment for innovation. Soft institutional failure: Informal institutions (e.g. social norms and values, culture, entrepreneurial spirit, trust, risk-taking) that hinder innovation.
	Interaction or network failure	Strong network failure: Intensive cooperation in closely tied networks leads to lock-in into established trajectories and a lack of infusion of new ideas, due to too inward-looking behaviour, lack of weak ties to third actors and dependence on dominant partners. Weak network failure: too limited interaction and knowledge exchange with other actors inhibits exploitation of complementary sources of knowledge and processes of interactive learning.
	Capabilities failure	Lack of appropriate competencies and resources at actor and firm level prevent the access to new knowledge, and lead to an inability to adapt to changing circumstances, to open up novel opportunities, and to switch from an old to a new technological trajectory.
Transformational system failures	Directionality failure	Lack of shared vision regarding the goal and direction of the transformation process; Inability of collective coordination of distributed agents involved in shaping systemic change; Insufficient regulation or standards to guide and consolidate the direction of change; Lack of targeted funding for research, development and demonstration projects and infrastructures to establish corridors of acceptable development paths.
	Demand articulation failure	Insufficient spaces for anticipating and learning about user needs to enable the uptake of innovations by users. Absence of orienting and stimulating signals from public demand. Lack of demand-articulating competencies.
	Policy coordination failure	Lack of multi-level policy coordination across different systemic levels (e.g. regional–national–European or between technological and sectoral systems; Lack of horizontal coordination between research, technology and innovation policies on the one hand and sectoral policies (e.g. transport, energy, agriculture) on the other; Lack of vertical coordination between ministries and implementing agencies leads to a deviation between strategic intentions and operational implementation of policies; No coherence between public policies and private sector institutions; No temporal coordination resulting in mismatches related to the timing of interventions by different actors.
	Reflexivity failure	Insufficient ability of the system to monitor, anticipate and involve actors in processes of self-governance; Lack of distributed reflexive arrangements to connect different discursive spheres, provide spaces for experimentation and learning; No adaptive policy portfolios to keep options open and deal with uncertainty.

Source: Weber and Rohracherb (2012)

Table 2. Functions of innovation systems

Function type
Knowledge development (either through research or learning-by-doing)
Commercial experimentation (i.e. commercial trails)
Knowledge diffusion/transfer
Funding
Mobilising (non-monetary) resources (e.g. in-kind contributions, supply human capital)
Market formation (i.e. commercialisation of innovative products/services)
Guidance of the search (i.e. identifying problems, recognising the potential for change, and showing the direction of search for new technologies, markets, partners)
Creation of legitimacy (i.e. counteract resistance to change and legitimate technologies)
Pure innovation brokering (i.e. focusing on networking, trust building and management of innovation processes)

An illustration of how the coupled structural-functional approach works is provided by Wieczorek and Hekkert (2012 see Table 3 for details), where for each system structural elements are defined and possible problems identified. These authors have therefore attempted to incorporate structural elements into the functional analysis of the systems. In the view of Wieczorek and Hekkert (2012) this should provide the necessary analytical blocks of a policy framework, aiming to identify systemic problems and propose systemic instruments to fix them. The first version of systems failure matrix by Klein Woolthuis et al. (2005) has been incorporated into Wieczorek and Hekkert's (2012) coupled functional-structural analysis framework mentioned above. By combining the four additional types of transformational failures with market and structural failures, the new integrated framework presented by Weber and Rohracher (2012) together with the coupled functional-structural approach taken by Wieczorek and Hekkert, (2012) are two very powerful analytical tools of innovation systems.

Table 3. Table description

System function	Structural element	Systemic problem	(Type of systemic problem	)Aim of Solutions
Knowledge development etc.	Actors	Actors problems	Presence?	Stimulate and organise the participation of relevant actors (1)
			Capabilities?	Create space for actors capability development (2)
	Interactions	Interaction problems	Presence?	Stimulate occurrence of interactions (3)
			Capacity?	Prevent too strong and too weak ties (4)
	Institutions	Institutional problems	Presence?	Secure presence of hard and soft institutions (5)
			Intensity?	Prevent too weak and too stringent institutions (6)
	Infrastructure	Infrastructural problems	Presence?	Stimulate physical, financial and knowledge infrastructure (7)
			Quality?	Ensure adequate quality of infrastructure (8)
(move to next function)	Actors etc.	Actors problems etc.	Presence?	Stimulate and organise the participation of relevant actors (1)
			Capabilities?	Create space for actors capability development (2)

Source: Wieczorek and Hekkert (2012)

3 Goal and Methods

This paper aims to apply the two complementary tools of Weber and Rohracher (2012) and Wieczorek and Hekkert (2012) in the context of the Scottish and Dutch agrifood innovation systems with the aim of revealing what happens in the systems, and in particular where particular strengths and weaknesses exist and the reasons for these

To achieve this the paper first attempts to map the national agrifood innovation systems of Scotland and the Netherlands, and assess their performance, through analysis of both their function and structural elements (i.e. structures' presence and attributes such as intensity, quality, capabilities). This is in line with Wieczorek and Hekkert's (2012) perspective. Second, it aims to explore those mechanisms that either facilitate or hinder the operation of the IS (the so-called inducing and blocking mechanisms, respectively). This follows the steps of Klein-Woolthuis *et al*. (2005), van Mierlo *et al*., (2010) and Weber and Rohracher (2012). Overall, the contribution of this paper is that it empirically applies methodologies that combine analyses of systemic structures, functions, strengths and weaknesses.

To identify key innovation agents in each of the two national agrifood ISs, Arnold and Bell's (2001) typology of actors in innovation systems was useful. This typology classifies actors into four broad categories, namely research domain, direct and indirect demand for innovation domains and innovation intermediary domain. In particular, the research domain includes universities and research institutes or private R&D departments (e.g. companies or NGOs) producing basic or applied research and primarily codified knowledge. The direct demand for innovation or enterprise domain involves the supply chain actors i.e. input suppliers, farmers, food manufactures or retailers who typically use codified and tacit knowledge, and produce tacit knowledge. The indirect demand for innovation refers to more distant actors demanding innovation, including final consumers, policymakers, social interest groups (e.g. charities and NGOs) and complementary markets to agrifood sector such as energy or pharmaceutical markets. Finally, innovation intermediary domain considers organisations that may not necessarily involve in knowledge creation or usage, but are playing a catalytic role in joining fragmented IS actors and facilitating knowledge/innovation flows. These organisations typically are education and extension services, actively-supporting levy or trade industry boards, consulting services or pure innovation brokers whose primary task is building bridges between knowledge/innovation providers and users. These categories are not mutually exclusive, due to actors' multiple roles, and evolving roles over time (World Bank, 2006). But it served us as an analytical tool, helping to identify important organisations to include in interviews and workshops. Another critical issue is that whilst the innovation systems concept may suggest collective and coordinated action, the system under investigation may not be recognised by its actors in its full entirety, due to weak interactions (Bergek *et al.,* 2008).

The aim was to fill the extended matrix of innovation system failures provided by Van Mierlo *et al*., (2010). In this matrix the various systemic failures (e.g. infrastructure failure, institutions failure, etc.) are set against the various categories of actors (e.g. researchers, farmers, government, innovation intermediaries etc.) However, it was deemed proper to avoid narrowing our perspective into capturing only systemic weaknesses, and instead to allow also inducing systemic mechanisms to be captured in the matrix. Following the lines of Weber and Rohracher (2012), the discussion in interviews or workshops explored whether structural elements have prevented or caused other systemic failures related to more transformative changes, with regards to directionality, policy coordination, demand articulation and reflexivity.

More than 15 semi-structured interviews and a workshop were held with experts at the national agrifood innovation system, holding a variety of position within the IS in each country. Therefore, researchers, consultants, multiple retailers, representatives of farmer unions, levy boards, governmental agencies and other innovation brokering or intermediary organisations were included in the list of interviewees or workshop participants. Although the focus was primarily kept at national level, interviewees were allowed to use examples of sub-agrifood sectors, or specific technologies to illustrate better their arguments, and make the discussion more precise and meaningful.

4 Analysis

4.1 Overall functional performance of the Agrifood Innovation Systems

In the Scottish Agrifood innovation system there is a paradox where knowledge generation through universities and research institutes is well developed, with some consistently ranking among the most productive in Europe. However this knowledge fails to generate new innovation and agrifood business opportunities. In the Netherlands, however, whilst the same is true for many industrial sectors, the AIS is considered to be performing quite well, and serves as an example for innovation policies. Table 4 summarises findings about IS actors' performance in different functions.

Table 4. Functions of Dutch and Scottish agrifood innovation system actors

Domain type	Actors type	Typical functions	Under-performing functions
Research domain	Universities; Research institutes; Private R&D departments (e.g. of companies or NGOs)	Knowledge development; Knowledge diffusion/ transfer; Innovation brokering; Commercial experimentation; Market formation	SC: Knowledge diffusion/transfer; Innovation brokering; Commercial experimentation; Market formation NL: Actors in the research domain tend to have stronger performance than Scottish counterparts, but there is still room for improvement
Direct demand/ enterprise domain	Food supply chain actors (e.g. Agricultural input suppliers; farmers, processors; retailers) SMEs; Large enterprises; Cooperatives	Knowledge development; Knowledge diffusion/ transfer; Innovation brokering; Commercial experimentation; Market formation ; Guidance of search; Resource mobilisation Creation of legitimacy	SC: Except for some multinational input suppliers, multiple retailers, the rest supply actors (especially farmers and indigenous SMEs) underperform in Knowledge development, Commercial experimentation; Market formation. Input suppliers and retailers underperform in Knowledge diffusion/ transfer and Innovation brokering NL: Direct demand actors have stronger performance than Scottish counterparts, but there is room for improvement especially for farmers and SMEs
Indirect demand domain	Final consumers; Governmental agencies; Other policymakers; social interest groups (e.g. charities and NGOs); Related market (e.g. pharmaceutical market)	Knowledge diffusion/ transfer; Innovation brokering; Commercial experimentation; Market formation; Guidance of search; Resource mobilisation; Funding; Creation of legitimacy	NL: The Dutch Government underperforms in Market formation; Guidance of search; ; Creation of legitimacy, but performs better than the Scottish Government in Innovation brokering
Intermediary	Education; Extensive services; Consultants; Actively-supporting levy/trade bodies; Systemic innovation brokers	Knowledge diffusion/ transfer; Innovation brokering; Commercial experimentation; Market formation; Guidance of search; Resource mobilisation; Funding; Creation of legitimacy	SC: Knowledge diffusion/ transfer; Innovation brokering; Guidance of search; Resource mobilisation; Funding NL: Innovation intermediary actors have stronger performance than Scottish counterparts

In Scotland, evidence suggests that universities and research institutes perform better than agrifood supply actors, especially farmers and SMEs, in knowledge development, but tend to underperform in areas which could lead to exploitation of the knowledge. Agricultural input suppliers, who are usually externally-owned (international or other UK-owned), and some innovation-oriented multiple retailers outperform other agrifood supply actors in some of the key functions (such as knowledge development, commercial experimentation, guidance of the search, resources mobilisation, funding, and creation of legitimacy). However they too face difficulties in knowledge diffusion/transfer and innovation brokering especially in their interactions with Scottish farmers. Scottish governmental agencies in general perform well in terms of identifying problems (guidance of the search), providing funding, and mobilizing resources, especially compared to other UK counterparts. In terms of these functions, the UK research councils and Technology Strategy Board (TSB) are seen to perform relatively strongly, but again underperform when interacting with Scottish farmers or agrifood SMEs. Levy boards have improved their performance in their key areas of operation but there is still room for improvement, especially in funding and knowledge diffusion/transfer. Some social interest groups such as NGOs and charities perform strongly in creation of legitimacy, guidance of the search and resources mobilisation. In many cases, the innovation intermediary domain of the Scottish agrifood IS tends to underperform in knowledge diffusion/transfer, creation of legitimacy, guidance of the search, resources mobilisation and especially innovation brokering, with the exception of satisfactory performance from particular innovation brokers such as SAOS and Biosciences KTN and to a less extent Scotland Food & Drink (SF&D).

In the Netherlands, agrifood innovation agents fulfill similar functions to their Scottish counterparts, but the performance appears stronger, especially in the side of the direct demand for innovation domain (i.e. agrifood supply actors) and the innovation intermediary domain. In particular, the Dutch agrifood IS has a longer tradition and accumulated experience in cooperation, shared-learning and knowledge co-production, using a multi-stakeholders network approach that also validates and exploits non-scientific knowledge, such as that of the farmer. In many cases, these collaborative networks are self-organised. Thus, the Dutch innovation agents tend to present a more satisfactory performance in knowledge diffusion/transfer, creation of legitimacy, guidance of the search, resources mobilisation, funding and innovation brokering compared to the Scottish counterparts.

However, the Scottish Government (SG) has taken a more proactive and leading role, compared to the 'hands-off' neoliberal approach of the Dutch Government that leaves the market to decide how the future of the sector should look like, based on where commercial companies see their business opportunities. Although for somewhat different reasons, evidence suggests that in both countries the reliance on the market has led to agrifood innovations systems where there are deficits within functions. Also, there has not been one actor, or a coalition of actors, able to unite the agricultural sector behind a common vision, which indicates a systematic problem relating to lack of vision and leadership. So, the Scottish agrifood IS benefits from deliberate efforts of the SG to fill this vision and leadership gap and eliminate other systemic deficits.

It is widely recognised that the abolishment of the traditional 'Education, Extension and Research (EER) tryptich' in the UK and NL, led to the privatization and a proliferation of new knowledge creators and providers. Although within the UK there were differences with the privitisation process in Scotland being considerably less severe than in England. So, the public extension service have been transformed into a considerably downsized private service, which competes with many emerging smaller (and some large) agro-consultancy firms in what can be called a pluralistic system of advisory service provisioning. Besides, some NGOs have their own-research facilities and universities offer consultancy services. In addition, new private organisational forms as well as new public/private partnerships for research and innovation (e.g. platforms and networks) emerged. This makes the boundaries between functions performed by those traditionally categorised as innovation creators, facilitators and users vague. Innovation agents now have been expanding their functions' range, aiming to adding value to their specialist services, and in turn increased competiveness in the innovation arena. Innovation-related functions are mainly extended in scope by either acquiring new 'in-house' competencies or entering into strategic partnerships with skills-complementary organisations. Criticism raised that current Scottish agrifood IS leads to an unbalance in jobs creation between research and the domain of direct demand of innovation i.e. agrifood supply chain actors. Also, because extension advisory services and consultants have to work now on a more commercial and demand-driven basis, basically on what the client is asking, this has resulted in both countries in the disappearance of certain fields of expertise, due to lack of demand, and that some public goods issues remain under addressed. Yet Scotland has maintained advice relating to public good provision at the farm level at least.

Next, the separate IS failures proposed by Klein-Woolthuis *et al*. (2005), Van Mierlo *et al*., (2010) and Weber and Rohracher (2012) are used as a framework to systematically analyse the inducing and blocking mechanisms in the Scottish and Dutch agrifood ISs.

4.2 Knowledge Infrastructure

First, the presence and quality of the knowledge infrastructure of the Scottish and Dutch agrifood ISs are assessed. It is clear that both systems benefit from a high concentration of universities and research institutes. They also both have a reasonably strong and wide network of education institutions, extension advisory services and consultants.

Knowledge infrastructure appears also reasonably strong and well-spread across the two countries across policy-making agencies[7] and social interest groups (e.g. Scottish Society for the Prevention of Cruelty to Animals – SSPCA, or various groups of nature conservationists and environmentalists in the Netherlands).

In the direct demand for innovation side, with some exceptions, the knowledge infrastructure of Scottish agrifood businesses is argued as rather weak and insufficient, and recognised as having a detrimental effect on the Scottish agrifood IS. In contrast the Netherlands appears stronger through the activities of independent advisors, input suppliers, food manufacturing, multiple retailers and farmer peer networks and other self-organised networks in the Netherlands.

4.3 Physical Infrastructure

Both the Scottish and Dutch physical infrastructure appear sufficient, including transportation (e.g. train or road network) or telecommunication systems (e.g. 3G mobile network and broadband) and availability of utilities (e.g. Gas). However, speed and coverage of broadband and 3G mobile network cited as almost the only significant restricting factors for innovation in Scotland. These deficits potentially can inhibit information/knowledge accessibility, interactive learning and ultimately innovation for all categories of innovation actors, however, the most likely affected are Scottish farmers, due to relatively low mobility and farm remoteness.

4.4 Hard Institutions

The Governments of the Netherlands and Scotland shape the conditions determine the agrifood sector's development by legislation and regulations, often derived from European directives. In both countries, interviewees reported the following regulations as having the most impact: environmental regulations that have restricted the options for intensive animal production; spatial planning laws; employment legislation and; health and safety regulations. In the Netherlands, as

[7] Except for the Scottish Government (SG), interviewees indicated as influential to innovation the following policy-making agencies: the Scottish Enterprise, Highland & Islands Enterprise, UK Research Councils, UK Technology Strategy Board (TSB) and particular governmental agencies including Scottish Environment Protection Agency (SEPA), Scottish Natural Heritage (SNH) and Forestry Commission (FC).

a highly-populated country, spatial planning laws are an issue with municipalities enforcing zoning rules and granting permission only for specific activities.

In both countries, it is observed that application procedures for innovation programmes were considered too complex, cumbersome and laborious. At the same time, agrifood industries in both countries have emphasised the need for greater Government support[8] in reducing the burden of EU/Government imposed regulations, cutting the 'red tape', and making flexible and streamlined regulations.

R&D tax credits and tax breaks, and Intellectual Property rights (IP) such as patents and trademarks were considered as powerful enabling factor for innovation in both agrifood ISs. However, the EU ban on GMO technologies was regarded by many interviewees as posing a significant barrier to innovation, and as potentially threatening the EU, Scottish and Dutch agrifood sectors' competitive market position. Despite its potential for substantial positive impact, the use innovation-oriented procurement mechanisms to directly stimulate the advancement of novel solutions is rather weak in both Scotland and the Netherlands, thus improvements are needed to this direction.

Public-funding Instruments

A common problem for most public-funding instruments appears the very tight EU control of state organisations on what is allowed to be funded. This is cited as a barrier in innovation projects, because only the start-up costs, and not the running costs can attract funding, while the on-going capital requirement for covering the running costs is the real constraint for agrifood businesses. However, in the Netherlands, one can see more and more the implementation of novel innovation instruments without giving companies the direct financial support that is prohibited by the EU, the so-called investment funds. These are often a mix of public and private funds brought together to invest in start-up companies with a market focus and commercial potential.

Much attention, especially in Scotland, has been drawn to the distortions caused by EU farm subsides that appear to have a strong influence on farmers' behaviour towards innovation. In particular, existing subsidies were regarded as hampering innovation, because they do not create enough incentives for innovation, efficiency and market-orientation. This is evident especially when being compared to unsupported industries where continuous cycles of innovation are witnessed.

Innovation vouchers were considered as powerful enabling factor for innovation in both agrifood ISs. In the Netherlands, specific policies are targeted at innovation and the agrifood sector, with a strong focus on stimulating the match of knowledge demand and supply through the funding of brokering initiatives. At the national level, a high profile 'innovation platform' was formed in 2003, identifying 'TopSectors' for Dutch innovation, including also flowers and food sector.

Production-oriented research in both countries is often funded by farmer or agribusinesses' (e.g. abattoirs) levies, which are a kind of sector specific tax. Though it appears that more of the levy is directed at research determined by farmers needs in the Netherlands when compared to

[8] Interviewees have credit the SG with already significant efforts to this direction.

Scotland. In legal terms, Scottish levies are still categorised as public/government money due to mandatory nature which automatically means that levies do not counted towards industry's required monetary contribution, supplementing the in-kind contribution when levy boards apply in most public-funding schemes.

4.5 Soft Institutions

The view is that at present, the demand for innovation from Scottish farmers is not that strong, with most farmers being passive receivers of advice, mostly for everyday management issues. This is evident from farmers' willingness to pay consultants for advice for administrative tasks (such as claiming CAP support) rather than seeking advice on innovative production and management practices. In the Netherlands, advisory services also concentrate on accountancy, legal advice regarding spatial zoning and environmental regulations rather than production.

In Scotland, other IS stakeholders talk of an attitude amongst researchers and consultants that hinders the development of relationships with their customers, named by interviewees as 'intellectual arrogance'. This refers to the subjective belief of having superior knowledge to that of their customers, and reflects a lack of accommodative attitude of outsiders to farmers and other industry actors' knowledge, perceptions and values (Assefa and Fenta, 2006). In the Netherlands, such an attitude amongst researchers and consultants is far less apparent, thanks to the long tradition of engagement in multi-stakeholders collaborative networks for learning and knowledge exchange. There is strong focus on learning in peer-to-peer networks, with study clubs being unabatedly popular. Apparently, collaboration and the idea of communities of practice are historically well developed in the Dutch agrifood IS.

One major weakness relates to the reported prevailing culture across different Scottish research providers, that communicating research findings to knowledge exploiting organisations takes a low priority over other tasks, such as conducting research, publishing in academic journals or reporting to public funders. Thus, organisational culture and institutional barriers are blocking innovative initiatives. Although, there is a relatively stronger pressure on Dutch researchers towards translating and communicating research findings, interviews revealed that lessons drawn from successful cases can have difficulties reaching the innovation pioneers of these cases.

4.6 Demand Articulation

Seeing researchers' behaviour from a slightly different perspective, one can see a demand articulation failure i.e. a deficit in anticipating and learning about user needs (Weber and Rohracher, 2012). First, the Scottish case provided evidence that researchers often do not seem to appreciate the innovation needs and expectations in terms of knowledge exchange of particular categories of funders, such as levy/trade bodies, farmers' organisation or the industry. This seems to be in contrast to the situation in the Netherlands. Overall, a mismatch between the ability or willingness of research providers to help and the requirements of knowledge exploiting actors e.g. levy/trade bodies or the industry, especially indigenous SMEs is apparent in Scotland. Furthermore, some interviewees pointed to the lack of the recognition that customer relationship management is a very vital, and different set of capabilities from R&D skills. As a result, most Scottish universities and research institutes have not arranged a single contact point for customers, but relying on individual researchers' skills and willingness to build (personal) relationships with commercial customers (e.g. retailers or input suppliers). This fragmented approach on customer relationships is recognised as a barrier to innovation. In the Netherlands, research institutes have relationship managers, which make connections with large clients, but also participate in agenda setting for farm level research issues.

4.7 Interactions

Repository of Knowledge Co-producing Experiences

Both countries provided examples of participatory and knowledge co-producing networks, some of which have a profound educational impact, and are promising initiative in fostering innovation. Overall, the Dutch, and recently the Scottish agrifood ISs have built a repository of positive local experiences from experimentation in learning and collaborative arrangements fostering innovation. These repositories potentially form a good basis to develop the knowledge exchange/networking approach even further, by drawing lessons and attempting to transfer these lessons to other areas or agrifood sub-sectors. In both countries, the farming press is a key mechanism for communicating innovation developments, as most farmers still like to receive information in written form.

Weak Network Failure

The Scottish agrifood IS has a high potential of benefiting from the Scottish Agricultural College's unique structural model of linking Research-Consultancy-Education under one roof. However, sufficient evidence suggests that currently this potential benefit has not been fully exploited, because there are too rigid lines between the three SAC' s divisions, especially between SAC consultants and researchers. This deficient interaction has become visible to external actors, and sometimes negatively effect on the institute's reputation, as SAC consultants often have not being kept update of the most recent research activity being undertaken within SAC research division. However, this fragmentation of knowledge infrastructure should not be mistakably considered a symptom observed only within SAC. Evidence suggests that is apparent across the whole fabric of the Scottish agrifood IS.

One major weakness evident relates to that in many respects Scottish universities have stronger links with spin-outs and externally-owned (international or other UK-owned) firms (evidence of strong network failure) than with indigenous SMEs. The former tend to have higher absorptive capacity and ability to capitalise on the knowledge generated at Scottish universities (e.g. maximise royalty revenues from licensing). Similar evidence for SME's absorptive capacity was provided in the Dutch case. Moreover, Scotland's universities appear not to regard indigenous SMEs as being good vehicles for licensing activity, compared to spin-outs or large-scale companies, often international in scope. In contrast, the Dutch agrifood IS benefits from short lines between policy makers, research institutes, agri-businesses and farmer unions, in which strategic cooperation is key. In particular, the close connection of WUR-Government-Businesses has become a role model for other Dutch sectors to follow and is featured prominently in the new TopSectors (Platform) innovation policy.

Strong Network Failure

Efforts in Scotland for overcoming the directionality failure (see Section 3.8) between research and industry by the SG, TSB and UK research Councils are partially successful for two reasons.

First, these efforts argued to have led to a strong network failure, where interactions are too dense between public funders with researchers, compared to their ties with other stakeholders to allow for novel insights or inspirations to emerge. Often this is reflected to the commonality in language used by policy-makers and researchers, in contrast to the language of agrifood businesses, levy or trade boards. Second, this observed consensus between policy-makers and researchers was further argued to result from policymakers' power over researchers as the main source of research funding. In fact, great dependency of R&D institutes on the Ministries of Agriculture for funding (such as DEFRA in the UK and especially SEERAD in Scotland) is observed in both countries. Evidence suggests that both Scottish and Dutch policymakers tend be more sensitive to the voice and influence of social interest groups such as NGOs rather than to that of agrifood businesses, levy or trade boards, even consumers. As a result, the same interviewees concluded that the prevailing model in supporting innovation in Scotland traditionally was and remains supply (research)–driven, providing less opportunities to generate solutions that fit the needs of agrifood businesses, levy or trade boards. It becomes apparent an almost complete mismatch between the type of knowledge being generated and demanded. In the Netherlands, whereas previous systems to support innovation amongst agrifood entrepreneurs was largely supply-driven and prescriptive, the current situation has a clearer demand-driven character thus requires more initiative from entrepreneurs. Moreover, the Dutch policy stresses the importance of inclusivity i.e. inter- disciplinary research projects involving a wide array of scientists, businesses, government agencies and NGOs in the process of creating knowledge and innovation.

Innovation Brokers and Intermediaries

The Dutch agrifood IS benefits from a wide array of innovation brokers and intermediaries which are established to function as 'catalysts of innovation' and 'market facilitators', by connecting innovation demand and supply in the markets of R&D and extension service. In Scotland, the array of systemic innovation brokers is smaller and more recently developed.

4.8 Directionality

The Dutch 'Hands-off' Approach versus the Scottish 'Hands-on' Approach

In the Netherlands, the main systemic bottleneck for innovation is the lack of a shared vision of the future of the agricultural sector and Dutch countryside. At the moment there is not one actor, or a coalition of actors, able to unite the whole agrifood sector behind a single vision. The Dutch Government takes a 'hands-off' approach, namely that the sector should be able to develop the way which entrepreneurs want to take, depending on where they see their business opportunities. In contrast, the SG has taken a 'hands-on' approach, after seeing that market forces had not eliminated deficits in the functioning of the Scottish agrifood IS, and there was not one actor, or a coalition of actors, able to unite the agricultural sector behind a common vision, indicating some lack of leadership. So, the SG attempts to define a direction by setting collective priorities in research and innovation that need to develop solutions for identified major societal-natural challenges e.g. climate change or sustainable agriculture. It also demands the integration and collaboration of land-based research institutes. However, some Scottish interviewees pointed to that creating a shared vision and setting strategic targets is just the beginning, they wait to see a clearer and more practical strategy of 'how" to achieve these targets. Behind the issue of the difficulty of articulating a common vision, are issues of interests and accountability mechanisms.

In particular, scientists are primarily evaluated on the peer-reviewed publications, farmers and agri-businesses on profitability, while Governments on delivering public goods and not ‘wasting’ taxpayers money on uncertain and possibly controversial innovations.

As a response to the need of accommodating better the needs of the Scottish agrifood businesses, the SG has strongly supported the establishment of non-for-profit organisations as systemic innovation brokers, such as Scotland Food & Drink (SFD), Interface, Scottish Agricultural Organisation Society (SAOS), Food & Health Innovation Service (FHIS) Scottish Enterprise (SE) and Highland & Island Enterprise (HIE). The SG assigned SF&D a leadership role and tasked with guiding Scotland's food and drink companies of all sizes towards increased profitability and competiveness in domestic and global markets. Innovation is a central element of SF&D’s strategy.

Innovation Agendas

In Scotland, the TSB has formulated an innovation agenda including energy (with a particular focus on renewables), food and drink sector (that comprises agriculture and fisheries) and tourism. In the Netherlands, innovation agendas have been formulated for the separate sectors e.g. the dairy sector, horticultural sector, poultry sector, etc. in cooperation with commodity boards and farmers’ organisations. However, the national innovation policy aims at sectors e.g. TopSectors/Innovation Platform, with little room for inter-sectoral innovation. At the same time, there is tension between collective and private interests with regard to funding of innovation support instruments.

4.9 Policy Coordination

Both the Dutch and Scottish Governments have made a steady progress towards overcoming another IS failure, namely policy coordination failure that goes beyond directionality failure. In particularly, both Governments have attempted to create coherent policy impulses from different policy avenues to ensure transformational changes in most layers of their national agrifood ISs. Evidence suggests that although progress has been made towards this direction, there is still considerable room for improvement. Incidents were reported that interpretation and application of specific EU directives or Government strategies sometimes differs amongst municipalities or Governmental agencies.

4.10 Reflexivity

Due to the uncertainty and inherent unpredictability surrounding innovation and sustainability challenges, interviewees in both countries acknowledged that although more fundamental scientific research is absolutely necessary, supplying even more of that alone is not going to solve these issues. Instead, interviewees called for more involvement of societal ‘stakeholders’ i.e. those actors that are either affected by, or possess the ability to influence its development. Interviewees pointed to the need of the Dutch and Scottish agrifood ISs to involve multi-actors in processes of reflection and self-governance by providing sufficient platforms for interaction and spaces for experimentation, monitoring and learning. Both the Scottish and Dutch Governments have seen as working on this direction, however, interviewees sometimes questioned their ability to stop or alter policies that turned out to be less promising than initially expected.

4.11 Competencies

In both countries, there is the problem of ageing population, and given the sectors' negative image among young people, their agricultural sectors are likely to continue suffering in attracting sufficient and well-educated labour force. There is a decreasing inflow of new students for studies focussing on primary production, both at the level of higher education, but especially the mid-level and vocational jobs. In recent years, labour needs in both countries are covered by cheap labourers from Eastern European countries to perform menial tasks on farms and in glasshouses. There is a shared concern about availability and quality of labour force that has led the industry, together with unions and agricultural schools in developing campaigns to attract more students.

Current systems to support innovation in Scotland and the Netherlands require more initiative from agricultural entrepreneurs, so as to be less supply-driven and prescriptive. This calls for competences with regard to knowledge and information acquisition and learning for innovation, i.e. sufficient absorptive capacity. Evidence in both countries suggests that such competences are often lacking in agrifood SMEs and farms. This affects their ability to define strategic, organisational and technological deficiencies in their efforts to express clear demands to researchers and advisors. Apart from competencies, farmers often lack resources such as time and funds to invest in new knowledge and technology.

Provided that there are skillful facilitators playing the role of translators the language barrier between researchers and farmers/agrifood businesses can be overcome. However, evidence in Scotland suggests that the direct relationship between researchers – farmers/agribusinesses is often problematic. This is due to researchers' weak communication skills in translating research findings into a simple, practical language, understandable by this particular audience. This may imply the need for research institutes to recognise that effective communication skills with industry actors may differ from the R&D skills. Furthermore, instead of requiring from any researcher to become an effective communicator, evidence strongly supports the strategy of identifying the people that already have proven adequate skills, and use them exclusively to facilitate sharing knowledge between researchers and users. In the Netherlands, such needs appear already recognised and served. In fact, amongst consultants and advisory services there are many managers of innovation processes available. Innovation brokering is also starting to get more attention in the education curriculum, at least in some of the MBA type of programmes

4.12 Market Structure

Strong evidence in both countries suggest that the privatisation of extension services has for long now led to increased competition, and the shielding-off of information either amongst different research providers or between research and extension/advisory services (sometimes within larger institutes e.g. SAC). Information that was freely exchanged into the state scheme of linking agricultural researchers-extension services-farmers, has become a (potentially) purchased commodity that actors now have strong interest to protect its commercial value. As a result, information asymmetries are apparent in the Dutch and Scottish agrifood ISs.

Overall, commercialisation and privatisation of knowledge have paradoxically slowed down the knowledge and innovation diffusion. Evidence is also provided from the demand side. Scottish and Dutch farmers appear to have a less incentive to seek knowledge due to a number of reasons. First, the charged fee rates are significant, while there is some mistrust on the neutrality of knowledge/information providers as having own-commercial interests. Second, 'information smog' has been created by mixed messages about new technologies or from separate innovation agendas (devolution in Scotland), plethora of providers and different types of knowledge supplied. Consequently, the industry face a difficulty in scanning the market, assessing differences in providers' quality, ex ante evaluating service value, and in many cases even identifying the provider(s) possessing the needed piece of information/knowledge they are looking for. The observed information asymmetry complicates the search for and selection of suitable cooperation partners, and raises transaction costs. Additional to that, a third challenge comes form the economic changes that food sector is facing at the moment, where short-term pressing economic issues destruct the supply-chain actors from the longer-term sustainability goals. The aforementioned reasons have a combined effect.

Both the Scottish and Dutch agrifood sectors have undergone structural changes and has become increasingly consolidated with a continuous trend towards fewer but larger-sized establishments, accomplished through merges, acquisitions, vertical integration, joint ventures and market exit. Farmers in both counties are confronted with substantial concentration of either sides of the farming sector: upstream i.e. agricultural input providers and downstream side i.e. food manufacturing and especially in food retailing sector (IFAP, 2002). There is the domination of a few large firms both in the input and distribution sides of the agri-food chain. There is genuine concern in the farming community and their levy boards that as a result, farmers have significantly less choice from whom to buy their inputs and to whom to sell their product, or about what and how to produce.

Much attention has been drawn to the dominance of multiple retailers, especially by Scottish interviewees. Especially in the UK, retailer concentration has skewed the balance of power in agrifood supply chains, which financially appear quite hard bargain-driven. Interviewees reported an increasing retail-to-farm price spreads, with the multiple retailers exercising excessive bargaining power over supplying food processors/manufactures, due to supermarkets' sheer market share, and easy access to imports markets. Tight profit margins, especially for SMEs, result from, first, the difficulty in passing on increases in production costs of raw material, due to increased agricultural input prices, and second, the requirement for food processors/manufactures to participate financially in retailers' promotion campaigns. More specifically, even large UK food manufactures find it tough to negotiate with multiple retailers. This economic pressure is transferred by food processors/manufactures to farmers who generally operate with the lowest profit margins in agrifood supply chains. Inevitably, tighter margins and low access to finance, especially for SMEs after the economic downturn (financial infrastructure failure), are highly regarded as posing significant growth and innovation barriers, affecting the ability and willingness (confidence) of farmers and agrifood companies to invest in knowledge and innovation development.

Evidence suggests that Scottish farmers, to an extent, remain dis-organised and scattered, that results in weak market power, and vulnerability to attempts by the large firms to exert control control In contrast farmers in the Netherlands appear more organised and willing to work collaboratively to secure greater power in the supply chain.

To a number of interviewees, retailer concentration and excessive bargaining power appear to an extent, to act as an innovation barrier. However, other interviewees also credit UK multiple retailers with offering to food manufacturers and their supplying farmers an increased access to consumers and being the real driving force for innovation within agrifood supply chains. Evidence suggests that food processors/manufactures tend to (sometimes be forced to) respond to retailers' demands, rather drive innovation.

5 Conclusions

The findings confirm the appropriateness of considering actors, functions, inducing or blocking mechanisms and innovation instruments as analytical tools to evaluate the performance of agrifood innovation systems. By combining the four additional types of transformational failures (Weber and Rohracher, 2012) with the two market failures (van Mierlo et al., (2010) and the four structural failures (Klein Woolthuis *et al.,* 2005), together with the coupled functional-structural approach taken by Wieczorek and Hekkert, (2012), the new integrated framework is proven to include all the necessary analytical blocks of a policy framework, aiming to identify systemic problems and propose systemic instruments to fix them. It produced a very rich and systematic analysis.

In both countries, blocking mechanisms in terms of actors' interactions and competencies as well as market and institutional structures were revealed. Many blocking mechanisms found in the Dutch and Scottish agrifood ISs were almost identical such as the impact of privatisation and commercialisation of extension services on the knowledge infrastructure. This may imply some universal effects of globalisation or the EU policy or even indicate similar trajectories and associated needs in the evolution of innovation systems over the years. In other cases, differences in the intensity of negative or positive impact of innovation-targeting mechanisms seems to be directly affected by the long traditions and cultures in each country that remain firmly rooted in the collective memory and consciousness of its people e.g. the Dutch people's inclination for collaboration, working on the basis of consensus, learning networks, and knowledge co-production. This may explains why the Dutch agrifood IS could be served better or for longer from a 'hands-off' approach from the Government, compared to the Scottish case, where the need to undertake a vision building strategy emerged earlier for the Scottish Government. In both cases, it was primarily the transformational failures of the agrifood ISs that most justified policy intervention, due the long-term character of transformative change, associated with the uncertainty surrounding innovation and change. Such conditions often go beyond interests or capacities of a fully competitive and decentralised market system to address.

However, the analysis benefits from the comparison of two countries which, one can say, demonstrate signs of different levels of maturity in terms of their propensity and capacity to innovate. In other words, it was interesting to see what kind of challenges faces a society (or agrifood system) that appears to have already comprehended the importance of multi-stakeholders collective learning, and have progressed with experimentation in learning networks, such as the Dutch agrifood system. Is it easy for actors to manage the accumulated experiences in fostering innovation processes, transform them from tacit to codified knowledge and disseminate lessons learned? Analysis shows that agrifood ISs tend to be so complex and changing over time similarly to the sustainability challenges that have to address, that such a task represents a huge challenge itself.

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Dynamics of Innovation in Livestock Genetics in Scotland: An Agricultural Innovation Systems Perspective

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Abstract: The application of genetic selection technologies in livestock breeding offers unique opportunities to enhance the productivity, profitability, and competitiveness of the livestock industry in Scotland. However, there is a concern that the uptake of these technologies has been slower in the sheep and beef sectors in comparison to the dairy, pig and poultry sectors. This is rather paradoxical given the fact that Scotland's research outputs in farm animal genetics are widely perceived to be excellent. A growing body of literature, popularly known as Innovation Systems theories, suggests that technological transformations require a much broader approach that transcends formal research establishments. Accordingly, this paper reports on preliminary work exploring whether and how an agricultural innovation systems perspective could help identify the dynamics of technology uptake in the livestock sectors in Scotland. Although the work has been undertaken in dairy, sheep, and beef sectors, in this paper, we provide the preliminary results obtained from a case study of the sheep sector only. The key objectives of this work were to map the sheep genetics innovation system in Scotland and identify the barriers prevailing within the system with regard to the uptake of genetic selection technologies. Although the sheep innovation system was characterised by the presence of all key domains and actors, it was found to suffer from some crucial weaknesses relating to network integration, technological infrastructure, and policies and institutional frameworks. The implications of these findings are discussed.

Keywords: Genetic Selection, Sheep, Scotland, EBV, Innovation System

1. Introduction

The livestock sector makes a significant contribution to the Scottish economy (Scottish Government, 2012; QMS, 2011). Excluding farm subsidy payments, ancillary industries and further processing, the sector generated revenues of approximately £1.8 billion and employed some 27,000 people in 2010 (QMS, 2011). Despite its importance the Scottish livestock sector faces some crucial challenges, including: a decline in livestock numbers (Scottish Government, 2012), fall in Total Factor Productivity (Barnes et al, 2011), increased competition in export markets (QMS, 2011), and the need to address consumer concerns for health and safety, animal welfare, and environmental sustainability (Simm, 2009; Wall, 2011).

Historically, genetic improvement of livestock through selective breeding has played a key role in maintaining the productivity, competitiveness and profitability of the Scottish livestock industry. Recent studies by the Scottish Agricultural College (SAC) and partners show a value of £29 million in sheep, £23 million in beef, and up to £147 million in dairy resulting from 10 years of genetic improvement. With higher uptake of modern breeding practices it is estimated that the value to the sheep sector alone could rise to £111 million (Simm, 2009). In

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addition to increased production and profitability, selective breeding has the potential to improve product qualities (e.g. leaner meat products), improve animal health and welfare, and lower Greenhouse Gas (GHG) emissions (Simm 2009, Wall, 2011).
Traditionally, farmers have selected animals by "eye", that is through visual inspection of the candidates for selection and their relatives. Since the phenotypic expression of animal traits are influenced by both genetic and environmental (including management) factors, animals selected in this way may not optimise genetic management for superior performance. Modern scientific inventions have provided unique opportunities to estimate the true genetic merits of animals more accurately. The key underlying procedures include the collection of pedigree and on-farm performance data of individual animals and then analysing these data through sophisticated statistical methods such as Best Linear Unbiased Prediction (BLUP). The results are then expressed as Estimated Breeding Values (EBVs).

An EBV is basically a numerical figure assigned to an animal for a certain trait, such as growth rate, muscle yield, maternal ability, etc. EBVs are often expressed in the same unit as the trait of interest, e.g. kilogram for live weight, millimetre for fat and loin depth, and percentage for number of lambs born. These EBV figures then indicate the predicted genetic merit of an animal for these traits. For example, a ram with an EBV of +4kg scan weight means that the ram's progeny are expected to be 2kg heavier at 20/21 weeks compared to the progeny of a ram with an EBV of zero. Depending on the breeding/selection objectives of farmers, EBVs on individual traits are weighted and combined to develop a selection index which farmers could use in their breeding programmes to optimise selection across many traits affecting profitability.

The adoption of EBVs in selective breeding is growing in Scotland. However, there is a concern that the uptake has been slower in the sheep and beef sectors in comparison to the dairy, pig and poultry sectors (Simm, 2009; Vipond, 2010). This is indeed a policy concern in Scotland, especially given the fact that Scotland's research outputs in farm animal genetics is widely perceived to be excellent (Islam, Lamprinopoulou, and Renwick, 2012) and that genetic improvement using EBVs is generally accepted as a working tool. Therefore, there is a need to understand why the uptake of EBVs in the sheep and beef sectors has been slower.

Until recently, the development and diffusion of agricultural technologies was thought to be a linear process involving public sector research and extension organisations. Such an approach, however, appears to be limited in explaining the slower uptake of EBV technologies in the Scottish livestock industry, in particular, given the strength in livestock genetics research that the country has. However, an emerging approach, popularly called the Innovation System (IS) approach, provides a much broader perspective and hence appears to be promising in investigating the Scottish context.

Accordingly, this work (on-going) explored whether and how an agricultural innovation systems perspective could help identify the dynamics of EBV uptake in the livestock sectors in Scotland. Although the work has been undertaken in dairy, sheep, and beef sectors, in this paper we report the preliminary results obtained from the sheep sector only. The specific objectives of this work were: (i) to map the EBV innovation system in the Scottish sheep sector, (ii) to identify the barriers within the system with regard to the uptake of EBV practices, and (iii) to discuss policy implications to further improve the uptake of EBV practices within the sheep sector.

The remainder of this paper is organised in the following way. In the next section we lay out a conceptual framework of the Innovation Systems approach. In section three, the research methods used in this study are described. The results of this study are presented in section four and in section five we draw the key conclusions and implications of this study.

2. The Agricultural Innovation Systems Approach

Innovation system thinking is not new in agriculture and dates back to as early as the nineteen sixties. For instance, the concepts of NARS (National Agricultural Research System) and AKIS (Agricultural Knowledge and Information System) that underpinned agricultural science and technology policies in many countries from the sixties up to the nineties were also based on systems thinking (see World Bank, 2006 for details). What makes Agricultural Innovation Systems (AIS) approach different from NARS and AKIS is basically its wider focus on organisations responsible for innovation, for example, the role of supply chain actors. As the World Bank (2006: iv) states *"The innovation systems concept embraces not only the science suppliers but the totality and interaction of actors involved in innovation. It extends beyond the creation of knowledge to encompass the factors affecting demand for and use of knowledge in novel and useful ways."* Accordingly, the Bank defines an AIS as the network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect the system's behaviour and performance (World Bank, 2006). However, as Klerkx et al (2009) state, although there is much emphasis on knowledge creation, exchange and use in the above definition of AIS, innovation systems need to fulfill several other functions that are essential for innovation. These functions include: fostering entrepreneurial drive and activity, vision development, resource mobilisation (e.g. capital), market formation, building legitimacy for change, and overcoming resistance to change by means of advocacy and lobbying (Hekkert, Harmsen, and de Jong, 2007).

The IS is however not a unified concept. Rather, depending on the boundary around which a system is conceptualised, four types of IS approaches are generally found, including: National Innovation System (NIS) (Lundvall, 1992), Regional Innovation System (RIS) (Saxenian, 1994), Sectoral Innovation System (SIS) (Malbera, 2002), and Technological Innovation System (TIS) (Carlsson and Stankiewicz, 1991). Regardless of their names, the basic elements that constitute an innovation system are more or less the same across these various approaches. They are: actors, networks/interactions, and institutions. The SIS and TIS approach however adds a fourth element – technology.

Actors within an IS approach could be any individual and organisation that contributes to the development, diffusion, and utilisation of a new technology, product or service, either directly or indirectly. As mentioned earlier, the IS approach takes a wider perspective in conceptualising which actor is inside or outside of a system. According to the activities and roles of these actors they are generally conceptualised under four key domains – research (or according to some, knowledge), enterprise, intermediary, and demand.

Examples of actors in the research domain include universities, research institutes, and so on, who create codified knowledge based on basic and applied research. In the enterprise domain are actors like technology companies who actually convert the scientific knowledge into innovative products or services and bring them into the market. Put together, the research and enterprise actors could be conceptualised as the suppliers of innovation. On the demand side are actors who use the innovative products or services. In between the supply and demand sides are the intermediaries such as extension and advisory services, farmers' organisations, trade associations, non-governmental organisations (NGOs) (World Bank, 2006), as well as specialized systemic intermediaries which merely facilitate interaction but do not give expert advice, which have been coined 'innovation brokers' (see Klerkx and Leeuwis, 2009) . These actors/domains are, however, not mutually exclusive. An actor on the demand side, for example a farmer, may be an entrepreneur. Similarly, research institutes/universities may sometimes undertake knowledge diffusion activities and therefore could be conceptualised as playing the roles of intermediaries. Ideally, a good performing system is characterised by the presence of a sufficient number and diversity of actors (World Bank, 2006). On the other hand, systems with missing actors may fail to perform (Woolthuis, Lankhuizen, and Gilsing, 2005).

Networks/interactions/linkages are the central components of an innovation system, as it appears from the very definition of the concept provided above. This is through networks of relationships (ties) that the different actors within an innovation system interact with each other, share resources and information, and harmonise their activities towards a common goal. This interconnectedness, harmonisation, and complementarities between various system parts are central in all systems theories (see for example, von Bertalanffy, 1976). However, these networks/linkages/interactions do not necessarily have to be formal. Instead, they can be informal and, sometimes, actors within a system may not even be aware of their existence. Whilst, all sorts of interactions are vital for an innovation system, a special focus on the IS literature is the flow of information/knowledge and competencies (skills) rather than the flow of ordinary goods and services only (Carlsson and Stankiewicz, 1991). Although ties are immensely important in technology diffusion, it does not mean that all ties within a system are always useful. For instance, although strong ties between system actors can be very productive and a source of synergy, they can sometimes be counterproductive (see Woolthuis, Lankhuizen, and Gilsing, 2005 for details).

Institutions are the rules-of-the-games that constrain (enable) the behaviour of actors in a society (North, 1990; Scott, 2001). Institutions are generally considered as the "environment" within which organisations are embedded. They can be *formal* and *informal*. Examples of formal institutions include government laws, policy decisions, firm directives, contracts, etc. and their enforcement mechanisms (e.g. rewards and punishments). Informal institutions are sometimes called "cultural rules" and can have normative and cognitive dimensions (Scott, 2001). Normative rules include *values* and *norms*, whilst cognitive rules include *shared beliefs*, *mental models*, *perceived logic of action*, and so on. Institutions have immense implications for new ideas, technologies, etc. to develop and diffuse. For instance, if a new technology does not correspond with the value system of a society, it will be difficult for the technology to develop and diffuse. This problem is widely documented in the diffusion literature and is known as "technological incompatibility" (see Rogers, 2003). A similar argument is forwarded in the so called "technological lock-in" theory (Arthur, 1989), which states that old technologies are difficult to replace as they are supported by existing institutions. By the same token, new technologies find it hard to be accepted because of a lack of corresponding institutions. Recent insights from innovation studies therefore point at the crucial importance of co-evolution between technology and institutional arrangements, such as markets, labour, land tenure and distribution of benefits (Geels, 2004; Hounkonnou et al., 2012).

At this stage it is useful to briefly outline the different categories of *innovation system failures* that have been identified in the literature as they provide a framework by which our results can be classified and analysed. Klerkx, van Mierlo, and Leeuwis (2012), following Woolthuis, Lankhuizen, and Gilsing (2005) and van Mierlo et al (2010), provide the following definition of innovation systems failures:

• *Infrastructural failures* concern (the absence of) the physical infrastructure, such as railroads and telecom are constraints requiring major investments that cannot be made independently by the actors of the system. They also concern investments in knowledge infrastructure (R&D facilities) and financial infrastructure.
• *Hard institutional failure* refers to laws, regulations and any other formalised rules, or the lack of them, hampering innovation. For example, lack of IP regulation takes away incentives from innovators as they cannot protect their innovation. Absence of environmental regulation on radically different systems, having an institutional vacuum, may slow down certain developments.
• *Soft institutional failure* refers to unwritten rules, norms, values, culture, or 'the way business is done'. They affect how actors interact, but also relate to their (in) ability to change their norms and values in order to enable innovation to take place.
• Related to institutional failures is *strong network failure*, which refers to actors locked into their relationship, which causes myopia and blocks new ideas from outside and prohibits other potentially fruitful collaborations. *Weak network failure* refers to a situation where actors are not well connected and fruitful cycles of learning and innovation may be prevented because there is no creative recombination of knowledge and resources. These two failures indicate an apparent paradox in networking for innovation: a quest for a balance between openness and closure, informal or formalized interaction, trust relationships or contracts (Håkansson and Ford 2002).
• *Capabilities failure* points to the lack of technical and organizational capacity of the system to adapt to and manage new technology and organizational innovations, such as a certain level of entrepreneurship, adequately educated persons, time to dedicate to innovation, and networking skills.
• Finally, *market structure failures* refer to the positions of and relations between market parties, such as a monopoly or the lack of transparency in the ever enlarging food chains, but also imperfections in the 'knowledge market' (Klerkx and Leeuwis 2009).

3. Methods

This research used an exploratory case study approach (Yin, 2003). The sheep innovation system was mapped and analysed using qualitative methods. Data were collected mainly through in-depth key informant interviews with scientists, industry experts, extension and consultancy service providers, farmer organisations/farmers, and other relevant stakeholders involved with the development, diffusion and use of EBV practices within the Scottish sheep sector. Furthermore, a workshop was held on 11 June 2012 with these stakeholders whereby various types of mapping exercises, group discussions, and brainstorming exercises were carried out. In addition, published and unpublished documents relating to EBV practices were collected and analysed. These results were then organised according to the concepts outlined in section two.

4. Results

In this section we first describe the EBV innovation system in the Scottish sheep sector and then discuss the factors within the system that constrained the uptake of EBVs.

4.1 Scottish sheep EBV innovation system: Key actors and their roles

The sheep EBV innovation system in Scotland was found to be characterised by the presence of all key domains of an innovation system, namely, research, enterprise, intermediary, and demand (Table 1). On the research domain there are two key actors – the research wing of the Scottish Agricultural College (SAC) and the Roslin Institute of the University of Edinburgh.

In the enterprise domain are three key organisations – Signet Breeding Services, Edinburgh Genetic Evaluation Services (EGENES), and Basco Data Limited.

Table 1: Key actors within the Scottish sheep genetic innovation system and their roles

Key actors	Roles	Domain(s)
SAC and Roslin Institute	Conduct basic and applied research on selection traits; create new methods/tools for genetic evaluations; provide technical support to EGENES; offer courses on animal genetics and breeding; organise workshops, seminars, etc. on animal genetics	Research (knowledge)
Signet	Compiles data provided by breeder members; cleans and stores data on Sheepbreeder or Basco website; provide EBV results back to breeder members; provide recording-related technical support, if required by members; publish EBV-related information on company website	Enterprise
Basco Data Ltd.	Stores and maintains an online database containing pedigree and performance data provided by breed societies, individual breeders, and Signet	Enterprise
EGENES	Performs genetic analyses by using data stored on the Basco database and/or provided by Signet; develop search engines for Basco database	Enterprise
Breed Societies	Collect, record and manage pedigree information provided by members; organise shows and events; publicise wide range of technical information, case studies, etc. on society websites; manage the Basco database (Texel and Suffolk societies only)	Intermediary
Press	Publicise EBV-related practices and events and activities, e.g. shows or sale information on indexed sheep, etc.	Intermediary
QMS (formerly MLC)	Collect levy money from abattoirs (paid by producers) and uses this money to provide funding support to Signet for undertaking genetic analyses and to SSS for undertaking KTE activities and events	Intermediary
SSS	Publicise EBV related technical information, case studies, etc on company website; undertake KTE activities on behalf of QMS; organise workshops and field days on EBV; conduct on-farm trials of EBV practices to demonstrate their effectiveness; publicise indexed rams and ewes on sale; work with supermarkets on EBV trials	Intermediary
SAC consultancy	Provide one-to-one advice and assistance to farmers on breeding and other wide range of agriculture-related services	Intermediary
EU, and Scottish/UK Governments	Create agricultural policies in Scotland; provide CAP support payments to farmers; formulate rules for payments; monitors activities of QMS; provide funding grants for R&D activities; publicise sheep industry information on official websites	Enabling (policy)
NFUS	Promotes and protects members' (farmers') interests by influencing government, supply chain actors, and consumers	Intermediary (policy)
Pedigree breeders	Record on-farm performance of sheep on selection traits; submit data to breed societies or to Signet or store directly on Basco database; receive EBV services from Signet; select and breed indexed animals; sell breeding ewes and rams	Demand
Crossbred lamb producers	Purchase rams from pedigree breeders and use them in cross-breeding to produce lambs for meat purposes	Demand
Auction Marts	Act as markets for the buying and selling of sheep; provide levy money to QMS based on per animal sold	Demand
Abattoirs/ Processors (maybe same)	Buy and slaughter sheep; provide levy money to QMS based on per animal slaughtered; process slaughtered sheep – cutting, grading, packaging, etc	Demand
Retailers (supermarkets)	Sell lamb meat and meat products	Demand

For simplicity, these various actors could collectively be labelled as the suppliers of EBVs. This supply side, however, is stretched beyond Scotland and is a unique blend of Scottish and English organisations. For instance, although Signet provides its services to Scottish farmers, the organisation is part of EBLEX (English Beef and Lamb Executive), which is an industry body for beef and sheep levy payers in England. Similarly, although EGENES provides its services UK-wide, the organisation is part of SAC and is based in Scotland.

On the demand side (actual and potential) there are pedigree breeders and commercial lamb producers who are expected to use EBVs to improve their flocks. In order to receive Signet services they have to pay an annual membership fee to Signet. These breeder members are required to record on-farm performance data in their flocks and submit these data to Signet and Basco. These data are then analysed by EGENES to estimate EBVs, which are then sent back to the breeders by Signet. The other actors within the sheep supply chain – such as auction marts, abattoirs, processors, and retailers – can also be placed on the demand side as they provide markets for the animals improved through genetic selection.

In between these two sides – EBV suppliers and EBV users – a number of intermediaries can be found (Table 1). One of these is the sheep breed societies for each of the major sheep breeds - including, Blackface, Bluefaced Leicester, Border Leicester, Cheviot, Texel, Suffolk, Charollais, etc. Some of these societies operate UK-wide whilst others operate within Scotland only. As shown in Table 1, the breed societies play a number of roles that have implications for the uptake of EBVs within the sheep industry. Moreover, two of the sheep societies – Texel and Suffolk societies – are the founding members of Basco Data Limited. Not all breed societies are however supportive of EBVs and some are, according to our interviewees, more “forward thinking” than the others. We have discussed this in detail in the next section.

Our findings suggest that other key intermediaries include the Scottish agricultural press, Quality Meat Scotland (QMS), Scottish Sheep Strategy (SSS), and SAC Consultancy Limited. The QMS is a Scottish statutory levy body run by the money collected from abattoirs (but paid for by producers) based on per animal sold or slaughtered and from exporters based on per animal exported. The QMS was created in 2005 as part of administrative devolution in the UK. During this, the then UK-wide levy body named the Meat and Livestock Commission (MLC) was dissolved and three regional structures were created – QMS in Scotland, EBLEX in England, and HCC in Wales.

The SSS is a subsidiary organisation created by QMS to undertake knowledge transfer activities with regard to EBV practices. SAC Consulting Limited, on the other hand, is a division of SAC that provides a wide range of advisory services to farmers on a fee-for-service basis. The organisation also provides free public good advice funded by the Scottish Government. Apart from these organisations, the research wing of SAC and the Roslin Institute also carry out some knowledge transfer and exchange activities through workshops, seminars, etc.

Furthermore, the EU and Scottish/UK governments were found to be important actors in terms of shaping an enabling environment for innovation (or, reversely, disabling). They provided policy and regulatory contexts within which the other actors operated. Also, the National Farmers’ Union of Scotland (NFUS) had influence on the government policy actors and therefore was an important intermediary at the policy level.

4.2 Systemic challenges in the uptake of EBVs

Five major systemic challenges were identified: a weakly integrated sheep supply chain, the presence of a powerful faction antagonistic towards EBVs, a challenging policy environment, a dismantled and weak advisory service with regard to EBVs, and an outdated and inflexible data management system. These are described below.

Weakly integrated sheep supply chain

Weak integration within the sheep supply chain was identified as one of the key factors affecting the uptake of EBV practices. If we look into the EBVs/selection indexes provided by Signet – the sole provider of sheep and beef EBV services in the UK – we see that these are promoted based on economic rationale, that is, as a means to increase farm productivity and profits (see Table 2). However, uptake of EBVs at the farm level and realising profits from this uptake were found to be constrained by a number of factors within the supply chain.

Table 2: Selection Indexes provided by Signet Breeding Services

Index	Main breeds	Main traits/EBVs	Breeding objectives/usefulness
Terminal Sire Index	Charollais, Hampshire Down, Ile de France, Meatlinc, Poll Dorset, Suffolk, Texel Vendeen	Leanness (Muscle and fat depth)	Increase lean meat and reduced fat in carcase
Maternal Index	Some Lleyn and Poll Dorset flocks	Litter Size, 8-week Weight, Mature Size and Maternal Ability	Increase lamb survival and pre-weaning growth rates (for high profitability)
Longwool Index	Blue Faced Leicester	Scan Weight, Muscle Depth and Litter Size	Enhance the carcase quality (conformation) of longwool rams and their progeny and thereby enhancing their financial productivity as crossing sires; growth rates are controlled so that mature size does not become excessive
Hill 2 Index	Scottish Blackface and North Country Cheviot	Mature weight, maternal ability, longevity and the number of lambs reared on weaning	Enhance the overall productivity of the ewe by improving several traits simultaneously, most significantly the number of lambs successfully reared; useful for ewe replacements

Source: Signet website at: http://www.signetfbc.co.uk/sheepbreeder/index.aspx?section=5anditem=58

As shown in Table 1, the main actors within the chain are pedigree breeders, commercial lamb producers, auction marts, abattoirs/processors, and retailers. As regards EBVs, these actors are engaged in the transaction of two key products: genetically improved live animals – such as high EBV or high index breeding rams and ewes – and genetically improved lambs for meat purposes (also called “prime lambs”). The selling and buying of breeding sheep, however, constitute only a small proportion of the market and the majority (around 75%) is for prime lambs.

The pedigree breeders sell their animals in two major ways: home sale (limited), and auction sale (main channel). In addition, pedigree breeders participate in show-based competitions with the potential to win awards. These awards in turn increase the prospects of attracting buyers. We found that in these marketing outlets, the EBVs and indexes offered by Signet have very little value. Rather, animals are judged based on their aesthetic attributes. For instance, in the case of Scottish Blackface – a Scottish hill breed – the valued criteria are features such as *bonny* heads,[5] curved horns, black faces with a V inside, black nose, and so on. Breeding animals sold on the basis of these aesthetic attributes could sometimes fetch a breeder a figure as high as £30-35 thousand for a single ram. Obviously, therefore, pedigree breeders achieving these figures have very little incentive to adopt Signet's EBVs. On the contrary, according to a number of interviewees, pedigree breeders may feel threatened by EBVs as these could potentially jeopardise, what in some cases, are their substantial incomes.

We also found that, over time, a culture has developed where the ability to raise and sell a sheep for a very high price not only brings pride to the sheep farmer concerned but also provides them with something of a celebrity status in their society. These so called successful breeders provide a kind of role model whom other farmers, including the younger ones, tend to emulate. An interviewee explained how this culture has perpetuated in Scotland by saying: "*it is the influence of the perceived leaders in each breed who get these ridiculous amounts of money; whether or not they are genuine, I am not going to comment on that, but everybody aspires to that…….the young men are aspired to selling a sheep at £100,000, not to selling 160% of their lambs you know; R3L's 21.4 Kilo – that's what they should be aspiring to, but no, they want the £100,000 Tup, and the rest maybe worth nothing (Farmer)*".

The commercial lamb producers sell their products (crossbred lambs) mostly through auction marts and sometimes directly to abattoirs on a deadweight basis. For instance, approximately 75% of the finished lambs in Scotland are sold through auction markets (Scottish Government, 2007). In these auctions, in particular in the North of Scotland, the vast majority of the crossbred lambs are bought by other farmers, called "finishers", who then fatten (finish) them within a short period of time and then sell them on to the abattoirs. This market is called the "store market".

Our study revealed that the above supply chain is characterised by three major problems that prevent breeders from seeing the financial benefits of genetic improvement. First of all, in auction marts, the quality of lambs is often judged based on their external looks, and according to one interviewee, this has created "*a generation of people who just really want to top that sale, and there is a lot of pride in it*".

Second, the predominance of store trade means that a vast majority of the crossbreed lamb producers are unable to see whether and how their sheep are valued at the end of the chain, i.e. at abattoirs. Moreover, lamb prices in Scotland are heavily influenced by seasonality and a poor quality lamb may sometimes get a higher price if it is available in the right time of the year. Consequently, in the words of an interviewee, "*producers are not rewarded for the product they have but for the time of the year they have it and the way they sell their sheep*".

Third, farmers selling lambs to the abattoirs also face many disincentives. The Scottish abattoirs use a system of carcass classification, called the EUROP system, based on carcass conformation, and fat range. This provides the basis for payments to producers. Therefore, lambs that do not conform to these specifications – for example, lambs with high fat content – could face penalties. These EUROP criteria directly correspond with many EBVs or selection indexes provided by Signet, for example, the Terminal Sire Index (see Table 2). Although this, in theory, provides an incentive for commercial lamb producers to use the Terminal Sire Index, it fails to do so, since the criteria like *fatness* and *conformation* are assessed "subjectively" by abattoirs (Maltin, 2010; Vipond, 2010). Moreover, there is no mandatory provision in place for abattoirs to report back the performance of individual sheep to farmers. This is despite the fact that all sheep in Scotland, by EU mandate, use ear-tags. Rather,

[5] *bonny* is a Scottish colloquial term for attractive

according to an interviewee, farmers are getting slaughter records back from abattoirs that just number their lambs, say, from 1 to 50. The records do not tell "*which lamb is which*" and, hence, the farmers concerned are getting no real feedback on how the different Tups – high and low index –eventually perform in terms of producing lean/low fat meats.

Although there is a widely held perception in Scotland that the deployment of video image analysis (VIA) technologies could improve objectivity about carcase quality (Maltin, 2010; Vipond, 2010), and the use of electronic identification tags (EIDs) could improve the traceability of individual sheep, interviews revealed that these technologies are still to be adopted widely. Although the QMS, supported by the Scottish Government, have pilot-tested EID technologies (through the so called "ScotEID project") in partnership with marts and abattoirs for over five years, interviews revealed that, only one abattoir has agreed to deploy the infrastructure needed for EIDs to be applicable.

From an innovation system perspective, the above findings highlight that the weakly integrated value chain means that there is a lack of 'demand pull' from the commercial production sector for EBVs. At the same time it highlights why there is also a lack of 'supply push' for EBVs from pedigree breeders. In terms of systemic failures, there are several institutional and 'hard network' failures which cause a lock-in of the system.

Antagonistic faction within the system

From a network failure perspective, we found that the sheep innovation system in Scotland was not a cohesive and fully integrated structure. We have already discussed the problem of this weak integration within the sheep supply chain. A similar lack of integration was also found amongst the various intermediaries in that there was an informal antagonistic coalition comprising breed societies, a section of the local agricultural press, and some influential pedigree breeders. According to our interviewees, this faction may be seen as a barrier to the widespread uptake of EBVs. In IS terms, what these factors mean is that the system is characterised by both 'weak network failure', the inability to form new innovative coalitions, as well as some 'strong networks' which keep the system locked-in to its current state.

As we have already mentioned in section 4.1, breed societies are influential players in the sheep innovation system, but not all of them are supportive of EBVs. Although many do not oppose EBVs in public, in reality, they just pay "*lip service*". A key reason for this is that the breed societies are reliant on the donations of powerful breeders – the ones making substantial incomes from agricultural shows. The breed societies and the powerful breeders, on the other hand, work through some influential local agricultural press. These newspapers rarely provide coverage of EBVs and, in some instances, are critical of the technology.

Our interviewees believed that a key reason why these newspapers may not be positive towards EBVs is that the funding generated from the shows is an important component of their income and therefore they are more willing to support an industry where the external looks of a sheep (e.g. *bonny* head) are more valued than those being associated with EBVs (see Table 2). During the workshop, the interviewees explained this situation by saying: "*Negative press attitude ... [towards EBV].... is linked to the breed societies, which are being influenced by the top breeders. The top breeders work through the press. They come up with all these negative reasons [for non-uptake of EBVs]....these people are working against people who want to innovate and improve because they [the former] have got vested interests; they want to keep the status quo. The whole point of a breed society is to maintain the looks of an animal, basically..... (Consultant) ....well, the X [name] society draws £20,000-30,000 a year ……. and that's all about bonny, bonny, bonny. So if you do away with bonny, bonny*

bonny and try and replace it with lean meat and growth rate, where is your £20,000? (Farmer)".

However, it is to be mentioned here that the roles played by breed societies are heavily influenced by whether the societies were led by "traditionalists" or "modernists" (these can be seen as soft institutional failures within the IS conceptual framework). Also, because of rotational (generally two year) leaderships within some breed societies, the advances made by modernist leaders are often reversed when they are replaced by the traditionalists. Interviews also revealed that QMS/SSS and Signet have tried to overcome this challenge by working with breed societies and there has been a slow but steady shift in attitudes.

Challenging policy environment

We found that, whilst the underlying rationale of EBVs and selection indexes provided by Signet emphasise farm productivity (see Table 2), some government policies and incentive mechanisms for agricultural development may be seen as incompatible with this purpose. The key policy in operation in Scotland, as in the rest of the European Union (EU), is the Common Agricultural Policy (CAP). Due to major challenges with the profitability of the sheep sector, the extent and nature of CAP support has an important role in the decision making of farmers in Scotland. Until the introduction of decoupling in 2005, the payment had been strongly correlated with the number of sheep stocked rather than the productive quality of the sheep. Therefore, as the market was not directly rewarding productivity, many farmers acted rationally and maximized stock numbers rather than productivity. Since 2005 this payment has not been linked with production (although the total amount received does depend on past levels of production). Rather, farmers now receive payments (known as the single payment scheme) regardless of the number of sheep they have. The only restriction is they have to maintain the land in good agricultural and environmental condition. However, for those receiving extra payments due to disadvantage (identified as Less Favoured Areas) there are minimal stocking rates that have to be maintained. There has also been a move to support agriculture in providing more general public goods (environmental benefits, etc.).

The fact that the link between stock numbers and payments has largely been broken could be seen to encourage farmers to focus on productivity rather than just the numbers of sheep – consequently encouraging the uptake of EBVs. However, a cross section of our interviewees believed that the decoupled CAP payments under such a public goods agenda were in conflict with the goal of raising farm productivity and profitability through genetic improvement. In reference to the negative effects of the greening payments on technological change in the sheep sector one of the interviewees (a geneticist) said, "*the signal [from CAP payments] is all you have to do is keep your grass short and here is the money to do it; you don't need a Ferrari-style Texel or something to do that, you just need the thing with four legs that licks grass…there is very little impetus to think about things like meat and product quality, and disease resistance, and so o*n".

The existence of decoupled payments was also argued to enable producers who were not focused on productivity to remain in production despite an inherent lack of profitability. That is the existence of the payments meant they could carry on producing using traditional methods rather than having to adopt new technologies.

Dismantled and weak advisory support relating to EBVs

Within the context of the privatization of advisory services across the EU (and worldwide), Scotland can be seen to have a relatively highly developed and successful farm advisory/extension service. Examples include the Monitor Farm extension network (see QMS, 2010). Despite this, however, the advisory support available to farmers with regard to genetic selection and improvement was found to be weak.

As shown in section 4.1 (Table 1) the advisory services with regard to EBVs are provided mainly by QMS and SAC Consulting Limited. QMS uses two main channels to provide their advisory support: Scottish Sheep Strategy (SSS) and local press. The SSS, in partnership with Signet and breed societies, uses a wide range of knowledge dissemination activities, including workshops, field days, on-farm demonstration trials, and publicising EBV-related information on company websites. According to our interviewees, whilst, these knowledge transfer activities have been useful in influencing farmers' attitudes to EBVs, they are deficient in two aspects.

First, many farmers, especially those who are the beginners, need one-to-one support (which farmers called "handholding") in such matters as which animal to select, when to select them, how to record and monitor their performance, how to handle the large quantities of data that the procedure generated, and how to analyse the costs and benefits of EBV uptake. According to some farmers, learning about these issues requires patience and could take from five to ten years. One particular challenge is data handling and calculating the benefits of EBV uptake that require considerable IT and computational skills. However, very few farmers, especially the older ones (whose mean age is around sixty years) that comprise the vast majority of the farming population, have these skills. Moreover, each farm has their unique biophysical and economic contexts that require individually-tailored support services. According to our interviewees, as these supports were not available, many farmers who had begun recording soon dropped out as they found "*too much hassle with too little benefit*". This does point to the fact that the advisory service may not be appropriate in terms of facilitating a local learning process instead of transferring a technology package.

This was however not always the case. Up until the year 2005, when the recording system was maintained by the UK-wide levy body (the Meat and Livestock Commission MLC), there were provisions for one-to-one advisory support to the farmer members. In the post-devolution period, the levy bodies have been unable to maintain such a service. In referring to the effect of this dismantled one-to-one advisory support a farmer interviewee said: "*Before that [pre-devolution] there were quite a lot of consultants who used to come around on to farms and help someone who started recording, when results [EBVs] arrived they used to take farmers through it [i.e. interpret for them]....there is absolutely no back up now ...*"

Linked to this is the view that devolution has made it harder for the Scottish to achieve the necessary scale of investment in activities to promote uptake of EBVs when compared to their English counterparts. As one informant commented, "*the reason that it [uptake] has varied in England is …….. on the back of huge amount of work and investment that EBLEX [devolved English organisation equivalent to QMS] made at the early stages of ... what they called the Better Return Programme, their knowledge transfer programme. And they promoted it very very well, huge numbers of meetings, two to three hundred meetings in a year, very very widespread coverage, they mailed every sheep producer in the country regularly with EBV information, and breeders saw direct results from that. I suspect if you ask English breeders you would get that kind of response. It hasn't been that great [here]….. the level of publicity and promotion has not been as high and QMS just don't have the budget to compete with that*."

We found that the above situations arose because of what we call "transition effect". As one interviewee explained, "*the break up of the UK levy board into English, Scottish and Welsh* *has a dramatic impact. I think the Scottish and Welsh players have become much smaller in scale and much less influential in some respect, certainly as they have got smaller budgets. Around this is also the turmoil to decide what they are there for*".

In terms of the domestic advisory landscape, historically the consulting arm of SAC has been the main provider of advice (including on breeding) to farmers. However, the organisation has gradually moved away from technical advice on animal breeding and focused more on helping farmers to manage CAP payments in the form of Pillar 1 and Pillar 2 payments (see Renwick, 2012 for details). This is largely because there are demands for these services within the farming community and hence they serve to provide good income for SAC consultants. In addition, the focus of government on supporting advice that was targeted at public good provision meant that public funds to support breeding were less available.

Outdated and inflexible data management system

As we have explained in section one, good quality pedigree and performance data are the keys to EBV estimation. In Scotland, the breeders (Signet members) are expected to record and provide these data to Signet, either individually, or through their respective breed societies. They also have the option to record data on an online database provided by the Basco Database Limited. Within this approach it is possible to identify some failures in terms of capabilities and infrastructure.

The database system used by Signet has been manual or paper-based. According to this, the farmers are required to record performance data on Excel sheets provided by Signet. Its staff then re-type the data into their database. Some interviewees have been critical of this approach as they feel it allows errors to occur and also has not kept up with new technologies. There was a view that this outdated data recording system also resulted in loss of economies of scale, which was in contrast with the situation in countries like Australia and New Zealand. As one farmer said, "*Here, the big flocks end up paying more, whereas the big flocks are automated. I can send in the lambing dates of 800 ewes with practically no errors electronically and we are paying miles more than the guy who has got 50 sheep. We should be paying less. In New Zealand, if you send electronically you pay a certain rate, but if you are a hobby farmer and you prefer paper you pay an hourly rate. What we should be doing is encouraging people to record bigger flocks and make it cheaper, but here it goes the other way round. We are being penalised…So, Signet is not ideal and people who are not recording are doing so because of these things*".

A concern was also raised that the antiquated nature of the technology involved meant that it was hard to evolve the system to allow for changes in the sector. For example, it was argued that the template for data entry used by Signet did not provide room for recording all traits and breeds such as those of Easycare systems where a major focus of selection was a sheep's wool-shading ability. Since the market value of wool was low, many farmers were replacing their traditional stocks with Easycare systems in order to save time and costs of shearing.

A similar problem was found with the Basco database. As already mentioned in section 4.1, the database was created through a partnership between three pedigree breed societies – Texel and Suffolk sheep societies, and Limousin cattle society. Later, through a UK government grant Signet and Basco Data Ltd. developed a partnership that allowed EGENES (SAC) to have access to the Basco database. However, according to our interviewees, the Basco database was not suitable for crossbreeds (e.g. Easycares) as "*it sucked in data by breed rather than by animal*".

However, interviews revealed that Signet and Basco, supported by EGENEs, have been updating the database system into a fully automated online system. The change however has been slow because of two main reasons. First, the high average age of Scottish farmers means that many are not fully skilled in the use of computers. Therefore, a paper-based system may be seen as more justifiable for them. Second, lack of availability of monetary resources constrained Signet's ability to update its technological infrastructure.

5. Discussion and Conclusions

In this paper we intended to explore whether and how an innovation systems perspective could help us identify the barriers to the uptake of EBV practices within the sheep sector in Scotland. The results support many of the well-known problems as stipulated in the diffusion of innovation theory (Rogers, 2003). These include a lack of compatibility of the technology (EBV) with the existing values of end users, absence of one-to-one advisory support, and so on.

However, our analysis based on an innovation systems approach provides some additional perspective in that the barriers to the uptake of EBV practices transcend far beyond the remits of the individual adopter and the formal science and advisory service providers and involve a wide range of actors, including breed societies, governments, farmers' union, supply chain actors, and the farmers. Moreover, the policy and institutional frameworks within which these actors operate/interact play important roles. Also important is the technological infrastructure needed for new behaviour and practices to be feasible. The results therefore support the claims often made by the proponents of agricultural innovation systems (e.g. World Bank, 2006; Klerkx et al., 2012).

This study also shows that a crucial aspect of the innovation system analysis is that it points to the importance of interconnectedness and complexity. As we have seen, many of the challenges faced by the sheep innovation system emerged over time out of complex co-evolutionary interactions between actors, policies, institutions, and technology. For instance, devolution in UK government administration affected the nature and scale of advisory support available to sheep breeders with regard to EBVs. Similarly, the uptake of EBVs is negatively affected by lack of uptake of other technologies – such as video image analysis and electronic ID's within the industry. Therefore, the innovation system analysis provides a holistic tool to diagnose systemic problems and improve agricultural innovation by going beyond investing in formal science (World Bank, 2006), and seeing innovation as a process of broadly reordering technical, social and institutional relationships within a given value chain (Klerkx et al., 2010).

For instance, based on our analysis we can see that an improvement in the uptake of EBV practices within the Scottish sheep industry would require a number of steps. First of all, there is a need for major reforms on the supply sides of EBVs, including the modernisation of Signet and Basco recording infrastructures. One way forward could be to use genomic tools in selective breeding that, arguably, can provide faster results and is less demanding in terms of time and efforts needed on the farmers' side. Although works on genomic selection have already been undertaken by SAC and Roslin (Wall, 2011), the science is still at a rudimentary stage and the requisite tools are not still widely available.

There is a particular need to reform and improve the capacity of Scottish marts and abattoirs to provide objective feedback to farmers regarding product traceability and quality. Adoption of video image analysis and EID technologies may help achieve this objectivity. Although the on-going schemes undertaken by QMS in conjunction with abattoirs are clearly in the right direction, as we have found, the uptake of these technologies has been slower. Research is therefore needed in order to better understand why this is happening and how the situation could be improved.

The above developments alone are however unlikely to improve the situation. As our results indicate, at present, there is a vacuum in the advisory landscape as there are very few consultants with expertise in genetic selection and improvement. Decades of diffusion research (Rogers, 2003) have shown that technology uptake is a complex socio-psychological process in which adopters require not just information through mass media but also skills training and mentoring support over a long period of time. This means that a mere reliance on newspapers and websites as the channel of EBV knowledge transfer is unlikely to be useful, unless this mass media campaign is combined with one-to-one advisory support, keeping in view the needs and situations of individual farmers.

The findings of this study also indicate that it would be necessary to counteract the resistance created by some powerful breeders (together with some breed societies and agricultural newspapers). Lessons from diffusion studies indicate that this could be done by promoting and rewarding innovative breeders and helping them to get established as role models in their societies. Another way is to provide one-to-one advisory support to farmers as interpersonal communication can help build trust with change agents and thereby reduce farmers' dependency on traditional leaders within their communities.

The above changes, on the other hand, would require substantial investment in terms of manpower and funding. The question that needs answering is where the money for these changes in research and advisory systems would come from. This raises the need for discussions as to whether genetic improvement is a public or private good problem and how much of public money could justifiably be invested for this purpose. In order to reduce costs of one-to-one advisory support, innovative extension methods such as Farmer-led Extension (FLE), in which innovative farmers are employed as extension providers (Islam, et al., 2011), could be tried. Lessons from various countries indicate that these methods are often cheaper and more effective in dealing with community level resistance to change (Killough, 2003).

However, criticisms on the individual orientation of diffusion research have shown that the context in which these individuals are embedded should also change. Therefore, beyond advisory services targeted at farmers, facilitation of joint learning process across the sheep value chain is a key requirement in order to create an enabling environment for individual behavior change (Leeuwis, 2004; Klerkx and Leeuwis, 2009). This would concern incentives such as product prices, legislation, which co-determine farmers behavior (Leeuwis, 2004). There is hence a need for both individual oriented advice, as well as systemic facilitation.

As regards systemic facilitation, there appears to be the need for work to be undertaken to allow the sector to jointly articulate visions for future development. This would also involve the development of an environment which enables the realisation of these visions in terms of changing hard and soft institutions, the establishment of new networks and breaking the lock-in in incumbent strong networks (Klerkx and Leeuwis, 2009; Smits and Kuhlmann, 2004). For example, in such a visioning and innovation agenda setting process, dialogues and clarifications are needed as to how the greening and other public goods agenda under the CAP could be promoted in a way that does not affect the productivity of agriculture in Scotland. One way forward could be to incorporate CAP payments with selection traits that minimise environmental impacts, such as the emissions of green house gases of ruminant origin, and making emission reductions mandatory for farmers as is currently the case for ear tagging of animals. This, on the other hand, would require the development of selection indexes for reducing GHG emissions which is on-going at SAC and Roslin but still at an early stage.

However, we would like to mention that, although this study provides some useful insights, it is still in its relatively early stage. Moreover, the generalizability of this study is limited as it is based on a single case analysis. A comparison of the sheep sector with the dairy sector, which has been relatively fast in taking up EBVs, is expected to develop more robust conclusions regarding the dynamics of innovation in genetic selection in the Scottish livestock sectors.

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LEADER

- an approach to innovative and suitable solutions in rural areas?

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Annotation: The research presented is part of the evaluation of Rural Development Programmes (RDP) in seven German "Länder" (federal states).Innovation is often mentioned as an important pillar of the development of rural areas. One part of Rural Development Programmes, which explicitly addresses innovation, is LEADER: a bottom up-oriented, participatory approach with cooperation by local actors in rural areas. In LEADER, a Local Action Group (LAG) with stakeholders of different institutions and origins comes together as a kind of a public-private partnership and decides about the financial support for regional projects.

The LAG can be seen as a kind of new "network of practice." In this context it is important for the LAGs to assemble people with various backgrounds and to foster a good communication and cooperative climate. A survey of LAG-members shows positive results: there are improvements in the "cooperation beyond administrative borders" (respectively, narrow village boundaries), in the "improving of understanding views from other groups" and in the „cooperation between different groups." Thus LEADER is an example of how an external programme can connect actors from different interest groups who would, without this programme, in part not have met.

In addition, LEADER offers the possibility to try out new approaches, as the regions have access to their "own" funding budget to implement their ideas. But in practice the possibilities of funding experimental or innovative projects via LEADER depend very much on the extent to which the RDPs are able to provide a suitable framework to fund projects outside the standard menu of measures. The assessments of the LAG-managers show that the real possibilities are limited, particularly compared with the former funding period (LEADER+). But despite these limitations, we found LEADER- projects fostering innovation in very different fields.

Key words: LEADER, Innovation, Evaluation, Funding

1. Introduction

1.1 Challenges in rural areas and innovation

With the "New Rural Paradigm," the OECD (1996) put forward the concept of territorial dynamics to denote a set of specific regional and local factors, structures and tendencies. These include entrepreneurial traditions, public and private networks, work ethics, regional identity, participation and attractiveness of the cultural and natural environment.

Thereby the challenges and problem situations in rural areas are very different. On the one hand, possibilities for attractive employment opportunities are small in disadvantaged regions and inhabitants can feel less connected to their area. Also, their willingness to invest time and capital to improve the „liveability" of their habitat deteriorates. Highly educated persons are often the first to leave, causing a so-called 'brain-drain' which leads to rural areas with low potential (Stockdale, 2006, Wellbrock et al 2012). On the other hand, there are rural regions successful in seizing the opportunities arising from globalisation and thus referred to as 'hot-spots' of development (Wiskerke, 2007; BBR 2008). In both cases, however, it is argued that in order to enhance rural economies, producers and consumers need to be reconnected within the region, products need to be re-embedded in the region, economic activities diversified and non-economic and economic activities entwined (Wiskerke, 2007; Wellbrock et al, 2012).

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Also the EU‘s innovation policy states that regional policy would be an important route for encouraging innovation. (EU-COM, 2003). It refers to the goal of the Lisbon strategy of „becoming the most competitive and dynamic knowledge-based economy.“

From the literature, there is a hypothesis that the factors behind the different economic performance in rural regions are related to an interplay of local and global forces, in which territorial dynamics, population dynamics and the current globalization process are thought to be main determinants (Terluin, 2003). By analysing differences in the economic performance Terluin (2003) proposes a kind of general guideline for economic development strategies in rural regions. This guideline recommends improving „the capacity (knowledge, skills and attitude) of local actors to establish and sustain development within the region” as one of the key issues (Terluin, 2003). Successful development approaches therefore include human skills, capacity-building and innovation as a crucial element (Tomaney, 2010). Thereby the commitment and creativity of the local people play a crucial role for the development and viability of rural areas (Kröhnert et al, 2011).

Innovation (in different senses) is mentioned in various pieces of literature as an important pillar for the development of rural areas or as a rescuer from problems in rural areas.

For example Neumeier (2011) states, that „innovation” is an essential aspect of finding suitable solutions for problems of rural development. Especially against the background of demographic change in rural areas, social innovations are regarded as one of the important aspects of successful rural development (Papageorgiou 2011, Neumeier 2011). In addition, innovation has been identified as one of „the five key drivers of productivity,“ so it is one of the key determinants of the relative economic performance of rural areas (Agarwal 2009, HM Treasury, 2001). Also the theories governing territorial innovation models highlight the diffusion of innovations as an important engine behind growth (Morgan, 1997; Terluin 2003).

It became appearent that the context of innovation as an insight into the driving factors behind the economic performance of rural regions is not only of scientific interest, but also of high political relevance (Terluin, 2003). This knowledge can reveal how the rural development could be supported by state driven opportunity structures.

Expectations on the policy are that it should be able to foster very different problem situations, because the support required for innovation in rural areas is highly context dependent and problem specific[2] (Tovey, 2008; Wellbrock et al, 2012). According to Asheim (2007) and Florida (1995), the success of support for regional learning and innovation depends on the arrangement of effective, co-operative and operational partnerships between actors of the different strings (Wellbrock et al, 2012).

1.2 Support for innovation in Rural Development Programmes

Facing the challenges in rural areas like economic problems, demographic changes or matters of renewable energy, a crucial issue in Rural Development Programmes funded by the European Union (RDP) is “innovation.” One part of Rural Development Programmes, which explicitly addresses innovation, is LEADER: a bottom up-oriented, participatory approach with cooperation by local actors in rural areas. Its intention is to cover all the above-mentioned aspects for a locally- based economic development.

The practical implementation is carried out through Local Action Groups (LAG). In these groups, stakeholders of different institutions and origins come together as a kind of a public-

[2] “*We have not tried to identify ‘best practices’ but rather to locate some ‘good practices’ for rural sustainable development, that is, practices that are context-bound and that are ‘good’ because of the way they help to embed sustainable development in local contexts. ‘Best practices’ are identified with a view to making them transferable from one location to another, but ‘good practices’ are not easily transferable: what is good in one context needs to be continually reinvented in new forms for other contexts*” (Tovey, 2008).

private partnership and make decisions about the financial support for regional projects. Those projects must contribute to the objectives of the Local Development Strategies (LDS), which were compiled by the members of the LAG.

History of the LEADER approach

From 1991 to 2006, Leader I, Leader II and Leader+ were conceived as a laboratory to encourage the emergence and testing of new approaches to integrated and sustainable development and to influence, complement and/or reinforce rural development policy in the Community (LEADER Guide, 2011).

So the LEADER approach disposes over broad experience in implementing innovations in rural areas, and has been a constitutive part of the RDP since the year 2007. In that funding-period (2007 – 2013), LEADER was extended to all European rural areas. But now, as LEADER is subject to the mainstream regulations of the Council on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) (Council Regulation (EC) No 1698/2005), there are concerns about losing the innovative character of the LEADER axis, based on the whole design and consequences in the regional implementation and the character of the projects (European Network for Rural Development, 2010).

For further improvements the lessons drawn from the three previous stages of LEADER should be used together with examinations from the current stage (Nardone et al, 2010).

1.3 Theoretical Framework of Innovation

Basically Rogers (2003) described innovation as an idea, practice, or object that is perceived as new by an individual or other unit of adoption.

Neumeier (2011) comprehends "innovation" in context of rural developement in an economic sense with new products and services as well as in a social sense (Neumeier, 2011) which contents new ways of organising infrastructure and participation. These elements can also be found in the context of LEADER. Several definitions exist on different levels, in general they all fit into Rogers' concept, but differ slightly in two aspects: the innovation itself and who perceives it as new.

The most common understanding of the „innovation itself" in the LEADER context is very broad:

- It includes products and processes as well as organizational, social and institutional and communication matters (i e., the RDPs of the federal states as an example here: HMUELV (2007), Neumeier (2011), OECD (2011), LEADER Guide (2011), Dargan and Shucksmith (2008))

And the most common understandings of the question "Who must perceive it as new" in the LEADER context are:

- The unit of adoption of the innovation at the local level,
- it is not enough if it is only new for the one who carries out the innovation.

But rules are lacking on who decides on "newness" at the local level.

Rogers' definition is embedded in the theory of the diffusion of innovation, which seeks to explain the spreading of ideas and technologies through cultures. It is similar to Schumpeters (1911) economics-related definiton which sees innovation as not only the invention itself but only fullfilled if it is taken over in the real (production) process.

The connecting factor to the LEADER approach is the intended diffusion of ideas and solutions between regions. It must be understood not only as a "new project," but as an approach to solve specific challenges in new ways.

Rogers described many factors for analysing “innovation”:

a. The characteristics of the innovation itself (by relative advantage, complexity/simplicity, trailability, observability)

b. The personal innovation-decision process (with the steps: awareness, interest, evaluation, trail, confirmation/adoption)

c. The relative speed with which an innovation is adopted by members of the social system (Rate of adoption)

d. The social system[3] as a set of interrelated units that are engaged in joint problem-solving to accomplish a common goal and the communication channels of these units, through which innovation is communicated between the members of the social system.

The differences between the stakeholders of the LAG play an important role, referring to theories of networks and communication. We know, that communication is more effective between individuals which are similar in certain attributes (origin, beliefs, education,…) or which share the same implicit knowledge (so called “communities of practice”) (Wenger, 1998), but it can lead to redundant information because there is less new information to exchange. A heterogeneous communication network holds much more potential for new information. But at the same time a certain degree of similarity is required for communication and diffusion of innovation.

Several scientists observed and analyzed this phenomenon and labeled it with different terms. To mention only a few: similarity and dissimilarity, social closeness and social distance, co-linear and non-linear, homophily and heterophily (Rogers 1970). Rogers (1970) states “Therefore, an ideal situation would involve two individuals who are homophilous in every way, except in knowledge of the innovation.” Manger (2009) expatiates two ways out of the dilemma: either the existence of “Boundary spanners” who are socialized in different communities and play the role of a translator. Or the development of new “networks of practice”, with members from different “communities of practice”, bringing in the heterogeneous aspects of their communities, but developing social bonds and common communication rules through regular meetings and exchanges.

In this context the LAG can be seen as a kind of new “network of practice”. It is important for the LAGs to assemble people with various backgrounds and it is also necessary to protect and foster a good communication and cooperation climate which is prerequisite for an easy exchange of “newness” (information, ideas, …).

1.4 Research topics of this paper

Within this paper only a few of the mentioned factors are further elaborated in the context of LEADER:

- The potential of innovation against the background of the various funding-frameworks
- Getting and creating innovative ideas and solutions as a „pre-“step of the innovation decision process
- Implementation in practice: occurence of innovative and suitable solutions
- The inter-regional communication channels.

[3] With focus on opinion leaders, theory of organisations (esp. collective and authority decisions) and the principles of homophily and heterophily

2. Methods

2.1 Framework of the study

The research presented is part of the evaluation of Rural Development Programmes in seven German federal states[4] started in 2007 and ending in 2015. Therefore the Common Evaluation and Monitoring Framework (CMEF) must be taken into account in choosing an appropriate research methodology. The seven federal states incorporate 98 LEADER areas and 23 other regions with Local Development Plans.

Concerning innovation, the main aims of our research are to identify the extent to which innovation happens in LEADER and what factors facilitate or hinder the occurrence of new approaches to address problems and challenges in rural areas.

2.2 Data collection tools

We used mixture of qualitative and quantitative methods depending on the specific question to be addressed. Until 2012 the main instruments for data collection were:

- more than 100 face-to-face interviews (project initiators, LAG-managers, LAG-members, governmental employees at different levels and responsibilities),
- two surveys with written questionnaires:
  - members of the LAG's decision bodies (N=2310, n=1430, response rate: 62%)[5]
  - LAG-managers of LEADER areas and other areas with local development plans and processes (N=121, n=114, reply rate 94%)[6]
- standardised annual requests of activities and organizational structures in the areas[7]
- analysis of funding documents and funding data.

A survey with written questionnaires (to project beneficiaries) is ongoing but not fully completed at the moment. First results will be presented in the session.

3. Results and Discussion

3.1 The potential of innovation against the background of the various LEADER funding-frameworks

The concept and constraints of innovation are not clearly defined in the Council Regulation 1698/2005 for the LEADER approach, it is only identified as one of the seven characteristics and the guidelines mention that the LEADER axis is meant to stimulate innovation. But innovation is not explicit mentioned as an eligibility criterion for project funding.

Projects

Within the LEADER context, the regulation (Art. 63 of Reg. (EC) 1698/2005) states that the possibility exists to fund innovative projects under the Leader axis, which need not correspond to the criteria of standard measures as regards Axes 1 – 3, but which contribute to the goals of one or several of these axes.

Here, especially the lack of a clear definition of innovation at the EU level produced different definitions which more or less restrict the selection of projects by the LAGs. In the beginning of this funding period, the RDPs of the seven federal states (included in this study) used the following designs to fund LEADER-projects:

[4] Hesse, Schleswig-Holstein, Mecklenburg-Pomerania, Lower Saxony incl. Bremen, North Rhine-Westphalia, Hamburg
[5] In the following text indicated as Pollermann et al (2010c)
[6] In the following text indicated as Pollermann et al (2010a)
[7] In the following text indicated as Pollermann et al (2010b)

a. Restricted to the measures of (nearly) one axis;
b. Restriction to the measures of two or all axes;
c. Possibility of funding for projects which contribute to one or more objectives of all axes.

It must be taken in account, that the axis-measures are subdivided into different components of measures, which can also be more or less innovative depending on the directive of the federal state. The crucial point is the restricted choice of projects by the LAGs, if the directive restricts to axis measures and there is no appropriate axis-measure for the special regional issue.

Other innovative elements

The general assumption in LEADER is that the networking and cooperation of stakeholders from different institutions, origins and sectors play an important role in creating new ideas, solving specific regional challenges and advancing innovation. Some conditions to assemble heterogenous partners in the LAG are set, as the following paragraph shows:

„A partnered local development approach shall be implemented by the local action groups satisfying the following conditions: (...) representing partners from the various locally based socioeconomic sectors in the territory concerned. At the decision-making level the economic and social partners, as well as other representatives of the civil society, such as farmers, rural women, young people and their associations, must make up at least 50 % of the local partnership; (...).“ (EC 1698/2005)

The stakeholder should come together to develop the regional strategies in a Local Action Group (LAG) as a kind of a public-private partnership and make decisions about the financial support for projects, in working groups to develop topics or projects in coherence to the local strategies. In these meetings the ideas and drafts are supposed to be evaluated, which can be seen as the of the next step of Rogers‘ innovation process.

For the further step „trying out new approaches,“ LEADER also provides opportunities as the regions have access to their own funding budget to implement their ideas.

3.2 Getting and creating innovative ideas and solutions as a „pre-“step in the innovation decision process

Rogers described the “awareness” of the innovation as the first step of the adaption process. This implies that the innovation itself already exists. The LEADER approach fosters the coming to light of existing ideas, but it also tries to start one step beyond by creating new ideas, actions and solutions within a region. As mentioned above, a general assumption in this approach is that networking and cooperation of stakeholders from different sectors play an important role in creating new ideas and advancing innovations.

The kick-off-meetings for developing the Local Development Strategies (LDS) are one of the first opportunities to meet and develop ideas. 75% of the LAG-members asked agree that there is a high compatibility of the strategy with the regional circumstances (Figure 1).

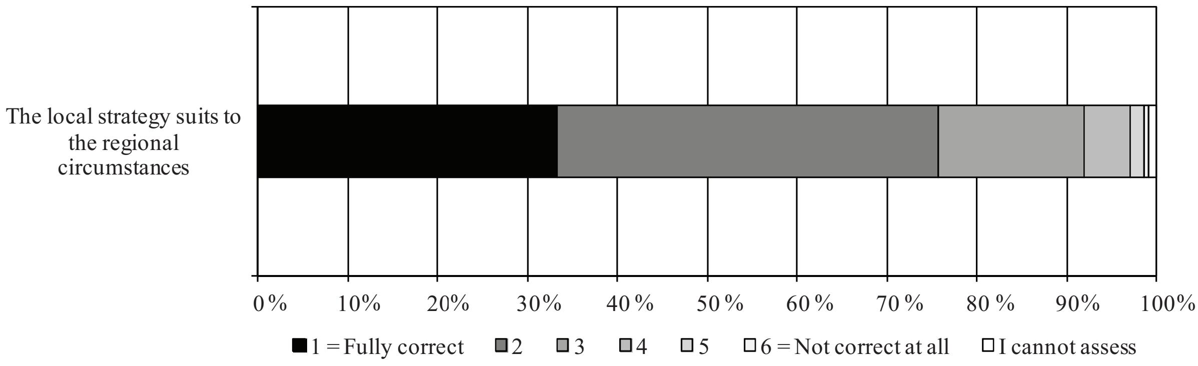

Fig. 1. Distribution of answers (in percentage of total) to the question “To what extent do you agree with the following statements?” by the LAG members (Pollermann et al 2010c)

Most of the projects implemented until 2010 were developed during or after the development of the regional strategies (Figure 2). In the old areas (which were already LEADER+) a few more project-ideas were already existent before developing the strategy, but all in all there is no significant difference between the old and new areas (which were selected as LEADER areas in 2007 for the first time).

It may be assumed that working together to develop or implement the strategies creates new ideas. It can also be realized that the development of a LDS brings about new actions and projects even if the regional actors had created the previous strategies seven years ago.

But the lists of ideas or concepts for projects in the LDS are often much longer compared to the projects carried out. As the analysis of the strategies shows, they either arose in working groups at the kick-off-meetings or individuals already had them in mind. However, the fact that they were made public is a step towards the awareness of innovation on a regional level.

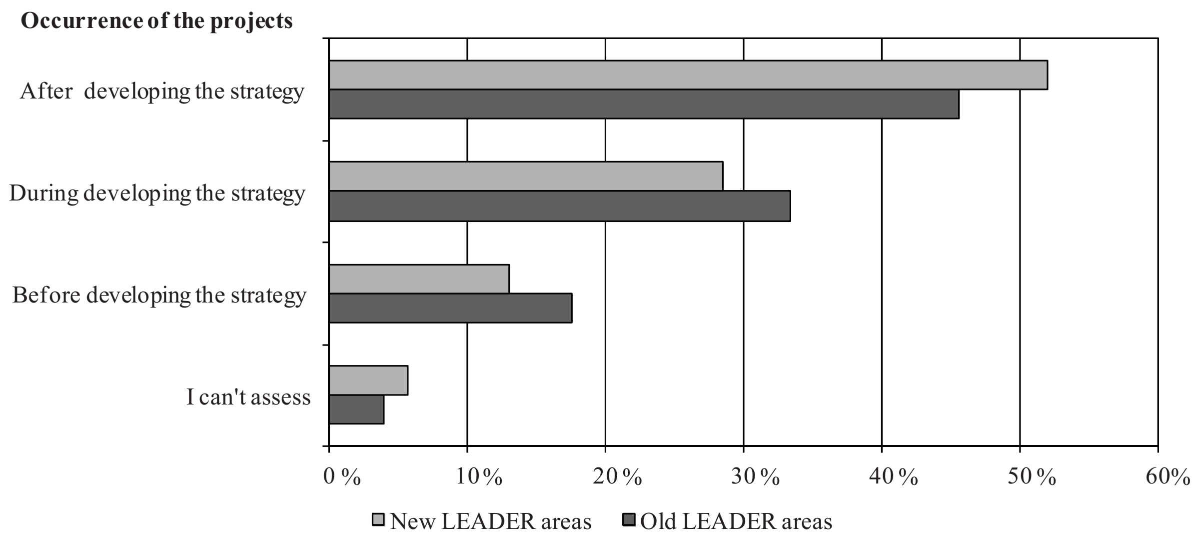

Fig. 2. Distribution of answers (in percentage of total) to the question “When did the ideas for the now LAG-confirmed projects occur?” by the LAG Managers (Pollermann et al 2010a)

Referring to the importance of heterogeneity some aspects were considered to assess the heterogeneity of the LAGs. On average the LAG may be seen as heterogeneous mixtures of people, but a closer look discloses wide ranges within the LAGs.

There are LAGs with only seven members, some with no women at all and some with only three different institutions represented in their decision-making bodies (Table 1). Furthermore the analysis reveals a high proportion of members with an academic degree (i. e., 86% in

Hesse), and almost half of the LAG members are more than 50 years old, while people under 25 are only occasionally represented.

Table 1. Heterogeneity within the LAGs by size and by sex, thematically and institutional origin of the members

	Maximum	Minimum	Average
Number of members of the decision- making body of LAG			
Hesse	32	7	13.9
Schleswig-Holstein	27	10	16.7
Mecklenburg-Pomerania	52	12	21.7
Lower Saxony	53	11	24.1
North Rhine-Westphalia	77	12	26.0
All of the five federal states	77	7	20.5
Proportion of women in the LAG's decision-making body(%)			
Hesse	50	0	20,7%
Schleswig-Holstein	44	5	20.2%
Mecklenburg-Pomerania	78	15	44.4%
Lower Saxony	54	11	29.6%
North Rhine-Westphalia	33	8	17.0%
All of the five federal states	78	0	26.4%
Number of thematical origins of the members of the decision making body of the LAGs			
Hesse	13	5	9,5
Number of institutional origins of the members of the decision-making body of the LAGs			
Hesse	8	3	5,1

Source: Own calculation based on standardised annual requests (Pollermann, 2010b)

Understanding LAGs as new "networks of practice" within innovative aspects can be exchanged, it is important to develop a good cooperation and communication climate.

Improvements in indicative aspects on quality of cooperation between the stakeholders in the LAG are found, shown in Figure 3.

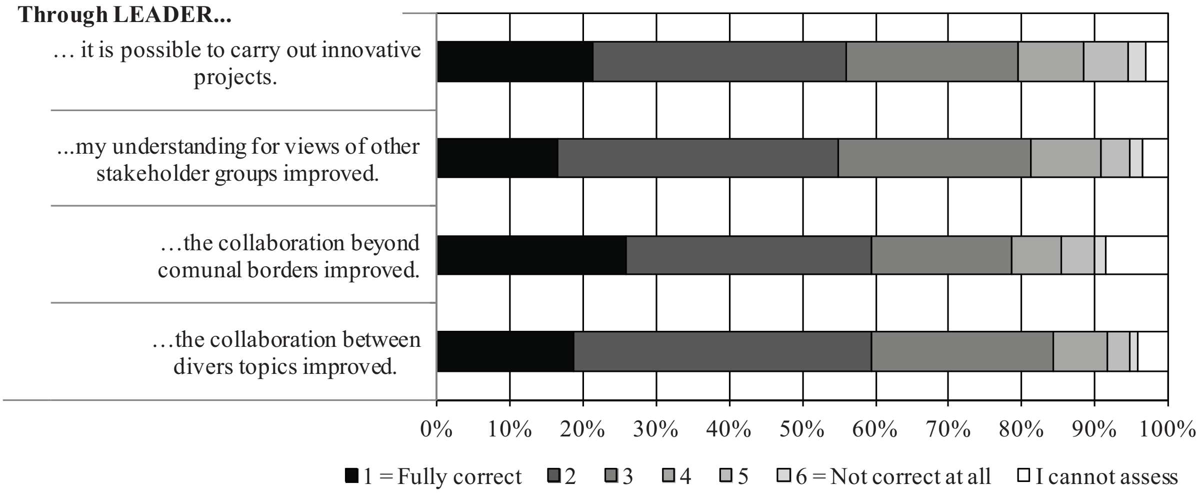

Fig. 3. Distribution of answers (in percentage of total) to the question: Including the whole work of the LEADER-process, in what way do you agree or disagree to the statements? (Pollermann et al 2010a)

The quantitative results are underpinned by qualitative data (verbal questioning and open questions[8] in written questionnaires) through statements of the LAG-members on "new positive effects beyond the LEADER process, but induced by the LEADER process":

- Improved cooperation between the municipal authorities
- Improved cooperation beyond administrative borders
- Improved cooperation between different groups

But not only improvements in the quality of networking were mentioned but also aspects of the innovation-process itself:

- transfer of knowledge between people
- inspiration for projects and actions
- improved sense of acting jointly in and for the region

Similar results were found for the question on advantages and disadvantages of the LEADER-approach (only the advantages are shown in Figure 4). But the summarized answers highlight more the circumstances for innovation (networking/cooperation) than the aspects associated with innovation themselves (innovation, learning).

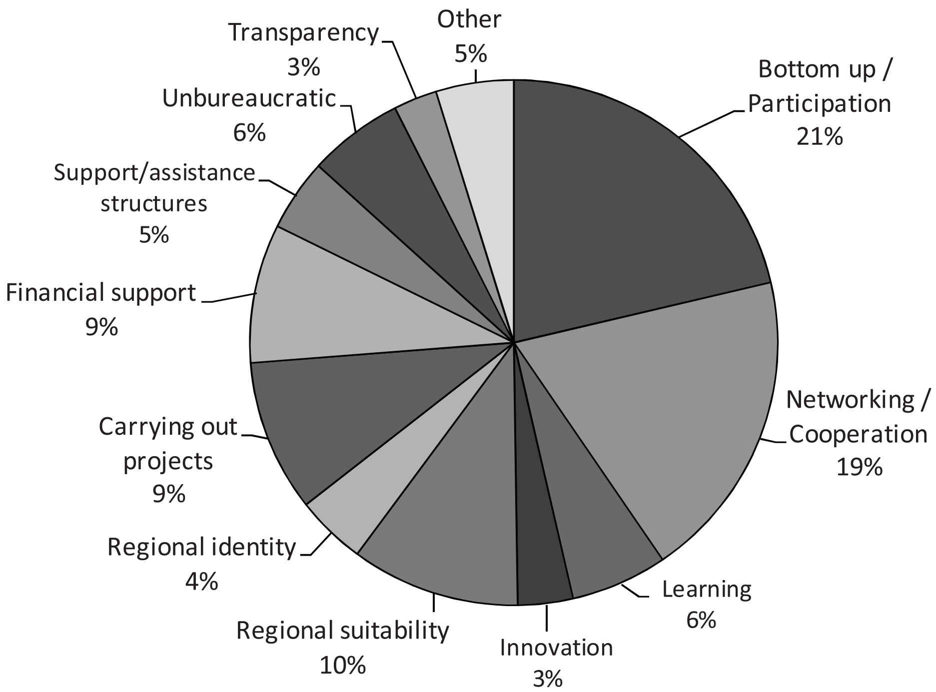

Fig. 4. Distribution of answers (in percentage of total) to the question "What essential advantages and disadvantages does the LEADER approach offer?" by the LAG members (only the advantages are shown here) (Pollermann et al 2010c)

As a boundary effect the image shows that other associated characteristics of LEADER, like bottom up and regional identity are also realized by the LAG-members.

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[8] One question they were asked: Which positive effects beyond the LEADER process but caused by LEADER (new ideas stimulation for own activities and joint activities with other LAG-members) did you recognise?

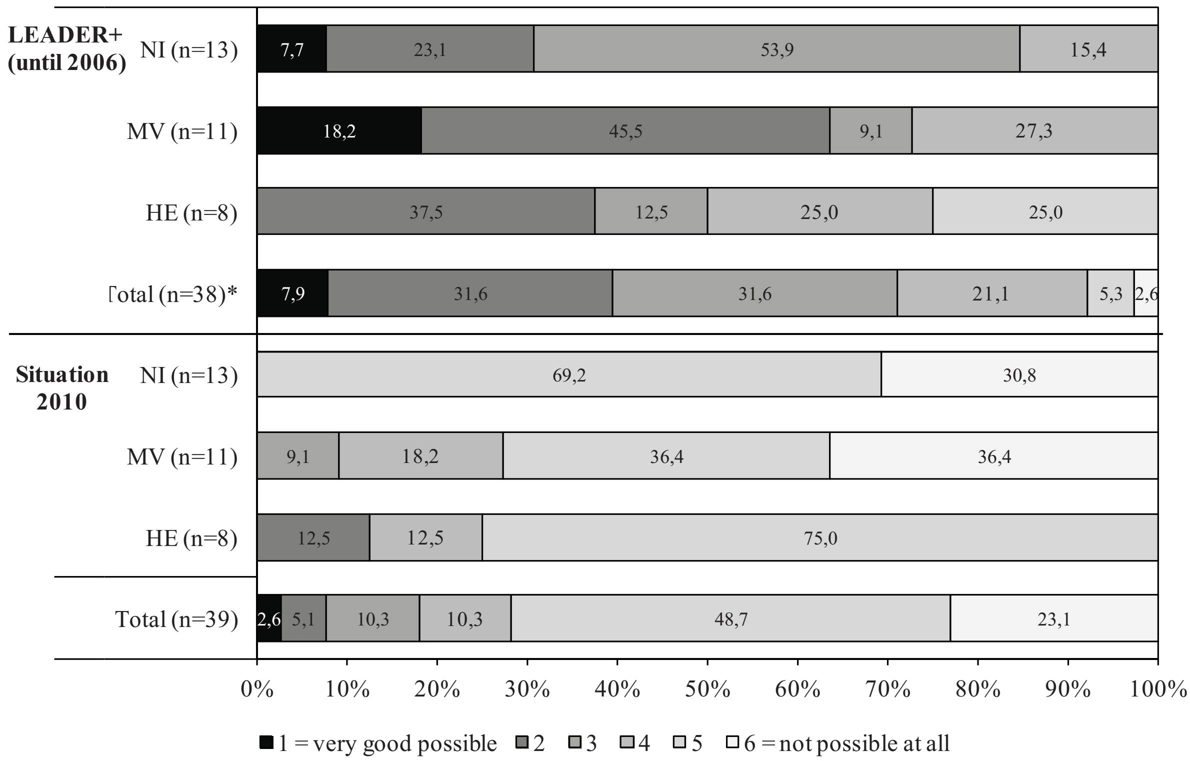
Furthermore, it should be noted that the understanding of the process of social capital formation, its determinants, and the effects of its impacts go beyond its measurement (Nardone et al, 2010).

3.3 Implementation practice: the innovation-process

As mentioned above, LEADER offers the possibility to try out new approaches, as the regions have access to their “own” funding budget to implement their ideas.

The assessments of the LAG-managers show that the possibilities for implementing innovative projects are limited, particularly compared with the former funding period (LEADER+) (Pollermann et al 2010a). The differences between the federal states can be seen in Figure 5.

Not all of the federal states offered the measure “innovative projects”, explaining partly the poor results. Other explanations for this were the limited or vague conditions and administrative obstacles (time lags in the approval procedure, no payment in advance to the beneficiaries, paperwork) resulting mainly of the mainstreaming of LEADER (to the restrictive rules of EAFRD).



*The results of North Rhine-Westphalia and Schleswig-Holstein are included in the total but were not presented separately because of the small size of the subgroups (1 and 5 respectively).

Fig. 5. Distribution of answers (in percentage of total) to the question “How do you judge the possibilities to carry out innovative project?” by the LAG Managers (Pollermann et al 2010a)

But the LEADER-projects realized wirthin the measure “innovative projects” are not so much different from regular measures under the other Axes, as the analysis of the project descriptions show.

Some federal states in Germany have already made improvements within this funding period because of these problems.

The findings will be supplemented by the current written survey of the beneficiaries. First results can be presented at the seminar, for example answers to the question: What were the starting points of innovative projects?

Although there are limitations, in practice LEADER brings forward projects on very different topics. So there are concepts for a sustainable usage of energy, youth projects for qualification, internet platforms (for education), but most of the projects are linked with touristic development. Other relevant topics for the rural development are underrepresented. As a matter of fact, the LAGs are forced to search for other ways to implement their ideas. Taking into account that not all ideas are worthy of implementation, as is also stated by the LAG-Managers either because it does not fit to the regional strategy or the quality of the project proposal is poor, there are a lot of projects which were (and will be) implemented on other ways (Source: Analysis of the Annual Reports of the LAGs). But some of the ideas are lost, due to the administrative restrictions mentioned before.

3.4 The inter-regional communication channels

Refering to Rogers‘ innovation theory, since the rural regions can be understood as members of a social system, to communicate between them is necessary to foster the adaption process. This means circulating information on successful projects and sharing good practices. Even if the new projects and ideas are not transferable as a whole to other regions, having heard of experiences might inspire participants to find appropriate solutions for their specific setting.

Various possibilities exist for the exchange between the actors of different regions. The LEADER-measure “cooperation” was established for the purpose of exchange and working together between the regions by carrying out joint projects, but the current status of implementation is poor, as the funding data from the federal ministries shows. It is remarkable that cooperation between different regions are carried out within „regular[9]“ projects. Hindrances are identified in the various adminstrative processes and forms (Pollermann et al 2010a, Pollermann et al 2010b, Pollermann et al 2010c).

As shown in Figure 6, the LAG-Managers prefer the personal informal means of exchange between regions, meaning meetings or phone calls with single managers. In the meantime, personal meetings of all managers in each of the federal states have been established at various institutional levels and different levels of involvement of the Ministries. These meetings are also perceived as an important exchange and assistance platform by the parties involved. The german National Rural Network as the insitution for the exchange between the federal states is less important than the personal communication, but still more than half of the managers judge it as an important offer (Pollermann et al 2010a).

The biggest gap between the general importance and the practical implementation is found at the federal-state-wide meetings. It points out, that it may be necessary to strengthen more the federal-state-wide meetings (Pollermann et al 2010a). Exchanges between other stakeholders (except the LAG-Managers) have not yet been analysed.

By the current survey, information will be collected about the origin of ideas and interests on implemented projects from others, as well as desired support structures for the beneficiaries.

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[9] Not the measure with EAFRD Code 421

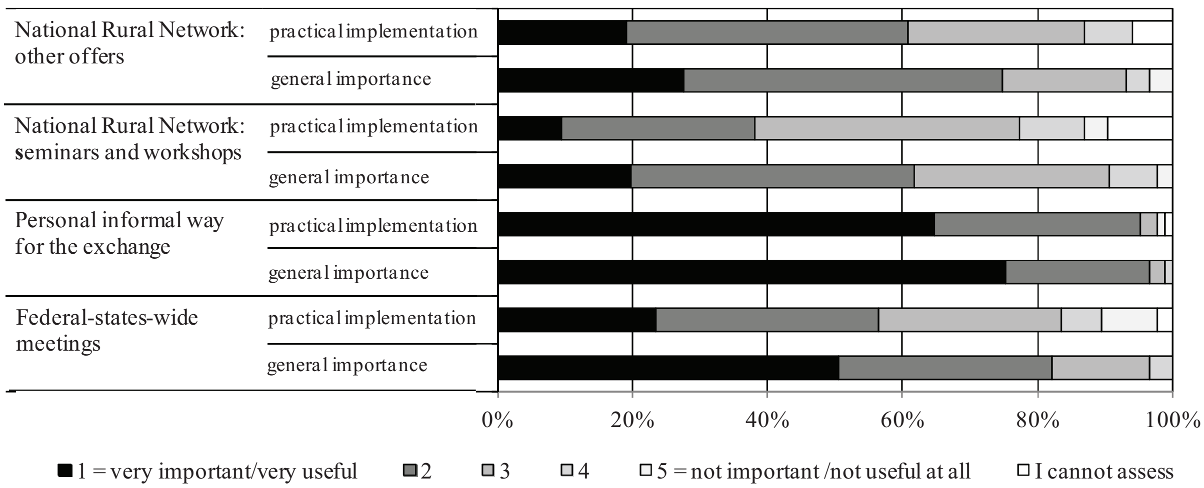

Fig 6: Distribution of answers (in percentage of total) to the question "How important are the following support structures and possibilities to exchange in general? How do you judge the practical implementation? (Pollermann et al 2010a)

4. Conclusions

1. The LEADER approach intends to foster innovation and the adaption process. The conditions set offer the possibility to take the steps to the innovation-process. LEADER provides opportunities to realize innovative projects to try out new solutions and meet the specific needs in the region. The crucial point is the restricted choice of projects by the LAG due to the directives of the federal states in terms of the restrictions to axis measures, as well as the narrow framework of EAFRD and the resulting administrative obstacles.
2. Referring back to the importance of having members with heterogeneous backgrounds in the LAGs to reduce redundant information it can be assumed that in most of the LAGs stakeholders from different sectors are working together. But the diversity within the LAGs (referring i. e. to number of members, theme or institutional origin, sex, age…) is sometimes close. Besides, it is also necessary to protect and foster a good communication and a cooperative climate which is prerequisite for the easy exchange of "newness" (information, ideas,…). From the view of the LAG members the quality of cooperation and communication within the LAG improves during the process. The fundamental aspects of the LEADER approach, like creating projects/actions suited to the specific region, connecting regional interests in common actions, innovative trials, learning/ exchange of knowledge and cooperation can be observed. Altogether LEADER focuses on establishing the preconditions for innovation and not on implementing the innovations themselves.
3. The kick-off-meetings, working groups and elaboration process of the Local Development Strategy are sources for the production of a number of new ideas for the specific regional development in the beginning of the process. Looking at the implemented projects, it is obvious that tourism-related actions are most frequent and other relevant topics for the rural development are underrepresented. Compared to the ideas from the beginning of the process, apparently a lot of ideas get stuck before being implemented. Of the various determining reasons, two will be mentioned as follows:
   - The possibilities of funding experimental or innovative projects via LEADER depend very much on the extent to which the RDPs are able to provide a suitable framework to fund projects outside the standard menu of measures.

- Caused by the mainstreaming of LEADER, a lot of administrative obstacles (time lags, advanced payment, paperwork) faced the beneficiaries compared to the former funding period.

   Although in theory innovation plays an important part in LEADER, in the output of projects it has been quite limited up to now.

4. Not only the lack of possibilities to implement innovative projects but also other obstacles in the beginning of this funding period led partly to de-motivation of actors for further involvement and loss of confidence in the LEADER funding. Some of the (potential) beneficiaries have developed a somewhat negative perception of the programme.
5. Forums for exchange exist for the LAG Managers, but increasing the interstate exchange might be helpful. The exchange between LEADER areas through carrying out joint projects by the intended cooperation measure is low.
6. The following question might be taken in account for further investigations in the field of innovation within the LEADER approach as well as stimulation for a discussion about the prospective policy:
   - Is there any need to restrict the sovereignty of the LAG in their choice of projects?
   - How is an optimal „network of practice“ composed? What is a minimum of heterogeneity in a LAG – how can it be made measureable and implemented in the regulations?
   - What are the differences in the content of the actions and projects between LEADER Axis and other Axes?
   - How can the conditions for cooperation projects (EAFRD Code 421) be improved? How can the exchange between the areas be improved, but not only involving the managers?

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Local Action Groups and Rural Development Projects: The LEADER Program in Slovenia

Alenka Volk, Štefan Bojnec[1]

ABSTRACT

This paper analyses the influence of a formal and informal system of the Local Action Group (LAG) board's performance on the perception of its members about suitability of rural development projects for LEADER funds co–financing. The unique in-depth survey data was obtained from the surveys with the 103 LAG board's members using the written questionnaire designed for the inquiry and from existing data analysis on projects which were co–financed by the LEADER funds in Slovenia in the years 2008 and 2009. The informal system of performance of the LAG board members was found to influence significantly its members' perception on the suitability of projects to be co–financed by the LEADER axis. The opposite was established for the formal system, which had insignificant influence on the board members' perception on the suitability of projects.

KEY WORDS: LEADER, rural development projects, board members, Local Action Group, formal system, informal system

1. INTRODUCTION

Rural development in the European Union (EU) countries has been supported by different policy measures and initiatives. One of them is the LEADER approach in establishing and supporting local development partnerships in rural development projects (Shucksmith 2000; High and Nemes 2007). The LEADER approach aims at encouraging to establishing and supporting local development partnerships between three groups of local actors – civil society, public administration and private sector – organized as Local Action Groups (LAGs). Our focus is on the LAGs role in rural development projects, which have been supported by the LEADER program in Slovenia.

The LEADER program can bring to rural development a new innovative theme in the way on how to develop the countryside with regard to the agricultural and forestry sector, and the environment and quality of life in the countryside (Hudečkova and Loštak 2008). It is based on the endogenous development concept (Terluin and Post 2001, 3) which builds on the capacities of the local actors. It is determined by three main characteristics which makes a basis of some sort of a postmodern laboratory (Ray, 2000, 174): First, all activities are implemented in a certain local area (not an economic sector any more, as it was in the exogenous development concept), which brings a greater interest of the of local population and interested in inhabitants for the development of the local area where they live in. Second, all economic and other activities implemented in a certain local area multiplies its effects and stays inside the local area. This means that local resources are being used by local actors who want their living area to be safe, healthy and a nice place to live in. Third, it is oriented towards the activation of the skills, knowledge, cooperation, and development capabilities of

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the local actors. With their participation and integration in the development activities they can get the opportunity to actively participate in the sustainable development of the local area.

The basic assumption of the LEADER approach is that local development potentials exist and they can be strengthened through local initiatives such as by LAGs (Thuesen 2010). These groups are expected to possess a relatively high degree of various intangible forms of capital, especially social capital which is believed to be the most important for LAGs (Loštak and Hudečkova 2008). The reason why social capital might be crucial for LEADER approach lies in the fact that through the established network-like cooperation, this can induce synergies and supports in strengthening the roles of other forms of intangible capitals such as intellectual, human and cultural. According to Schumacher (2000, 60), economic development does not come from goods, but from educated, well organized and disciplined people without whom the resources rest unused, latent and only intellectual capital, which is available in the local area and by the local actors living there, they can activate them. So, we can say that the distinctive characteristic of the LEADER approach is that reliance is placed on the people who live in local rural areas, and on their ability to discover what is best suited to their local development area needs (Nemes 2005; High and Nemes 2007).

Lowe (2000) argues that the integration and encouraging network-like cooperation between local people and local actor groups in local development activities does not necessary mean that they possess the appropriate knowledge and experience to implement such local development activities. Therefore, the core question for the LEADER approach is if different groups of local actors really possess the necessary skills, knowledge and capabilities to implement the entrusted local development activities? If this innovative local development approach is to work well, the local actors must have the necessary capabilities or they have to acquire them in order to develop project ideas. They need to have know–how and the human resources to devote to particular local development and local employment activities. They also need to have the financial skills to manage those activities (European Commission 2006, 15). Moreover, when implementing LEADER programmes, some irregularities might appeared such as approving co–financing of the project which had already been implemented, non–transparent selection of the local development projects, the dominant influence of the public sector in the LAG's board and financing of the projects which were not developmental–oriented (European Court of Auditors 2010). All the above–mentioned deficiencies and shortcomings are likely to be due to the lack of appropriate capabilities of the LAG members. More precisely, of those LAG members who through LAGs participate in the local development activities.

The aim of this paper is to empirically investigate the impact of a formal and informal system of the LAG board's performance on the selection of rural development projects. The LAGs define local development strategies and policies, and make decisions on awarded grants for local development projects, which should comply with the objectives of the local development strategy. The formal and informal system of the LAG board's performance determines the opinion of their members and thus directly and indirectly determines the selection of rural development projects. The empirical analysis using the unique in–depth survey data and related available secondary data is focused on the role of the LAG board's performance in the case of the LEADER programme in Slovenia and particularly in the selection of suitable rural development projects for LEADER funds co–financing.

2. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

One of the main objectives of LEADER is to allow through buttom-up approach participation of local community actors to more effectively voice their needs. The LEADER aims to improve governance mechanisms in rural areas in order to harmonise interests and solve potential conflicting interests by encouraging decision-making process closer to local rural citizens. The LEADER approach through decentralized and buttom-up governance may lead to innovative approaches in rural development (Dargan and Shucksmith 2008), which may contribute to a more efficient use of resources and may lead to a reduction in territorial local rural and social inequalities (Nemes and Fazekas 2007; Nardone et al. 2010).

In this study the focus is on the role of the LAG's board members on efficiency of LEADER related rural development projects. The LAG's board members are appointed under the expected requirement to have all the necessary skills to implement LEADER's rural development activities. Namely, the LAG board is the legal structure responsible for leadership and control of the LAG activities. Each LAG member can be a candidate to become a LAG board member, regardless of education and/or previous experiences, but by getting enough election votes. An elected member gets the opportunity to have an influence on a direction of the further development of the local rural development projects. The only formal limitation is that the LAG board has to be composed of 50% of public institutions representatives, 25% of economic sector representatives and 25% of civil society representatives. By representing different groups of local actors every member brings a unique insight into the needs of the local rural area development, but may have a quite different level of expertise in serving on LAG's board structures (Irish LEADER Support Unit, 2006). Once composed, the LAG's board should operate in accordance to the adopted rules and regulations regarding board meetings, decisions-making procedures and other formal rules and regulations. This formal system encompasses the LAG's rules and regulations that help the board to function effectively and make decisions (Maharaj 2009, 107). However, only focusing on a formal system of the LAG's rules and regulations alone neglects the LAG's board's actual behaviour and the LAG's board's process. Therefore, in addition to a formal system, also an informal system of characteristics related to behaviours and attitudes that help the LAG's board to function effectively and make decisions should also has to be considered.

Maharaj (2007) shows that the experience and personal attributes of the individuals comprising the LAG board members and the decision–making process of the board's behaviour do affect good organizational governance. The informal system focuses on how formal systems are embedded and translated and goes beyond the superficial adherence to the formal system and looks at three major LAG board members' characteristics that are required for effective decision-making process. According to Maharaj (2007, 72), this three major LAG board members' characteristics are: knowledge, groupthink, and values.

Knowledge represents the actual depth and breadth of knowledge of the LAG board members. Knowledge is a prerequisite for LAG board members and involves the knowledge base and expertise of individual LAG board members. They need it to better understand issues and to be able to synthesize received information and to be fully engaged in discussion and dialogue during LAG board meetings. Yet, it does not mean that LAG board members should be experts, rather knowledge should encompass their ability to critically evaluate received information. Furthermore, LAG board members should also possess learning capabilities which include their ability to absorb new knowledge, to synthesize this knowledge and to develop problem–solving skills, i.e., ability to create new knowledge (Maharaj 2007). The knowledge base of each LAG board member should fit the needs of the LAG. Therefore, it should include knowledge of the seven key features that summarize the LEADER approach, acquaintance of the Local development strategy and the knowledge needed to identify the potential for further development of the LAG's rural development area. Moreover, they should be willing to share this knowledge and expertise to ensure effective decision–making and not be afraid to ask tough questions in a case that they are not clear about an issue.

Groupthink represents LAG board members' ability to interact or the groupthink mentality of LAG board members and the level of engagement and questioning of LAG board members. More specifically, Maharaj (2007, 75) called groupthink "when receiving information, board members may succumb to the persuasive power of their peers in their thinking patterns and opinions." Groupthink occurs when a person's thought process and decision–making capabilities become heavily influenced by peer pressure. This may cause the group to overestimate their power and morality, causing the members to ignore the ethical or moral consequences of their decisions. This pressure may cause the LAG group members to withhold their opinions for fear of having an opinion different from that of the group. This silence may create a domino effect where silence may be considered as consent among the LAG group members. If a LAG member expresses a strong argument against the majority of the group, however, direct pressure may be exerted on that member to ensure that the LAG member understands that dissent is contrary to what is expected of loyal members. The level of participation among LAG board members at board meetings can be used to reduce the negative effects of groupthink. LAG board members, however, need to be able to think independently and not conform to in–group pressures. Thus, it is necessary that LAG board members question each other and the management to preserve the integrity of the information and avoid groupthink. If board members are not able to think independently, free from group pressures, then this may adversely affect the decision–making process.

The values of the LAG board members measure both personal and organizational values. According to Maharaj (2007, 74) values, both personal (such as beliefs, education and social status) and organizational (as expressed in the organization's code of ethics, vision and mission statements), may elicit a more valuable insight into the LAG board members. They are important as they determine the choices that are made by the LAG board member. Therefore, it is important that they are aware of their personal influence in the decision–making process. During LAG board meetings, board members must ask tough questions, use their knowledge and experience, and refer to the organizational values when making strategic decisions. As LAG board members refer to the company values, a sense of cohesiveness will be established among board members and this synergy will enable the board to act as a unified body. LAG board members must also act honestly, be committed to their function, avoid conflicts of interest and put their own personal interests behind them.

While in general LEADER approach can be beneficial for local communities in addressing rural problems and promoting rural development, there are a rare studies to investigate formal and informal systems that might cause effectiveness of LEADER rural development partnerships. Experience with the implementation of the LEADER approach in EU countries shows that local actors need time to build up the strategic and operational capabilities necessary to design and implement a local development strategy in the framework of a larger rural development programme (European Commission 2004b). As is the case in the new Member States of the EU, they are less prepared for this endeavour, which may require a whole programming period for experimental and preparatory steps. On the other hand, experienced local stakeholders may develop expensive, bureaucratic and technocratic behaviours and isolate the group from other local actors (Kovách 2000; Marquardt, Möllers and Buchenrieder 2012).

This paper aims to a fill this gap in literature by analysing factors of the formal system (as the only criterion followed when forming the LAG's board) and the informal system on which the LAG's board in Slovenia operates (as the basis to analyse the knowledge and abilities of the LAG board members to implement rural development activities) and empirically test their influence on the LAG member's opinion which rural development projects are suitable to receive LEADER co–funding.

The main thesis of the study is that based on the opinion of the LAG board members, which projects are suitable for LEADER co–financing, this is influenced by both formal and informal systems: the informal system which reflects the knowledge and ability of the LAG board members to implement development activities, is more important than the formal system.

The main thesis is empirically tested by the following two hypotheses (H):

H1: The opinion of the LAG's board members on which rural development project is suitable for LEADER co–financing is positively associated with the LAG's board informal system.

H2: The LAG's board formal system has an ambiguous impact on the opinion of the LAG's board members on which rural development project is suitable for LEADER co–financing.

3. METHODS

The research has been designed in three steps. Firstly, in the way that the LAG's Annual implementation plans (AIP) for the years 2008 and 2009, when LEADER projects first started to be implemented in Slovenia, have been analysed in order to establish what kind of projects were recognized as suitable for LEADER co–financing in this period.

Secondly, based on the analysis of the implementation results a questionnaire was developed through which the formal and informal system was analysed using Likert's type scale from 1 = not important at all to 5 = the most important. The questionnaire consisted of five sets of questions: first, the knowledge of the LAG's board members was measured. Second, the group thinking inside the LAG's board was measured. Third, the values of the LAG board members were measured. Fourth, the formal factors were measured. Fifth, genuine information such as age and education was measured.

The questionnaire was pre-tested on a pilot sample of 5 members of LAG board members. After then it was entered into a web tool and a link with an invitation to participate in the research was sent by e–mail to all 267 LAG board members in Slovenia between 15 March 2011 and 15 May 2011. In the survey 38.58% of all the LAG board members participated or 103 respondents fully completed the written questionnaire: 59 women (57.3%) and 44 men (42.7%). Average age of the respondent is 44 years (vary from 29 to 65 years). By education, the structure is the following: 21% secondary education, 22% higher education, 52% high or university education, and 5% master or PhD. This implies high level of formal education, which does not necessary guarantee a suitable knowledge and skills for the LAG needs. By the representation of local action groups, the structure is: 49.5% from the public sector, 29.1% from civil society, and 21.4% from the private sector.

Thirdly, the unique in-depth survey data obtained from the questionnaire designed for the inquiry has been analyzed using quantitative methods: first, descriptive statistics. Second, multivariate factor analysis and the regression analysis are used to test the two set hypotheses on the association between a formal system, an informal system and the perception of the LAG board members about which projects are suitable for LEADER co–financing.

4. RESULTS

Projects co-financed by LEADER in Slovenia in the period 2007–2009

In the programme period 2007–2013, an axis LEADER has been implemented in Slovenia for the first time. In order to find out how successful Slovenia has been in taking the first steps of implementing LEADER, some basic data was collected. In the years 2008 and 2009 two public tenders were published and 33 LAGs were approved for co–financing, which covers in total 97% of the Slovenian territory (without towns). With the intention of gathering more information, the AIPs for the years 2008 and 2009 were reviewed.

Firstly, the amount of funds spent was analysed and the results showed that in the observed period for co–financing the LEADER projects, €6.2 million had been allocated, which represents at the end of the first half of the programme period only 26% of all available LEADER funds. This lack of spending is a result of delays in establishing legal rules and legislation at the EU and national level and corresponds to the situation at the EU level.

Secondly, the structure of the final beneficiaries was analysed and the findings clearly show a strong domination of beneficiaries from the public sector. More specifically, in the years 2008 and 2009 the final beneficiaries in 58% of all projects approved for co–financing with LEADER funds were from the public sector, 27% of the final beneficiaries were civil societies and only 15% of the final beneficiaries came from the private sector. The reason for such a distribution of LEADER funds may be related to the fact that the public sector has more experience in managing EU projects and has better access to financial resources to provide assets for financing or co-financing of the projects. But based on the experience from the LEADER + (European Commission 2004a) another possible interpretation would be that in the LAG's boards, the public sector representatives have a greater influence in the decision–making process, which means that their proposed projects have a greater privilege and thus biased advantage in the selection process. An additional explanation is that the LEADER approach is not well known among potential beneficiaries in Slovenia as is apparent from the interim report of the Regional development programme 2007–2013 in Slovenia (MAFF 2010) and as a result, such a biased beneficiaries' structure may occur. MAFF (2010) also states that the LAGs are not active enough in promoting LEADER approach opportunities for local rural development.

Thirdly, the analysis of the content of the approved projects for co–financing by the LEADER funds in the years 2008 and 2009 showed that almost 27% of the projects cover topics related to the development of the tourism offers in the countryside. In addition, 15% of the co-financed projects were in the field of education and 11% of the co-financed projects were related to investments in the municipal infrastructure and public facilities, events and similar activities. Moreover, 9% of the co-financed projects were in the fields of natural, cultural and ethnological heritage, 8% in marketing and promotion of the local products, 6% in preparation of projects documentation and only 3% for private investments. Yet, an in–depth review of the contents of the approved projects for co–financing by LEADER showed that also projects which bring nothing new to the area with contents that have already been implemented in the area meaning the danger of a deadweight loss, they were also recognized as a suitable. Those include different traditional events, well known among people, investments in municipality buildings and activities that would have to be paid from their own resources such as arrangements to do with the school boiler, kindergarten surroundings, purchase of chairs, set up of the municipality's official web site, maintenance of the municipality's building surroundings, financial support for running the sport's and cultural societies. One would argues it is very difficult to find LEADER features in those activities or they could not reveal an innovative character, which is thought to be the biggest advantage of the LEADER programme.

Finally, regarding projects in order to improve the knowledge and abilities of the local actors to participate in and implement development activities, the results showed that none of the projects in the field of education was oriented towards capacity building of local actors. Instead of local capacity building development, the contents of the projects were related towards the traditional topics such as learning of foreign languages, the use of the internet and information and communication technologies and learning how to cook, which supply is widely available on the market. This finding suggests the conclusion that the LAGs in

Slovenia, similar to the LAGs in the other EU countries (Maye, Kirwan and Simson 2010), they consider unnecessary to gain more knowledge in capacity building in the topics related to fostering rural development.

To sum up, the Slovenian initial LEADER experiences confirmed main similarity with the previous experiences at the EU level in terms of the tendency of the public sector to prevail in the decision–making process and in their perception of LEADER as an additional source for financing their local projects (European Commission 2004a). In addition, the main initial orientation of the Slovenian LAGs was tourism development, which was also the main field of investment at the EU level in previous LEADER programmes (European Commission 1999). Considering that small and medium sized enterprises have been the main generator of jobs in the rural area, there is a need for the creation of innovative rural development projects that originate in the private sector and actually address the development problems in the local area.

Recognition of the main LEADER features among the LAG board members

In order to investigate the influence of the formal and informal system on the performance of the LAG board members, the written questionnaire was developed. One of the questions was devoted to determine how in-depth the LAG board members were acquainted with the seven distinctive characteristics of the LEADER approach. Namely, the position of the European Commission (2004b) is that many difficulties, which occurred when implementing LEADER, could have been avoided with better recognition and compliance of the basic LEADER features. The results of the conducted research showed that the most recognized LEADER features among the LAG board members were that the Local development strategy originates from the local area (81%), the LAG role in public–private partnership (72%), and the bottom–up approach (71%). However, only a half of the LAG board members recognized cooperation and innovativeness as a LEADER feature, and less than a quarter knew that a LEADER characteristic is also a networking and multi–sectoral and integrated initiatives. LEADER is a very specific approach, which builds on the intangible forms of capital. If not properly understood even among the key local stake holders, i.e., among the LAG board members, who are supposed to act in the "LEADER spirit" and promote LEADER approach, its overall effectiveness can be questionable.

These findings are also reflected in the opinion of the LAG board members on their perception and possible selection choice of rural development projects, which are suitable for LEADER co–financing. Among the respondents, 76.69% of the questioned LAG board members were familiar with the fact that such projects should be in line with the Local development strategy. Furthermore, only 71.84% of the respondents thought a LEADER co–financed project should be developmentally oriented in order to bring to the local area new products and new solutions. Yet, 31.68% of respondents thought municipality projects were eligible for LEADER co–financing simply because municipalities contribute the largest part of co–finances. This should not be a selection reason for approving a LEADER project for co–funding. However, a structure of the final beneficiaries in 2008 and 2009 clearly proves that this is important for the project approval. 27.18% of respondents believed that LEADER projects should be mostly from the area of tourism and 23.3% from the area of agriculture. 21.36% of the LAG board members who participated in our written questionnaire survey even thought that LEADER co–financing was more suitable for projects, which have already been implemented in the local area because this fact represented less risk in its implementation.

These findings clearly show a lack of understanding of basic LEADER features among the LAG board members. This is also reflected in the range and content of the projects approved for LEADER funds' co–financing in 2008 and 2009.

Informal system, performance of LAG board members and the selection of the development projects co–financed by LEADER

Knowledge

For the purpose of this study, factor knowledge was measured with the questionnaire, by the LAG board members as the respondents, which had to choose on the scale from 1 = totally disagree to 5 = totally agree on how they gained additional knowledge, which they needed to participate in the LAG board process. The empirical results showed that the arithmetic mean for the statement "if I do not know the topic that is being discussed at the board meeting very well I will ask my acquaintances who are experts in the field" was found at 3.68, with the statement "I know all the topics that are being discussed at board meetings very well" arithmetic mean value at 4.03, and with the statement "I will seek the knowledge I need as a board member in the professional literature" arithmetic mean value at 3.09. It was also investigated on how well they knew the basic documents related to the LEADER programme in Slovenia (such as LEADER basic guidelines, Local development strategy, and Regional development programme for the period 2007–2013) and the results for the mean value were between 2.93 and 3.83.

To sum up, it was established that many LAG board members in Slovenia did not know the basic development documents, and did not know the topics that were being discussed at the LAG board meetings. Yet, in general, they did not seek extra knowledge in the professional literature or ask acquaintances who were experts in the field.

Groupthink

Factor groupthink was measured with the questionnaire, where LAG board members had to define their perception towards the following statements (from 1 = totally disagree to 5 = totally agree):

- If I do not know a certain topic that is being discussed in the board meeting well enough I would support the opinion of the majority (arithmetic mean value = 2.99).
- The opinion of each board member is considered equal to the opinions of the others when decisions are being made (arithmetic mean value = 3.86).
- Every board member has the opportunity to state his or her opinion (arithmetic mean value = 4.24).
- When I am certain that I am right, I hold strongly to my opinion even though it is opposite to the opinion of the majority (arithmetic mean value = 3.72).
- Asking tough questions is well accepted in our board (arithmetic mean value = 3.73).
- Usually I do not interfere in the discussion at board meetings (arithmetic mean value = 2.10).
- In our board decisions are made after constructive debate and consensus (arithmetic mean value = 3.83).
- I estimate my influence in the board as important (arithmetic mean value = 3.54).

This analysis indicates a rather disturbing situation and a clear presence of groupthink in the LAG board's process. Considering that for almost two thirds of the projects in the years 2008 and 2009 the beneficiaries were from the public sector and that one third of in this research participating LAG board members think municipalities' projects are eligible for LEADER co–funding simply because they contribute a great deal of funding to the LAGs, it can be established that apart from the lack of knowledge, groupthink also contributes to discrepancies in the LEADER implementation.

One of the issues that influences the presence of groupthink in LAG board meetings is the dedication to the function; whether all board members participate at board meetings; if board members are able to respect the views of other board members even when these views might be different; if new board members are comfortable asking questions and whether there is a high level of 'independent–mindedness' on the LAG board. In our written questionnaire, LAG board members were asked to state how often they (from 1 = never to 5 = always):

- Attend LAG board meetings (arithmetic mean value = 4.13).
- Examine the material before a board meeting (arithmetic mean value = 3.86).
- Consult an expert before the LAG board meeting about the topics they do not know so well (arithmetic mean value = 3.36).
- Consult with other LAG members whose representatives they are (arithmetic mean value = 2.93).

As we can see from the answers, the respondents from the LAG boards rarely consulted with other LAG members although they were elected to represent their opinion and interests. Apart from this, they attended the LAG board meetings on a quite regular basis even though they were not well prepared and they did not study the material they received before the meeting. Here is confirmed once again that the formal system itself is not enough. In a spite of a fact that the LAG board member receives the material for the board meeting on time, it is less likely to be studied for a meeting in advance. It is also questionable how legally does the dictated formal composition of the LAG board contribute to equally represented opinions from all three groups of local actors if the actual representatives do not come prepared to the LAG board meetings, or they do not consult other LAG members, or they succumb to peer pressure or do not even understand what LEADER is all about.

Values

For the purpose of the written questionnaire study the following questions were asked (from 1 = totally disagree to 5 = totally agree):

- Our LAG has clearly established its strategic goals (arithmetic mean value = 3.75).
- LAG board members put their own interests behind them when decisions are being made (arithmetic mean value = 3.44).
- The values of our LAG board correspond to my own personal values (arithmetic mean value = 3.64).

From these statements it can be deduced that LAG board members in Slovenia are not quite familiar with the values of their LAG or that the values are not clearly stated. That might also be the reason for the fact that not all board members put their own interests behind them when decisions regarding important LAG issues – such as financing of projects – were being made.

Formal system, performance of LAG board members and the selection of the development projects co–financed by LEADER

The formal system is set in the official documents and contains rules and regulations. Our intention is to establish whether the formal system had any influence on the LAG board members' perception on which projects were suitable for LEADER co–financing and were developmentally oriented. The respondents were asked to evaluate the influence of the following activities (from 1 = does not influence at all to 5 = has a major influence):

- Frequency of LAG board meetings (arithmetic mean value = 2.62).
- Delivery of materials within the specified period (for example 5 days before the LAG board meeting) (arithmetic mean value = 2.94).
- Formal structure of the LAG board (arithmetic mean value = 2.89).
- Formal decision–making process (arithmetic mean value = 2.93).

As we can see the LAG board members estimated that the formal system does not have significant influence on the performance of LAG Board Members and on the selection of the developmentally oriented rural development projects, which are co–financed by LEADER.

Testing of set hypotheses

The testing of set H1 was conducted in two steps owing from a larger number of variables that are used in the analysis. In the first step by using the factor analysis, common factors were deduced from the individual variables that were measured using the written questionnaire and then in the second step the regression analysis was used to test the set of H1. Finally, the set of H2 was tested by using only regression analysis.

Testing of set H1

With the factor analysis all the collected data for variables was analysed and five new common factors in the informal system were created: specific knowledge, willingness to obtain information, decision–making process, commitment to the function, and values. All five new common factors were applied for the purpose of testing H1 with the regression analysis.

The regression results in Table 1 show the following:

Factor specific knowledge, which measured the acquaintance with the basic LEADER related documents, had a positive impact on the LAG board members' perception that LEADER projects should cover the widest possible range of LAG areas.

Factor willingness to obtain information, which measured how well LAG board members knew the topics that were being discussed at the LAG board meetings, how often they sought additional information in their social network and in the literature, had a positive impact on the LAG board member's perception that not only tourism projects or agricultural projects were suitable for LEADER co–financing.

Factor the decision–making process which measured if all LAG board members had equal possibility to state their opinion, if they were equally taken into account, if they expressed and defended their opinion even when it was different from the others, asking tough questions, and the level of involvement in discussion and making decisions based on consensus, had a positive impact on the opinion of the LAG board members that for LEADER co–financing projects should be developmentally oriented.

Table 1. Regression analyses for testing of the set H1

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Specific knowledge	-0.086	0.085	-0.031	0.002	0.195**	-0.041	0.064
Willingness to obtain information	0.103	0.057	-0.161**	-0.243***	-0.011	-0.055	0.076
Decision–making process	0.087	0.157***	-0.091	-0.071	0.067	-0.018	-0.009
Commitment to the function	-0.200***	0.013	0.050	0.082	-0.068	-0.131**	0.030
Values	0.042	-0.095*	0.099*	0.086	-0.049	0.109**	0.030
Constant	0.311***	0.718***	0.272***	0.233***	0.515***	0.214	0.408***
Adj. R^2	0.107	0.189	0.101	0.178	0.059	0.143	0.035
F-test	3.44	5.77	3.287	5.411	2.279	4.398	1.733
N	102	102	102	102	102	102	102

Dependent variables:
(1) Projects in the municipality interests because they contribute the most of finance.
(2) Developmentally oriented (formation of new approaches, products, services).
(3) Particularly from the field of tourism.
(4) Particularly from the field of agriculture.
(5) Project activities should cover the broadest area of the LAG.
(6) Already conducted at the LAG area, because such projects represent lower risk in implementation.
(7) Innovative if their effects are not visible immediately it is nothing wrong because they encourage in searching of new solutions.
*, **, *** indicate significance levels at 10, 5 and 1 percent respectively.

Factor commitment to the function which measured how often LAG board members attended LAG board meetings, if they read the material before LAG board meetings, if they obtained additional information about the topics they did not know well enough, how often they consulted with other LAG members, had a positive impact on the opinion of the LAG board members that municipalities' projects were not suitable for LEADER co–financing simply because municipalities co–funded LAGs.

Factor values also had a positive impact on the LAG board members' perception that projects which had already been implemented and posed a risk of a deadweight loss were not suitable for LEADER co–funding.

Key findings partially confirmed of set H1 that the informal system had an influence on the perception of the LAG board members on which projects were developmentally oriented and suitable for LEADER co–financing.

Testing of set H2

When testing of set H2 the regression analysis was used and the results confirmed that the formal system of the LAG board did not have a statistically significant influence on the LAG board members' perception on which projects were developmentally oriented and suitable for LEADER co–financing (Table 2). Therefore, these results clearly proved that formal rules and regulations were inadequate; they had little effect upon decision-making by LAG board members.

Table 2. Regression analysis for testing of the set H2

	(1)
Frequency of LAG board meetings	0.094*
Delivery of materials within the specified period (5 days before the LAG board meeting)	-0.113**
Formal structure of the LAG board (public sector, civil society and private sector)	0.002
Formal decision–making process (voting)	0.057
Constant	0.144
Adj. R^2	0.019
F-test	1.493
N	102

Dependent variable: (1) Particularly from the field of agriculture.
*, ** indicate significance levels at 10 and 5 percent respectively.

To sum up, informal system must be considered in unison with the formal system when discussing the performance of LAG board members and the effect it has on the selection of the projects which are co–financed by LEADER funds.

5. CONCLUSION

Slovenia has, in the programme period 2007–2013, met with the implementation of the LEADER approach/axis for the first time. Based on the experiences of other EU countries, it was expected that it would take time to optimize the operational axis of the implementation process of LEADER and to build the local group actors capability. In terms of the implementation of formal procedures, it can be established that Slovenia has been quite successful, as 33 confirmed LAGs currently operate in Slovenia, which cover almost the entire Slovenian rural areas and receive LEADER axis funding for their operation. With a 12% realization of spending on the LEADER axis until the end of September 2010, Slovenia, together with the Czech Republic has been the best in realization of the LEADER axis between the new EU countries that for the first implemented the LEADER approach.

A rather different picture is evident regarding the capability of local stakeholders for the implementation of LEADE development activities. A unique in-depth survey using the written questionnaire was conducted among LAG board members. It clearly showed that the respondents knew little about the basic features of the LEADER approach. The most recognized features, as identified by two–thirds of the respondents, were public–private partnerships, a Local development strategy that originated from the area, and a bottom–up approach. Approximately half of the respondents knew that the basic features of the LEADER approach were co–operation and innovation, and only a quarter of the respondents knew that for this approach, networking and integrated and multisectoral actions were also typical. Similar findings were established at the EU level and particularly for a new EU Member State such as the relevance of social networks for LEADER in Romania (Marquardt, Möllers and Buchenrieder 2012). The European Commission even considers that several irregularities regarding the implementation of LEADER programmes derive from the lack of recognition of the basic characteristics of the LEADER approach.

An analysis of the AIPs for the years 2008 and 2009 showed the strong domination of the public sector among LEADER co–financing beneficiaries. Although they have more financial resources and knowledge to implement various project's activities, the results of a survey among LAG board members showed that the reason for this structure also lies in the lack of recognition of the basic LEADER features, specific knowledge of the LAG board members, their willingness to obtain information, the decision–making process, commitment to the function and their values.

The regression analysis confirmed the set of H1 that the perception of the LAG board members on the suitability of rural development projects for co–financing by the LEADER axis has been a positively associated with informal system of the LAG board's performance. It has also confirmed the set of H2 that formal system of the LAG board's performance has had an insignificant impact on the perception of the LAG board members on a selection of projects of rural development, which were suitable for co–financing by the LEADER axis.

As a recommendation for a more effective and efficient implementation of the LEADER axis, it follows that more attention should be devoted to improving the capability of the LAG board members. In particular, they need to improve their knowledge regarding the basic features of the LEADER approach and ensure the transparent operation of the LAG board and a systematic evaluation of its performance. Finally, it is necessary to increase the awareness that learning by their own mistakes is time–consuming and costly, and that it would make much more sense to look at good practice in the LAGs around the EU, which have had many years of experience and are in a more developed stage. Therefore networking and transnational cooperation as an instrument for the exchange and introduction of new methods and best practices in rural development is an opportunity to build and strengthen the capacity of LAGs in Slovenia and other new EU countries which are building their local development capacities in the frame of LEADER axis.

The informal system of performance of the LAG board members was found to influence its members' opinion on the suitability of projects to be co–financed by the LEADER axis. The opposite was established for the formal system, which had insignificant influence on the board members' opinion on the suitability of projects.

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Assessing of the Projects Promoting Innovations in Rural Areas in the Czech Republic

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Annotation: Innovative approach is essential for a growth, but the understanding of the content of it is not unified. The term innovation itself is broad and can cover wide range of activities. The article deals with the projects promoting innovations in the rural areas of the Czech Republic (CR) financed from the European Agricultural Fund for Rural Development (EAFRD). Strategy Plans LEADER (SPL) submitted by Local Actions Groups (LAGs) which are operating under the LEADER[1] scheme are analysed and their approach towards innovation is evaluated. The importance of the innovations in the projects is evaluated on the basis of established preferential criteria for selection of the projects and finances devoted to the measure Fiche[2] which includes innovative projects. On the basis of case studies of the projects aimed on education I am coming to the conclusion that various types of projects are understood as innovative, but sometimes the term is misinterpreted. Preferential criteria for selecting projects defined by LAGs should be more precious and concrete. Despite the fact that innovations are one of the obligatory criteria for selecting projects which will be financed, its inclusion is mostly formal. Its relative weight in comparison with other criteria is quite low. Besides, the importance of innovative projects is not sufficiently underlined by finances. I argue that there is not adequate attention paid to the real contribution of the projects to innovations. I recommend the revision of the term innovation and its stronger inclusion into the preferential criteria for selection of the project in order to ensure that selected projects clearly correspond with the innovative approach.

Key words: innovative projects, rural area, Local Action Group, Strategic plan LEADER

1 Introduction

"Innovation in general and its spatial dimension in specific has been a primary object both of scientific analysis and of policy." (Steiner et al, 2011) "Innovation is widely held to be a key driver of economic growth at the heart of the knowledge economy" (OECD, 1996 in Dargan and Shucksmith, 2008), although according to Dargan and Shucksmith (2008) the social and cultural dimensions of innovation are often neglected. They argue that "innovation policies are frequently regarded as central to improving a region's competitiveness. Innovations are not only developed by scientist and taken up by practitioners and does not originate only in urban areas." In the most studies, the technological aspects of innovation, new product and development are the subject of analysis. Despite the fact that it may seems that only huge transnational companies can deliver the desirable amount of innovations, current studies revealed the fact that also innovations in rural areas are possible. "Many recent studies show that innovations occur without scientific knowledge." (Dargan and Shuccksmith, 2008)

Ability of producing innovations of the small and medium firms in the rural areas concerns Steiner et al (2011). They explore innovative behaviour through reviews and interpretation of the theories of regional innovation and concepts of innovative milieu. They analyse how specific milieu of the region affects the innovative potential and searching for the factors influencing innovative behaviour in rural areas. They conclude that range of innovation potentials in studied areas "are not an automatic outcome of this specific type of region but call for the organization and promotion of the revealed factors for innovation behaviour." (Steiner et al, 2001)

[1] LEADER is an abbreviation from French "Liaison Entre Actions de Développement de l´Économie Rurale" – i.e. Links between Actions for the Development of the Rural Economy".

[2] Fiche = measure

European Council emphasise the importance of involving regional and local authorities in the design and delivery of results from EU programmes. (Bachtler et al, 2007) The EU policy goal (promoting growth, innovations and competitiveness) can be achieved only "if it is owned by all stakeholders – at EU, national, regional and local levels." (Hűbner in Bachtler et al, 2007) "Specific features and potential of rural areas for innovation deserve special attention." (Steiner et al, 2011)

1.1 Special innovation factors in regions

"Every region has its own economic and social infrastructure, its existing networks and organizations as well as its specific physical infrastructure. This set of factor endowments and assets determine the region's ability to innovate and successful regional innovation result in enhanced productivity and prosperity." (Steiner et al. 2011)

Policy makers must respect that the sources of innovations in rural areas are rather different than in urban areas. As Steiner et al. (2011) point out; the focus must be "more on intangible assets such as **conscious behaviour**, **cooperation** and **collective learning** than on the classical determinants of competitive advantage." Current studies also emphasise **social relationships** and focus especially on the **influence of the community**, **social norms** and **behaviour rules** as on the important factors that help to enhance innovations. I point out two principles on which the LEADER programme is based: cooperation and mutual learning.

1.1.1 The importance of cooperation for innovations

Roles played by a variety of different actors have been recognised in recent studies. Strong relationship between innovatory economic development and a strong civil society, focusing especially on the presence of networks, both within the territory and between its actors is suggested by many authors (e.g. Dargan and Shucksmith, 2008). The relations are essential, because according to Leeuwis and van den Ban (2004 in Dargan and Shucksmith, 2008) "co-operation between actors with a variety of different forms of knowledge and experience, who are then able to contribute to the development of innovations and can facilitate knowledge transfer", contribute to promoting innovatory economic development in rural areas.

1.1.2 The importance of learning for innovations

"In view of the shift towards a knowledge-driven economy, the capacity of urban and rural regions to support processes of learning and innovation has been identified as a key source of their competitive advantage." (Dargan and Shucksmith, 2008)

One of the key factors which are seen as essential for the innovation is **regional knowledge base**. "Common regional knowledge base is not just crucial for an effective communication and information exchange between local actors, but also contributes to a sustainable economic development and a successful innovation system." (Longhi, 1999 in Steigner et al, 2011)

Current approaches emphasis the role of learning rather than scientific findings in the innovation processes. "Learning need not necessarily imply discovery of new technical or scientific principles, and can equally be based on activities which recombine or adapt existing forms of knowledge." (Smith, 2000, in Dargan and Shucksmith, 2008)

There are many concepts which highlight the importance of **knowledge and learning** in the rural areas: **relational assets**, **learning regions**, **social capital**, **institutional thickness** and **associational economies**. (Mackinnon et al, 2002 in Dargan and Shucksmith, 2008)

Steiner et al (2011) name concept "**learning-by-doing**" as a one of the key factor which can lead to the innovations. Some scientists emphasises the theory of **collective learning**, **agglomerative preconditions** of **innovative behaviour** or "milieu innovateur". They focus mainly on the intangible tacit knowledge. Untraded interdependencies constituted around tacit conventions and informal agreements assist to the economic learning and adaptation. One of the possibilities how to enhance learning is through better education of the rural population.

1.1.3 The importance of education for innovations

Education in the rural areas is essential to build up local identity and create an environment for innovation. The support of the human resources in the rural areas (Steiner et al, 2008) is strictly recommended as they often face brain drain.

According to the proclamations of the officials (Hlaváček, 2012) "one of the main pillars of the future economic growth on the European continent will be support of the research, implementation of the innovations and strengthening of the Europe. To make this pillar effective, it is necessary to ensure constant increasing education of all population."

However, the over-estimation of the educational programmes does not have to lead to the desired results. Mackinnon et al (2002, in Dargan and Shucksmith, 2008) criticised that there is a growth of a so-called regional development industry, which is oriented toward the production and circulation of knowledge in the form of reports, conferences and seminars. Despite the effort of the police-makers, the demand from regional agencies for concepts and models of development which offer guidance on how to increase competitiveness and foster innovation in their areas still persists. The question is "whether the explanation for poor economic performance lies within (poor collective learning) or outside (dependency on external capital)." (Dargan and Shucksmith, 2008). Lagsey´s (1984, in Dargan and Shucksmith, 2008) came to conclusion that poor learning characteristics that are internal to regions themselves can result to under-development of the regions.

I presume that this might be because of the nature of the selected projects. Programmes implementing the projects through the bottom-up approach suppose that the local actors have the right notion about the development of the region. They are assumed to know the best, which projects to choose in order to bring the growth and development to their region. However, this might not occur in all cases. Therefore the selection process of the projects has to be examined.

1.2 LEADER programme

European Union's LEADER programme has been initially designed to develop innovative approaches to the rural development. "This is a programme that supports development in particularly vulnerable rural regions of the European countries, members of EU. It supports creative and innovative projects that can contribute to the long-term and sustainable development in these regions." (Vidal, 2009) It became integral part of the EU´s approach to the rural development.

LEADER has twin focus: (a) "on economic development and on democratic development and (b) on democratic learning and widening the "local" (endogenous) governance aspect of the initiative." (Papadopoulou et al, 2011). There are characteristic features making the programme unique, such as flat or lose hierarchical structure, which allows greater control over the projects by the local participants (Papadopoulou et al, 2011), involvement of local actors, bottom up approach, mobilization of local knowledge, strengthening of the social capital, searching for flexible public-private partnerships, multi-actor, multi-level and multi-dimensional approach (Hradiská and Hudec, 2010).

1.3 The role of the Local Action Groups

LAGs submitted their SPL within Rural Development Programme (RDP) implemented during the programme period 2007-2013. Chosen accredited LAGs have been allowed to select the projects which will be co-financed from the EAFRD. "Support may be given to the projects which are in accordance with the approved SPL of the LAG and according with the measures set out within the RDP." (SAIF, 2012) The applications are submitted by the various applicants to the LAG´s selection committee. It selects the projects for implementation according to the prior defined preferential criteria. This should ensure that only particular project aimed exactly on the previously stated objectives will be chosen. Also the conflict of interests will be prevented.

LAGs are left with relatively wide freedom regarding the setting of the scoring criteria. Certain number of them is obligatory; some can be established on the voluntary bases by LAGs themselves according to the regional needs. The emphasis on innovation is clear especially in the measure IV.1.2 *Realization of local development strategy*, where one of the compulsory evaluation criterions is the innovative approach. The weight given to this objective is left on the LAG. Some LAGs also include this criterion into their set of optional preferential criteria.

Selection process of projects by LAGs takes place at least once a year. Accepted application for grants has to be administratively checked by the LAG and has to undergo eligibility check. (Ministry of Agriculture, 2012) Unfortunately, the lists of projects with preferential score are not published.

2 Methods

In order to assess the understanding of the term innovation by LAGs, the paper analysis in detail their SPLs. The selection of LAGs for analysis was made on the basis of their success in the 10th call for applications for grand under measure IV.1.2 *Realization of local development strategy*. Only LAGs, which implemented projects linked to the education, were included in the case study. The sample consists of 21 LAGs.

The analysis of strategic documents' content was performed and the key indicators of innovative approach were highlighted and categorized. Consequently they were assessed and quantitatively evaluated.

The importance of the innovations for the LAG can be assessed by preferential score given to them during the selection procedure and hence by the amount of financial means devoted to the innovative projects. Therefore the forms for each Fiche were analysed and relative share of the score for the innovations on the total preferential score was calculated. The financial plan drafted in the SPL was used to establish the percentage of financial means for the particular Fiche. Special attention was paid to the innovations in educationally aimed projects.

3 Results and Discussion

3.1 Evaluation of the LEADER programme

Document *Mid-term review of the LEADER programme* evaluated its implementation positively, although some deficiencies were pointed out. The whole concept of the Axis IV and its functioning is according to the evaluators of the Rural Development Programme (DHV and TIMA, 2010) underestimated. The potential for rural development was not fully used and the traditional top-down approach remained the same. "LEADER was not considered as a method which would enable independent decision making of the LAGs." Therefore the original purpose of the programme could not have been fully achieved.

LEADER programme as a whole is evaluated according to the set of criteria. There are mostly of the quantitative nature and fail to measure qualitative benefits of the programmes.

Economic criteria and procedures of their evaluation are easier to establish and to be checked. "View of managing authority, which is focusing from its external perspective more on formal attributes, control and financial mechanisms, is not acquainted enough with the internal situation of the LAGs." (Hradiská and Hudec, 2010) Evaluating questions may ask for the qualitative benefits, but it is not clearly declared, what indicators should be used to answer them. Evaluators face the problem, how to articulate the results of the programmes.

As Papadopoulou et al (2011) argues, LEADER "effects are so different between regions and countries that any trans-regional generalization is likely to be unreliable." Therefore the possible form of evaluation can be rather based on the extended communication between paying agencies (which select the projects) and local actors (applicants) than on the "hard" evaluation methods. Ministry of Agriculture of the CR holds annual evaluation of Local Action Groups and divides them into four groups according to their performance and contribution to the local development. This assessment takes in account number of criteria with the aim to point out the best performing LAGs and their good practices.

3.2 Assessment of the understanding of the term innovation by LAGs

Each LAG has to answer the question about incorporation of the innovative factors in the selected projects in its SPL. It should describe the changes in the approach of solving local problems, the way, how the local potential will be used for innovations and make a list of innovative activities. According to the official declaration, the innovative approach within the framework of the LEADER programme is understood as:

- Introducing of the new products and services, which are reflecting the specificity of the particular location;
- Non-traditional ways of management and involvement of the local inhabitants into the decision making processes and the project realization;
- Introducing of the new methods for using the potential of the area;
- New action or activity which is performed in the area for the first time.

The innovation approach declared in the LAGs´ SPLs was analysed. The statements about what is considered as innovation can be categorised according to the main idea included. Naturally, the number of ideas exceeds the number of LAGs.

In the most cases (42), it is supposed that innovation is included in the way of co-operation. Especially the co-operation between traditionally separated sectors, involvement of public sector, private sector, non-profit sector, co-operation between municipalities and farms was considered as a benefit in 9 occurrences. Project preparations and realization based on community planning was mentioned five times as same as involvement of the local community in decision making, management and realization of projects, involvement of new inhabitants in region. In two cases, the pure establishment of the LAG itself was viewed as an innovative deed. I argue that it might be true for the first year after the funding of the LAG, however, the mere existence of it cannot ensure innovative approach in the future years.

Introduction of new products, services, technologies or activities was considered to be innovative in the 21 cases. The emphasis was laid particularly on the local products or services. In 10 cases, LAGs gave the preferences to the support of labelling of local or regional products, original product reflecting the specifics of the area and traditional products, because they consider them innovative. However, the nature of the projects raises doubts if they are truly of the innovative nature - for example, the renewal of the old traditional carnival.

The innovative approach should have been ensured by the support of the entrepreneurs in 7 cases. According to the 4 SPLs, the innovations are included in the projects supporting food companies, entrepreneurship incubators and local incubators of production based on woods and plants; while in 3 cases, the establishing of the new companies such as biogas plants, renewable energy producers or various kinds of micro companies itself shall ensure the enhancement of the innovations in the rural areas.

Innovations resulting from the connection of the projects, their broader scope or enrichment were considered in 7 cases. Mutual connection of projects in production process, cumulative and linked activities are seen as key factors for bringing innovations.

Innovations in the area of tourism were mentioned in 6 SPLs. The local actors consider innovative the projects which are improving the attendance of the sites outside the season, tourism management and co-operation between providers of the tourism services; further the projects which support suburban tourism and agroturism. New methods in education or alternative kindergartens were mentioned as innovative in 3 cases. Innovations which ensure sustainable development in rural areas were stated 2 times as same as the appreciation of a cultural heritage which should lead to the development of the region, or to the incensement of the tourism.

Among other mentioned innovative activities was building of infrastructure, non-profit activities for rural development, localization of the projects in small municipalities, market for local products from small producers, new methods of usage of potential of the people and new usage of the local resources. It is questionable, if the projects aimed on infrastructure building can ensure innovations and in what area. Similarly, non-profit activities does not necessary imply that they are innovative. What is innovative about the fact that the project is implemented in the small municipality? The same question is if establishing of a market itself could bring innovation and in what area? According to my opinion, the criteria should target the nature and content of the projects, rather than its localization of it or the conditions it is creating. Despite that the new methods of usage of potential of the people and the local resources are not further specified, I am at the opinion, that this is the way, how should be the projects assessed in terms of innovations.

3.3 Assessment of the relative importance of innovations in the projects

My aim is to find out, how important are the innovations in the projects selected by LAGs to be implemented within Axis VI. of the RDP in the Czech Republic. To evaluate the importance of the innovative approach within the projects I compare the approaches applied by each LAG during selection process.

Each project submitted by applicant within certain Fiche is evaluated according to the prior declared criteria. The relative score given by LAGs to the innovation as one of the obligatory (and in four cases also voluntary) criterion can point out on the importance of the innovations for the local actors. It is also necessary to support the declared significance by finances. Therefore financial plans stated in LAGs' SLPs and 2008-2013 financial breakdowns have to be explored. The aim is to assess whether the means are devoted to the Fiches where innovations are highly valued.

The innovations were included mostly only in obligatory preferential criteria, sometimes exclusively in voluntary criteria. No more than four LAGs included innovations in both categories. The relative score in percentage (i.e. (score for innovation/total preferential score)*100) was calculated in order to enable the comparison between different Fiches and LAGs.

The preferential points for innovations remains usually the same in all Fiches measures (e.g. LAG Region HANÁ, c.a.[3] is awarding innovations with 30 points in all Fiches), but the total score of the preferential criteria varies. Therefore the relative weight of innovations can be reduced.

Average score given to the innovative projects during selection procedure was 9.46 % (i.e. 9.46 preferential points out of 100). However it varies significantly from one LAG to another (standard deviation was 4.86 percentage points). For example LAG Posázaví put the 10 mandatory points for innovation criterion out 335 in total, while Rýmařovsko, p.s.c.[4] 50 out of 200, which accounts to the one quarter of all preferential points. It was also the LAG who gave in total the most preferences to the innovation during its selection procedure. On the other hand, the minimum score was given by LAG nad Orlicí 0.79 %. It evaluated projects within the framework of all its Fiches only by 3.22 %.

Histogram of frequencies shows that 5 LAGs evaluated innovations in submitted projects under 5 %, while only 2 LAG gave to the innovation significance over 15 %. Most of the LAGs gave score to the projects between 5 % and 10 % (7 LAGs). The distribution of points follows the normal distribution.

The most of the projects, where innovations are relatively highly considered, were aimed on the tourism or tourism infrastructure. Business supporting projects were awarded with the highest preferential score in 6 cases. From the point of view of innovations, also projects concerning cultural heritage were important.

LAGs have to present in their SPLs allocation of finances to each Fiche and, in some cases, to their functioning. The maximum share which was devoted to the LAG´s management was 20 %. The initial thesis is that the importance of the highly innovative projects should be underlined by the amount of finances devoted to the measure, where innovations have relatively high weight in the selection process.

27 projects, where innovations were highly scored amongst preferential criteria, were selected. In average, there was only 12.23 % of the financial means devoted to the Fiche with highly scored innovative projects.

The maximal allocation of the finances to the Fiche where the innovations are highly valued was established only in three cases. The best example is LAG - Partnership Moštěnka, c.a. which allocated on *Fiche 2: Colourful life in our home in the rural area*, where the innovations are rated by 50 out of 640 points (15.63 %), 40% of the finances for the period 2008-2013. LAG Region HANÁ, c.a. planned to allocate 15 % of the finances to the *Fiche 4: Development of the municipalities, infrastructure and service*s. The innovations in the projects are awarded by 30 points out of 520, which is the highest score of all LAGs' programmes. Another LAG, BYSTŘIČKA, p.s.c., awarded innovations in the projects by 50 out of 250 points in the framework of *Fiche 2: Village renewal and development, infrastructure* and planned 20% of the budged to spend on this Fiche.

These three LAGs are the only who actually support the innovative project with significant percentage of its expenditures. Otherwise, the most of the financial means were devoted to the Fiches where the innovative element in the project was not so important. For example LAG Strážnicko allocated 45 % of the budged on *Fiche 8: Our people in action* where innovation preferential criterion has only low significance (3.91%). Another example is LAG Moravská cesta (Litovelsko-Pomoraví), c.a, which favours within *Fiche 3: Tourism* the innovations by 50 points out of 270 (i.e. 18.52 %), but the financial amount devoted to this measure is only

[3] civic association

[4] public service company

3 %. On the other hand, 45 % of the financial means goes to the Fiche 2 which is improving the quality of life in the rural areas. The innovations are not highly scored in this type of projects; only 50 out of 380 are given as preferential points (13.16 %).

However, it must not be forgotten that the distribution of finances is only a plan, which could differ from the reality according to the number of approved and financed projects.

3.4 The innovations in the LEADER educational projects

Education is considered to be one of the most important drives for the innovations. Therefore the projects within the axis *IV.1.2 Realization of local development strategy* aimed on education or related to the education were selected. The list of LAGs and their approved projects can be found in the Table 1. in Appendix. There is a Fiche specialized on the trainings and schooling. However, only few LAGs actually took the advantage of implementing it. Therefore the projects were selected from all LAGs' projects despite the fact that they were implemented under different Fiche.

Only 6 out of 21 LAGs established the measure aimed on education. *Fiche 11: Education and cooperation for active development* was introduced by LAG nad Orlicí, LAG Krkonoše implemented *Fiche 11: Education* as same as LAG Blanický les - Netolicko *Fiche 7: Education*. LAG Pošumaví named its *Fiche 6: Education and information* while Citizens Association Aktivios aims in its *Fiche 1* on *conditions for training and education*. *Fiche 7* of the Region Pošembeří, is focused on *education across generations and region*.

The score given to the innovations in the projects is generally very low as same as the amount of finances. The average for all six LAGs is only 6.2 %. It can be interpreted that the project gained only 6.2 out of 100 preferential points due to the fact that it was innovative. LAGs in average devoted to the educationally aimed Fiches only 5.84 % of their financial means.

4 Conclusion

The aim of the article was to present general approach to innovation within public financed programmes in the Czech Republic. On the basis of the analysis of the LAGs' SPL I came to the conclusion that under the term of innovation it is mostly understood innovation in the way of co-operation between various actors, communication and the fact, that the local actors are involved in the decision making process. However, I am of the opinion, that these innovations will be exploited in the few first years of the functioning of the programme or project.

Secondly, introducing of new products, services, technologies or activities is viewed as innovative. However, the new nature of the projects can be questioned in several cases. In the most of the cases, the products or services are not new themselves, but only to the area, where they are implemented. I have doubts if for example a project introducing regional brand is still innovative when similar ones are introduced by many other LAGs.

The innovation does not seem an important preferential selection criterion. Only three LAGs include innovations as their voluntary preferential criterion, while others used it only obligatorily (or voluntary only). The score for including innovations in the projects usually remains the same regardless the topic of the project (i.e. in all Fiches), but as the total score is different, the relative importance of innovations is diminished.

The importance of the highly innovative projects should be underlined by the amount of finances devoted to the measure, where innovations have relatively high weight in the selection process. However, most of the LAGs planned to devote the maximum amount of finances to the projects which do not prefer innovations in the selection process.

Considering the innovations in educationally aimed projects, I came to the conclusion that they are not highly valued there and are not an important criterion for selection of the project for financing.

It can be concluded that in selected projects the innovations are seen only as an obligatory need. I provided some examples, where it was clearly visible that under the term innovations was possible to include various aspects of the project – in some cases very questionable. I proved that in comparison with other preferential criterion, innovations are treated disproportionately. Besides, the projects where innovations are highly valued do not, according to the LAGs' financial plans, receive sufficient amount of financial means. I am aware that my methodology is dealing only with official documents which are publically accessible. The challenge for the future research is deeper analyses of concrete implemented projects, larger and cross-year sampling.

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Appendix

Table 1. The selected projects aimed on education

	Name of the LAG	Educational project
1	LAG nad Orlicí	Cycles of educational courses for the municipality employees
2	LAG p.s.c. for Czech paradise	Expansion and renewal of the educational trail in the Eco-centre
3	LAG Krkonoše	Touch – open centre for education and entertainment and meeting of the inhabitants of the east Krkonoše
4	LAG Gate to the Czech paradise	Village school in new; Information on time and everywhere
5	LAG Opavsko	Summer archaeological school
6	LAG Blanický forest - Netolicko	Modernization of the kindergarten
7	LAG Posázaví	Vlašim´s observatory – a popular educational activity – education in the area small craft
8	„Strážnicko“ Local Action Group	Hroznolhotsko´s cultural association – Development of cultural activities in Hroznová Lhota
9	Kyjovské Slovácko in move	Municipality Milotice – The library more accessible to the citizens; Municipality Želetice – Modern cultural house; Municipality Ratíškovice – Municipal library – the world of information for everybody; City Bzenec – They have where to play
10	Local Action Group Hříběcí mountains, c.a.	Following forman roads, paths – through the Moštěnka and Hříběcí mountains
11	LAG - Partnership Moštěnka, c.a.	Following forman roads, paths – through the Moštěnka and Hříběcí mountains
12	Civic association Aktivios	Meetings – the way to others
13	Rýmařovsko, p.s.c.	Municipality Václavov u Bruntálu – Let the people have entertainment
14	Vyhlídky, c.a	Municipality Chorušice – Building of the penthouse with the background for social events in Velký újezd
15	Region Pošembeří, p.s.c.	Civic association SOSák – Material-technical background for cultural events
16	Moravian path (Litovelsko-Pomoraví), c.a.	Municipality Náklo – Leisure area for children and adults
17	LAG BYSTŘIČKA, p.s.c.	Municipality Doloplazy – To our children for pleasure
18	Development partnership of Region Hranicko	Czech beekeepers association c.a. - Educational bee trail
19	Region HANÁ, c.a.	Civic association AKTIV+ - We are doing it for kids
20	LAG Pošumaví	Úhlava p.s.c. – Get known your neighbour; Education of the rural population in the area of diversification
21	LAG of Mikroregion Frýdlantsko	Information technologies for development of the educational capacity in Frýdlant area

New transitional pathways in direct marketing of food: Case study on farmers' markets in the Czech Republic

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Annotation: Text of the abstract, between 200 and 300 words.

Key words: Up to 7 key words.

1 Introduction

Farmers' markets are seen as being representative of the alternative food networks (AFNs) that have been spreading all over the Europe and other countries (Renting and Marsden 2003). As such, farmers' markets form a new network of producers, consumers and other actors that exemplify an alternative to the conventional mode of food production, distribution and consumption.

The general goal of the paper is to describe how farmers' markets have evolved in the Czech Republic. This question becomes particularly interesting if we compare the development of the initiative with examples from other European countries. The Czech initiative clearly differs in several aspects. The farmers' markets developed relatively quickly (in two years the initiative gained national scope), in fairly radical form (the markets are organised in accordance with formal rules that accentuate an alternative quality of food), based on cooperation of different actors (it is rather the non-governmental organisations (NGOs) and municipalities in the role of organisers, than the agricultural producers, as the name of the markets would suggest). In this paper, we assume that the farmers' market in this form represents a clear departure from the "usual business", bringing about a radical change in the existing food supply chains. We therefore ask *how* this change has occurred, what actors and driving forces have enabled the change to take place and what their outcomes are.

The ongoing changes are investigated by means of the case study method, using the concepts of transitional studies. The study is a part of the FP7's FarmPath research study (Assessment of transition pathways to sustainable agriculture and social and technological innovation needs), which is focused on the transitional process in the European agrarian sector. Major parts of the paper draw on the national report of the selected case study realised in the Czech Republic by the authors.

2 Conceptual framework and methods

2.1 Key terms of the transitional perspective

The conceptual framework for the study is based on a transitional perspective (Darnhofer 2011; Geels 2011). This perspective stems from different theoretical backgrounds, such as the structuration theory, innovation studies and evolutionary economics.

Regarding the overall theoretical framework of the FarmPath project, a multi-level perspective was applied, developed by Geels and Schot (Darhofer 2011: 4),

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which assumes that transitions represent a non-linear process, resulting from simultaneous and mutually intertwined development at three analytical levels: niches (representing innovative initiative), socio-technical regime (that includes a set of dominating practices) and landscape factors (long-term aspects that influence changes in the given field).

Niches represent the radical innovations different from existing practices embodied by the regime. Niches are created by different groups of actors on a typically local level. Elzen et al. (2008) regards niches as the seeds of systematic changes, including the fact that many of these "seeds" eventually perish.

Regime represents networks of actors, rules, knowledge and infrastructure that exist on a meso level. Regimes include relatively stable patterns (cognitive routines, favourable institutional arrangements and regulations, binding contracts) and their structure represents a lock-in. Many regimes can be divided into sub-regimes related to different fields.

Landscape factors are present on a macro level and express long-term trends affecting development processes. Geels and Schot (2010: 24) according to Darnhofer (2011) assume that these trends cannot be influenced in the long term by changes in the niche or the regime. However, landscape factors can bring about direct changes at regime as well as niche levels. In this way, they can fortify the existing patterns of the regime, or create a tension within a regime, opening a window of opportunity for the successful development of a niche.

Such a theoretical framework enables the description and analysis of the transitional process and an understanding of not only what is being changed, but also of how the change occurs, what has enabled the change and what are the outcomes of the change. The framework has been applied in the case study research of farmers' markets in the Czech Republic. The empirical application of the main terms is presented at the beginning of the Results section.

2.2 Methods

The study draws on the primary research that was conducted in Winter 2011 and Spring 2012. Data for the case study have been collected by different research techniques (semi-standardised interviews with organisers of farmers' markets /NGOs, local authorities/; farmers and policy makers). Additional empirical materials were obtained through a document study. Altogether, 16 interviews were conducted (5 farmers' market organisers, 7 producers, 2 public administration bodies, 1 key informant, 1 town council representative). The relevant data were qualitatively coded (with regard to the conceptual framework) and analysed with the use of the NVivo software.

3 Results and Discussion

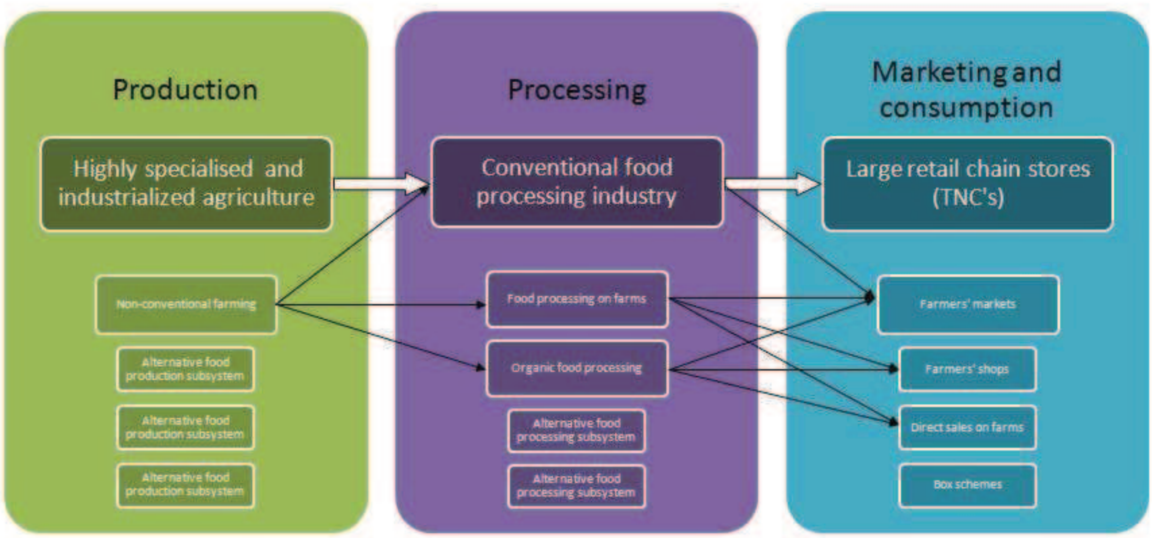
3.1 Description of the incumbent regime

Regarding the key conceptual terms, the main focus of the study is the agro-food regime. Food production, as the main focus of the regime, is based on several intertwined actions – agricultural production, processing and marketing (under which we also include marketing). Those three areas represent the three subsystems of the studied regime (see Figure 1).

One can see that the dominant regime forms a relatively stable production vertical that follows the same logic throughout all its subsystems. The same holds for the alternative vertical that stems from a specific form of agricultural production methods, develops selected areas of alternative food processing and continues with a specific form of marketing and consumption. The relations between the subsystems and possible combinations (showing how the subsystems can be aligned) are shown in the diagram below.

The dominant regime that draws on modern industrial agriculture and the processing industry is directly related to the distribution of food via large retail chain stores (supermarkets and hypermarkets). This mode has been prevailing in the Czech Republic since the early 1990s. The penetration of the Czech market by transnational corporations was obviously related to the fall of the communist regime in 1989. During the period of economic transformation (liberalisation of prices, initiation of private businesses, termination of state monopoly on international trade), the existing network of the small retail store was broken down. This opportunity was seized by foreign businesses, which brought new forms of food marketing, known from the developed Western European countries, into the Czech Republic.

Figure 1 *Agro-food regime and its structure*



The historical view shows that the first supermarket was opened in summer 1991 under the name of "Mana" by the Ahold company. According to the advertisements of that time, the store offered "smooth, fast and convenient sales" in combination with "good organisation, quality control and a broad range of goods for family shopping" (iDnes 2006). The success of this new form was ensured, due to the fact that none of these aspects was present in retailing before 1989 in the former Czechoslovakia. The new stores were extremely appealing to Czech consumers. In 1998 the first hypermarket was opened and the retail sector increased its market concentration. This process was followed with increasing competition that later on resulted in the market exit of some companies (e.g. Carrefour and Delvita, or the Delhainze Group). The pace of the market concentration process can be illustrated by the following figures: in 1993 the market share of the 10 largest companies was about 7%, in 1999 it was one-third and currently it is two-thirds of the retail market (Skála 2007: 13).

The large transnational companies (TNCs) also began to function as important market integrators. From the position of retailers, companies stepped "down" the production vertical towards processing (e.g. in the meat industry). Cooperation between actors in the incumbent regime was framed by industrial logic. Large stores were thus interested in collaboration with large processing companies and large producers, who could most likely supply their goods throughout the year in the required quantity and quality. It was this trend (in combination with consumer demand) that created the dominant position of the industrial regime and that later started to shape all subsystems of the agro-food chain, leaving no room for any alternative development (until about 2005).

Current data show that the Czech Republic is typical of a very high penetration of hypermarkets (4th place among European countries). There are 26 hypermarkets per 1 million inhabitants (268 altogether), whereas their networks span a catchment area in which about 90% of the Czech population reside. Supermarket networks are not so dense, in comparison to other European countries (10 large supermarkets per 1 million inhabitants, and 116 smaller supermarkets per 1 million inhabitants). Hypermarkets have become the main place of purchase for 43% of Czech households, supermarkets gaining 15% and discount stores 25% (Incoma GfK 2011a). The vast majority of food purchases are therefore conducted in the stores of the retail chains.

The high number of stores resulted in robust competition among companies, who mostly emphasise the low prices of their products. It appears that the race for low prices has been accompanied by the poor quality of products and processing. In recent years, the Czech media have created several food scandals which have increased the sensitivity of consumers to food quality (iDnes 2012). Due to the economic power of retail chain stores, the high market penetration and low price of the offered products, the position of the dominant regime has remained unchallenged in practice.
Moreover, the main retail chain stores in the Czech Republic have innovated their strategies and also directed their focus on more conscientious consumers (offering organic food, premium food brands, promotions, special labelling of Czech products and an emphasis on freshness) (Incoma GfK 20012b). Such trends suggest minor changes in the regime as a result of the inner tensions and exogenous pressure that can be related to the known "quality turn".

In order to understand the mechanisms of the regime, it is important to describe its guiding principles and the institutions ruling the regime. In the past, the activities of large retail chain stores were relatively sparsely regulated. Their proliferation was seen as a result of increasing material wealth (in contrast to the communist regime) and therefore they were welcomed by the authorities and citizens. The attitude towards chain stores started to change in the late 1990s. At first, criticism was articulated by the anti-globalisation movement. With the growth of the civic society in Czechia, there were increasingly more examples of citizens who opposed the construction of new stores. The discussion on the sustainability of large retail chain stores has been mostly related to environmental aspects and urban planning. Questions of the impacts on agricultural producers and processors have been neglected.

Just recently, the Czech government started implementing new rules to limit the powers of retail chain stores by applying the *Act on significant market power and its abuse* (395/2009 Coll.). One of the goals of this legislature was to reduce the pressure of the chain store companies on processors and producers. The TNCs have criticised this law and lobbied for its change. Proposals for new legislation are still being discussed.

In the past year, a debate on food quality has been opened. Comparison of Czech stores with their foreign branches has suggested that the quality of food sold in the Czech Republic is lower (and at the same time more expensive) than food sold in foreign branches of the same retailers (IHNED 2011). This finding proves that the TNCs in the Czech Republic are counting on the relatively low conscientiousness of Czech consumers in comparison with other countries. This discussion has recently caused official authorities to step in to increase controls in food stores. The State Food Inspection Authority is currently preparing a new information portal to present the results of its control and to share this information with consumers.

One of the key questions related to the changing regime is the sustainability of the system. Discussion on the un-(sustainability) of the dominant regime has been supported by the activities of the Agrarian Chamber. One can find several notices pointing out suspicious practices of large retail chain stores. However, the entire discussion is focused mainly on economic aspects. Environmental and social issues have been neglected in this issue.

The economic sustainability of the regime is related to the pressure that is put on suppliers and producers. The Agrarian Chamber recently lodged several complaints, saying that retailers receive a 30% margin on food (ZS ČR 2010). The Chamber thus proposes to put limits on the retailer margins that are constantly increasing, despite the fact that producers cannot increase their prices (ČT24 2012).

3.2 Pressures from the socio-technical landscape

The agro-food regime has been faced by many different landscape factors, creating tensions or opportunities in inner parts of the regime. It is important to note that tensions as well as opportunities can emerge within the incumbent regime, as well as within a niche (for more see Elzen et al. 2008: 7).

1) *Robust competition among retail chain stores.* Transnational companies often use their economic power to increase their competitive advantage. One of the implications is the pressure put on suppliers (Nazemi 2012). From time to time, information is published about conflicts between stores and suppliers (usually one or other large company, such as Danone, Ferrero Rocher or Coca-cola). Economic power is often abused in price negotiations. In order to maintain profits, suppliers are inclined to decrease prices, which is then reflected in the product quality. Many consumers find this situation problematic, creating a tension within the regime.

2) *Quality turn.* The current decrease in the quality of some foodstuffs due to economic pressure (see above) has led to product differentiation and new marketing strategies for different consumers. This approach can be seen as a part of the "quality turn" that follows the known trends from Western European countries (Zagata 2012). Consumers are starting to recognise process-based food qualities (where it comes from, how it is produced, what the impacts are of its production on the environment, society, etc.). This attitude of consumers has been proved by many statements by the farmers' market organisers. This trend led to the launch of a Facebook movement: "We want farmers' markets in Prague". The aim of this group was to convince local authorities to facilitate the organisation of farmers' markets.

The above-mentioned "quality turn" is also followed by supermarkets that change their marketing strategies and try to improve their public image, for example, by increasing the offer of regional products (Incoma 2011).

3) *Influence of public policies.* The activities of public administration bodies (including state and local authorities) have created many important opportunities for successful anchorage of the alternative initiative. One of them was the dialogue between local politicians and the Facebook community in 2010. The positive attitude of the local authorities was most likely framed by the upcoming elections in fall 2011 and therefore the motivation of politicians to increase their public popularity. Incidentally, the Mayor of the Prague district where the markets were organised for the first time was appointed Minister of the Environment a year later.

The Ministry of Environment set up a grant scheme in 2011, which has become a key opportunity for development of the initiative and its anchorage in the regime.

3.3 Description of the niche

The farmers' market is one of the oldest and most widespread forms of direct food marketing (Gale 2011). However, the tradition of this form of sale was significantly challenged after 1989, when the new industrial system of production and consumption was being established. The farmers' markets that are described here have their origins in the year 2009. The evolution of the initiative has gathered a very rapid momentum, which included a radical break in the regime that could be explained with regard to the inner tensions and opportunities that emerged in 2010.

In 2011, there were more than 200 locations with farmers' markets. The total turnover of farmers' markets in 2010 reached CZK 1 billion and, in 2011, it was CZK 1,5 billion (1 euro = 25 CZK), which is still very low in comparison to the financial power of the retail chain store (see the description of the regime).

Technical and technological changes are not crucial for transition, however they provide some important innovations in the area of (1) hygienic rules for selling food and (2) communication with customers.

The niche keeps a critical stance towards food that is produced on an industrial basis within the "hygienic–bureaucratic mode" with its own standards of quality (Marsden 2006: 203). The organisers of farmers' markets point out a new food quality which challenges the above-mentioned perspective. Due to this fact, there is strong disagreement about the hygienic framework for food sales. What prevail are the hygienic standards that are taken from the industrial regime and applied universally.

The second factor to be considered in the technological aspect is related to communication. The incumbent regime is based on long supply chains and anonymous relations. In contrast to these, the organisers of farmers' markets are trying to provide enough information about the market as well as about the farmers (this aspect was evident in many interviews). For this purpose, social networks and informal word-of-mouth communication among customers are often used. Most farmers publish information about their activities on websites. The information provided is intended to strengthen a relationship of trust.

The initiative is not too large from the market-share perspective, but it introduces an important leap in the minds of people. In this way, the initiative has selected the societal aspects of the regime. Consumers have discovered the issue of food quality with regards to product- and process-based qualities. There is a great shift in the relationship between producers and consumers, between rural and urban areas. This change was enabled by a radical departure from the previous mode of marketing. In order to anchorage the initiative, a change in the farmers' attitudes must occur. Organisers of the first farmers' markets related how they needed to convince farmers to cooperate with them:

> *“Farmers did not believe that… with some difficulty, we got together about 35 producers who agreed to arrive. Everyone was thinking – 'OK, let’s try it and we will see, we are not confident about its future success'.”* (organisers of the farmers' markets)

The current situation is very different. Successful farmers can choose from different farmers' markets. Organisers visit farms and invite farmers to arrive at "their" markets.

An important aspect of cooperation is the collaboration between organisers. They often share a list of farmers and information about them. This informal control helps to maintain the necessary quality. It is interesting that farmers also share information about the market organisers and their approaches. The most popular actors in the initiative can freely choose with whom they want to cooperate.

Main network anchorage was based on the activities of "outsiders", actors who originally did not belong to the regime sector. However, they had a close relationship to gastronomy (conferences, competitions, exhibitions) and some of them were engaged in experiments with different AFNs and SFSC (such as box schemes, consumer groups, etc.). The organisation of the farmers' market was in this way a continuation of the previous efforts that reflected a (presumed) societal demand.

In the beginning, the market organisers had fairly close relationships and shared their experience. This situation changed later on, when the sector grew and competition among the organisers increased (due to a limited number of suitable producers). This aspect is obvious in Prague, where the market potential is very high and where "organisers perceive each other as competitors and do not cooperate at all" (Prague farmers' market (FM) organisers). This competitive relationship undermines the potential for institutional anchorage. Organisers from different towns are more open to collaboration. Together they have created a "black list" of unreliable producers, which helps to ensure the markets' quality.

The main institutional actors related to the agro-food regime started to pay attention to the initiative after the concept of the farmers' market appeared to be successful (i.e. in 2010). The Ministry of Environment created an important opportunity for the proliferation of the initiative by its grant scheme. The Ministry of Agriculture (which is more influential in the sector) initiated a discussion group among the main organisers with the goal of codifying the concept of farmers' markets. Participants in the discussions told us that the Ministry was not willing to play a more active role and, due to this, did not gain much respect from the niche actors.

The initiative tried to challenge some of the universal rules of food quality which are embedded in the industrial regime. They did not succeed in this. Each organiser is obliged to have a formalised market order that must be in accordance with the legislature of the municipality. This document must also be approved by the State Veterinary Office and State Food Inspection Authority. When the initiative started to grow rapidly in 2010, the Ministry of Agriculture initiated a round-table discussion with representatives of these authorities and the organisers. The main purpose was to create a codex for farmers' markets. The Codex was issued, but it never became obligatory for farmers' market organisers and some competing organisers do not respect the Codex.

In 2011, the Ministry of Environment stepped in to establish a grant scheme for NGOs and municipalities that were interested in creating a new farmers' market. The number of applications greatly exceeded the allocated funds, so they needed to be increased repeatedly till the final limit of CZK 10 million. The requirements of the applications were not too strict (acceptance rate was 90%). Due to this support, the number of locations with farmers' markets in the Czech Republic very quickly doubled (from 100 to 200).

Another disputed point in the institutional anchorage of the initiative is the foundation of the Association to bring together farmers' market organisers. One group of organisers agrees with establishing an Association to become a formal representation of the initiative. One of the main tasks of the Association should be the creation of a stricter codex and certification systems for the markets to guarantee the authenticity of the sellers and producers. A specific goal of the Association should be the promotion of the initiative and the lobbying for changes in legislature to facilitate organisation of the markets and sales of some products. Other groups of organisers (also very strong) are convinced that the Association is not needed, because the current formal framework enables the effective organisation of farmers' markets. These organisers are also worried that the new codification of rules would enhance standardisation of the markets, which would then resemble the industrial regime.

Looking at the new learning opportunities for farmers, one can see that farmers are gaining new competencies in the methods of selling their produce directly to consumers. Even after the successful anchorage of the markets in the capital city, they were quite sceptical about farmers' markets in other towns. Later they realised that these doubts were unfounded.

Some farmers who are active in the niche still keep in touch with the regime. These relationships are based on pragmatic (economic) reasons. For example, large farms still cooperate with industrial processing companies, but a part of their produce is intended for their own processing on the farm and for direct marketing. On a farm with a small milk processing facility and a very successful farm store, they process 95% of their produce on their own, the remaining 5% is sold to an industrial processor, just to keep the contract between them valid. The main advantage of direct marketing for them is the fact that they do not have to negotiate the price or conditions of the supply. Low economic power often meant that they had not been able to succeed in negotiations with a strong partner.

It appeared that many farmers combine different forms of direct marketing that they have gradually developed. Besides farmers' markets, it might be a farmers' store, on-farm sales, delivery service or restaurants. For many producers, the farmers' markets have become (when they developed into new channels) a small addition to their activities.

It clearly appears that the learning process also continues on the part of the organisers. They put a lot of effort into shaping their own concept of the market to make sure that it is a place for purchasing and for the meeting of people, as well as a place that complies with the formal requirements (legislative requirements).

Concerning the impacts of policies and their effects on the niche development, one can see that there were two important opportunities. Firstly, it was the fact that 2010 was an election year, so local politicians were relatively more open to entering into dialogue with the public. Many politicians also "promised" citizens to open farmers' markets in their towns, if elected.

Secondly, it was the grant scheme administered by the Ministry of Environment. The financial support for the market was focused only on the opening in the year 2011. Since these were 1-year projects, there is the question of their sustainability. Exact data are not available to show how many farmers' markets actually are being held in 2012.

Thirdly, the last important aspect of the institutional anchorage is the decision about establishing the Association. The Ministry of Agriculture supports it, but is not actually active in deed in setting up the Association. The main issues related to the Association are the questions of financing and its competencies.

3.4 Interactions between the niche and the regime

The specific form of the farmers' market is based on the organisers' ideas. The first farmers' markets (concept 2010) have become an inspiration to other organisers, who have modified this concept and adjusted it to local conditions. Market organisers also have very different views on collaboration with actors from the regime.

One group of organisers emphasises the specifics of the markets, the renewal of tradition and public spaces in towns, enhancing the community aspects of the municipality, educating people about food quality and support of local producers, as one can see from the following extract from an interview in Pilsen:

> *"To us, quality food does not mean that it looks good and tastes good, but we are also interested in how it was produced and processed."* (farmers' market organisers)

This excerpt represents one type of organiser who follows its own values, which are reflected in the organisation of the market. Usually these organisers are not interested in organising markets which do not correspond with their values (i.e. emphasising process-based qualities of food). For them, cooperation with actors of the regime, such as supermarkets, is forbidden. The farmers' markets that have been opened in collaboration with supermarkets in unsuitable sites (such as a supermarket's parking lot) are what they oppose. They see this as a threat to the initiative.

Besides those, there is another group of organisers which utilises the positives of the globalisation process and is more integrated into the dominant regime. To them, the organisation of farmers' markets together with supermarkets is not seen as a problem. Contrary to the process-based quality of food, they emphasise the quality aspects related to taste (gourmets) and new experience. Farmers' markets are seen as a form of "business" that can be deliberately organised. In the interviews they presented several arguments defending collaboration with supermarkets: convenient purchases for consumers, easy transport, enough space, use of cars, better infrastructure (water and electricity) that helps to meet the hygienic requirements. These organisers also argue that some towns do not have suitable public spaces and in those cases it is necessary to find a space – and this can be even at a supermarket. However, they admit that it is another opportunity for the retail chain store. This study was not focused on consumer attitudes towards farmers' markets, but we could see that even this type of farmers' market could prove popular with customers.

In this way, one can consider two types of actors, i.e. hybrid actors. They include those who enter the hybrid forum (Elzen et al. 2008) from the regime and enter into cooperation with actors in the niche. Due to their activities, the initiative is being changed, gaining a new focus from "oppositional" alternative towards collaboration with the regime, when retail chain stores are asking market organisers to hold a market on their premises. The second group includes the actors who are originally from the niche, however, who are active in collaboration with the regime.

Hybrid actors from the regime are typically represented by the retail chain stores that "order a farmers' market for themselves" (interview with Nalok). Their interest stems from the economic opportunity that the 2011 FM concept discovered. The economic potential of the initiative doubled during the years 2010 and 2011 and the retail chain stores obviously wanted to profit from it. Representatives of the retail chain stores claimed that the farmers' markets are so small that they do not threaten their position. Their idea is to attract customers who buy some fresh foodstuff on the farmers' market and then the rest in the conventional store. Some people are referring to this situation as a "Macdonaldisation of the farmers' market". This process was visible right from the beginning of the initiative. In 2010, this was apparent only in Prague, but later was also so in other towns.

Hybrid actors from the niche are represented by organisers who extend their activities and who enter into collaboration with regime actors through networks. The decision of a successful market organiser in Prague, who helped to open another farmers' market in Moravia for a selected supermarket, represents a good example of this process. This is mentioned in the following extract:

> "[…] *they gave them the complete know-how, created graphics, selected farmers. Now they continue on their own with the use of a manual that was prepared for them."* (farmers' market organisers)

Collaboration like this significantly helps in spreading the initiative all over the country (anchorage in the regime), however, the integration in the regime has brought about inevitable changes to the initiative.

Different types of organisation also affect the decision of farmers about participation. The primary criterion for them is the question of revenue. However, some of them mentioned that they would not participate in markets held at supermarkets, because they did not agree with them.

Successful anchorage of the initiative is also seen in the development of the new forms of direct marketing. In particular, those producers who have been successful at farmers' markets have discovered the potential for a subsequent growth in direct marketing. These new forms mainly include a method of farm shops to resolve some contradictions about farmers' markets (a shop can be open every day; it is possible to delegate sales activities; hygienic and other requirements can more easily be met; it is possible to cooperate with other farmers and create a shop with a specific focus, etc.).

The proliferation of farmers' markets (FM concept 2011) has also created pressure on the original values of the initiative. Similarly to other movements, the dilemma of growth has arisen, showing a mass growth of the initiative can be achieved without modification of its original values.

One of the issues is related to the question whether foreign goods should be sold on farmers' markets. Some organisers emphasise the localness of the goods sold, allowing only products from the Czech Republic on the markets. Other organisers argue that the markets should offer products from any geographic region around the Czech Republic. This issue tackles the question whether e.g. to sell sea fish. Some organisers, in order to complete the range of products, are offering sea fish, however it means that they must cooperate with a common supplier who also delivers fish to retail chain stores.

The proliferation of farmers' markets was followed by great media attention. In the first stage, farmers' markets were positively accepted. Later, the opinion of the markets became more critical. This included a few articles with a clearly negative evaluation of the phenomenon. Market organisers confirmed to us that information in the media significantly shapes the discussion about authenticity. There were a few cases of markets, where sellers were not "genuine" producers, but merchants who had bought the products and were offering them on the markets as their own. In the interviews, some organisers speculated that this information could be spread by supermarkets that want their market shares back. Despite the fact that media attention (positive in the beginning but, later, occasionally negative) plays a crucial role in the development of the initiative, it is not included in the overall figure of the anchorage process due to its complexity.

Looking at the policies and programmes which helped the proliferation of farmers' markets, one can see that the initiative has been supported mainly through the state and local administration. The success of the first farmers' market concept in 2010 opened up a great opportunity for future development. The Ministry of Environment clearly responded to this opportunity by establishing a grant scheme for new farmers' markets.

The support was drawn from the revolving fund. The maximum contribution was CZK 150,000 (1 euro = 25 CZK) and the duration of the project was 6 months. Projects under this support were realised in 2011. The support was framed by specific points related to healthy lifestyles and support for new organisers (farmers are not mentioned in this context). Most projects were prepared by municipalities. Applicants could use the support for purchasing technical equipment or securing the necessary infrastructure).

Other support for the initiative often came from the municipalities themselves. Town, city districts and regional councils often transferred money for starting a farmers' market in their area. The subsidies were typically included in the support for cultural events and/or free time. This was obvious especially in 2010 when the elections took place. One can assume that political parties wanted to gain some support from the public through this. Another (however minor) source of support were specific foundations, focused mostly on environment-related projects.

The initiative improves the quality of life of farmers. This is related to the economic aspects (higher profit), but also to social aspects (positive feedback from customers, creating new relationships with consumers). A direct form of marketing rediscovers a marketing channel that enables a farmer to sell his produce without the middle man, typical in conventional food networks. Farmers' markets assist local producers and, in this way, generate revenue for regional economies.

Overall, there is no consensus about the localisation of the markets and their purpose. Currently there is ongoing discussion about the authenticity of the markets: What is a real farmers' market? Who should be selling there and what should they be selling? The contested nature of this question is weakening the potential for institutional anchorage. A specific result of this situation is the fact that the actors of the initiative have not so far been able to establish the necessary Association.

3.5 Characterisation of the emergent transition

One may distinguish different types of anchorage which co-evolve to lead to a transition.

Firstly, it is *technological anchorage* which includes the "concept" of the farmers' markets that has gradually developed over two years. The success of the first markets founded a basis for new coalitions between the actors. Organisation of the market has in this way been transformed into a marketing concept that can be transferred or sold as a know-how to other partners.

The potential for creating an alternative channel has been growing for a long time. Before the initiative took off in 2010, there were some examples of the AFNs. This type of engagement later created a relatively stable network of actors, who, together with others created a Facebook community entitled: "We want farmers' markets in Prague". Representatives of this movement entered into dialogue with the local council. One can assume that the closer cooperation with citizens was conditioned by the upcoming elections in fall 2010. Local authorities decided to support the organisers of farmers' markets in Prague (since, at that time, it appeared to be quite an uncertain business) and opened the first farmers' markets in March 2010 (concept FM 2010). Other large cities followed, e.g. Pilsen opened a market in May 2010. The concept appeared to be extremely successful, due to the very high demand by consumers.

In order to set up the market, several elements needed to be aligned: organisation of the collective action, willingness of the local authority and an experienced network of people who had previous experience of different AFNs. The first market event was attended by 15,000 people, with some farmers already running out of produce by 10 am. This experiment proved the great potential of direct food marketing. This potential could only have been guessed at before that. The first evidence came from Prague due to this event, which created a real opportunity for other actors.

The opportunity was taken up by the Ministry of Environment who launched support for new farmers' markets all over the country. On this basis, a new mass model for farmers' markets (FM concept 2011) was established. This concept could already use the experience from the previous year. At this stage, *the institutional anchorage* of the initiative was still not too strong, because the Codex was not obligatory, but the demand of consumers ensured its success. Currently, the FM concept 2011 is translated into new forms of direct marketing, such as the farmers' shops. This process is supported by a combination of network anchorage that has been created in a parallel way. A good example of such a network is the Internet portal, Nalok, which shares information about producers, communicates with consumers and provides information to farmers' market organisers. Nalok virtually operates as "the eyes of the market" and represents a strongly *anchored element in the social dimension*.

Actors in the niche were in opposition to the conventional regime. Keeping up the differences between the alternative and industrial product was the key to the initial success. Later, the original concept of the markets was modified (creating FM concept 2011) and one version of it counted on the cooperation of large retail chain stores. However, these cases are only known in large cities. Due to the inner tension of the regime, people accepted the markets even in their controversial form.

Despite the mass proliferation of the markets, their market share remains very low. The main reason is that conventional marketing and consumption is so strongly anchored in the agro-food regime that it cannot be so rapidly undermined. The disadvantages of the farmers' market are higher prices, limited time framework for purchases (typically once a week) and localisation in towns or cities.

Due to the institutional anchorage, the initiative has gained an influential position - it has become a partner of the Czech ministries. The first opportunity was linked to the round-table discussions organised by the Ministry of Agriculture. Another set of discussions - towards official Associations - was unsuccessful. One can assume that this step (institutional anchorage) could become a safeguard for the initiative to enable it to gain a clear status in the agro-food regime and for its goals to be clearly defined. This step has not yet been achieved. Current policy is indifferent to the initiative.

A very important step in the institutional anchorage was represented by the grant scheme of the Ministry of Environment, by which new farmers' markets were supported. Since the support was provided by another Ministry (different from the Ministry where the first network was established), the project did not have to reflect the previous discussion and requirements set out by the Codex. The new markets (concept 2011) thus had more lax rules, which went hand in hand with the mainstreaming of the initiative.

4 Conclusions

The emergence of farmers' markets in the Czech Republic signifies the changes in the food networks that have been observed in different countries in Europe. The initiative as such has resulted in four major outcomes:

1) De-routinisation. Regarding the agro-food regime, an important shift in the approaches of farmers has appeared. The FM concept has proved to be viable. On this basis, a range of new approaches became visible. The farmers' market concept has been translated into a new network of farmers' shops (such as Český grunt/Czech basis). Successful producers from the market have become more independent and have often made the effort to open up new marketing channels, such as web-shops and other types of collaboration.

2) Shift in power relations. The initiative strengthens the negotiating power of producers in the vertical chain. Some of them have managed to get rid of them completely, some of them have decided not to (yet). Some producers have taken the opportunity to invest in new processing technologies (e.g. a fruit producer in the Pilsen region that has newly focused on must production and dried apples). This new position of producers depends on the nature of production, type of commodity and also the size of the farm. This description also sheds light on how the links between the subsystems are created.

3) Localisation. The FMs' concept and new forms of direct food marketing are disembedding producers from transnational relations. One can also note that the concept of the FMs was originally created in contrast to the actors of the regime, who are not authentic producers. Some markets do not allow the sale of foreign products, but there is no agreement about this rule.

4) New model of food governance. Anchorage of the initiative has been successful in the technological and social (networking) dimensions. The institutional dimension (creating a new mechanism of coordination) has not yet been achieved. This is obvious from the experience with the Association, the non-obligatory nature of the Codex, and not initiating new financial support for the market organisers. The organisers in Pilsen have opened a farmers' shop and are currently starting a new box scheme combined with a web-shop.

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Ethical consumption from niche to mainstream – Discovering consumers' information need

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Annotation: Fair Trade-products gained increasing importance during the last 15 years and entered the mainstream market. Nowadays, they are no longer sold only by a few selected shops but supermarkets and discount shops also offer them. The entrance into a different market is accompanied by an adjustment to a different group of consumers, which necessitates the exploration of consumers' information needs regarding quantity and quality of Fair Trade-products. In this study, coffee as a popular Fair Trade-product was exemplary chosen in order to explore the task. As a survey method, an Information Display Matrix (IDM)-experiment was chosen in order to be able to trace the information acquisition behaviour and the final purchase decision. IDM experiments are suited to sequentially trace information search. The IDM was accompanied by a complementary questionnaire; both survey methods were conducted computer assisted. Results show that among the tested product attributes, product price, production methods, Fair Trade-label and the ethical attribute 'protection of children' were most important. Consumers are also willing to pay a higher price for a product which fulfills their requirements of a Fair Trade coffee. With regard to information acquisition behaviour, results show that consumers perform a rather extensive information search and apply strategic approaches, whereof attribute-based strategies are most popular.

Key words: ethical consumption, Fair Trade, information search behaviour, Information Display Matrix, IDM, organic

JEL classification: D12, M 31

1 Introduction

Not only recently, a growing trend towards the consumption of 'ethically' produced products can be observed. 'Ethical products' comprise a range of aspects, such as animal welfare, environmental protection or 'fair' trade conditions for both producers from industrial as well as from developing countries, whereof the present study focuses on Fair Trade-products from developing countries. Market shares of the latter products are growing in industrial countries, not least due to their increasing availability in supermarkets, and high sales growth could be attained within the last years (cp. BioVista 2012, Fairtrade International 2012, Hira and Ferrie 2006). More and more important food manufacturers such as Mars, Kraft, Nestlé and Starbucks resort to commodities from Fair Trade. Thus, one can conclude that Fair Trade-products are on the way from niche to mainstream markets (Raynolds 2006, Moore 2004), also since the share of Fair Trade-labelled[1] products which are marketed via worldshops is 7% of all Fair Trade-products only (Forum Fairer Handel 2010). However, it needs to be questioned whether Fair Trade-products are prepared for mainstream marketing, as doubted by Hira and Ferrie (2006). They explain that one of the major challenges for Fair Trade-products on their way to the general distribution is a lack of agreement on what Fair Trade

[1] Please note that not all Fair Trade-products are labelled. Especially in worldshops, products often do not carry a Fair Trade-label. Further, it should be noted that a governmental label does not exist as well.

comprises. One starting point to define what "fair trade really is" (Hira and Ferrie 2006: 107) is to elaborate what consumers 'think it should be'.

At the same time, Fair Trade-products are characterised by their feature as 'credence goods', implying that consumers can not verify whether the product fulfills the advertised attributes (Dulleck and Kershbamer 2006). Thus, trust into product attributes is essential. Trust builds up upon information. However, too extensive information can lead to consumers' information overload which should be avoided. Consequently, it is again important to know customers' information need. The central objective of the present survey is to identify, which ethical arguments are of particular interest to consumers, and how intensive consumers search for information on the additional ethical value of a product. The focus of this study is on information which is given on product packages. This means that the information uptake immediately prior to the purchasing action is examined. Furthermore, label importance for the purchase decision is examined. The results shall contribute to a target-group specific communication-strategy for Fair Trade-products. Fair Trade coffee as a well-known Fair Trade-product with a comparably high market share is used as an exemplary product in the present study.

The paper is structured as follows: Chapter 2 explains the applied methodology and the study design. Next, the results on both the information search extent and the preferred information are presented. Finally, conclusions are drawn.

2 Methodology

The data survey is based on the conduction of an Information-Display-Matrix (IDM) experiment which is supported by a written questionnaire. The IDM was embedded into the questionnaire; both were carried out computer assisted. A short introduction into the IDM methodology will be given first. The research design of this study is described next.

2.1 Information-Display-Matrix

The IDM is a quantitative research method which aims to explore the information search behaviour as well as the decision behaviour of consumers. The idea of the IDM is to offer participants various products including defined information on the products. The goal is that participants select one product they intend to buy. The IDM is designed as a matrix which consists of the different products and general product attributes in columns and rows respectively. The fields of the matrix contain specific information on the products. Participants can access the specific information by clicking on fields (see Figure 1 and 2) and access as much information as needed in order to make the purchase decision. As consumers' information search is registered by the computer, the researcher can gain insights into the complete decision making process including the tracking of information search, the evaluation of alternatives and the purchase decision at the end. Thus, an analysis of amount, content and sequence of information search can be conducted.

Instead of direct inquiries, where a bias between actual and reported behaviour can occur (Jacoby et al. 1976; Jacoby et al. 1978), the IDM dynamically protocols the information uptake simultaneously to its course. If the IDM is conducted using a PC as it is common nowadays, the social desirability bias is minimized due to the reduced interviewer effect (Berekoven et al. 2006). Even though in this study, the IDM was conducted in a real shopping environment, it is an artificial situation which therefore implies the advantage of having controlled circumstances. Nevertheless, the IDM is criticized for its low correspondence to reality because the information is delivered in an abstract manner (Kroeber-Riel et al. 2009, Arch et al. 1978) where the information uptake takes place sequentially (Kroeber-Riel 2009, Kuß 1987). This could be handled via not covering the matrix fields of the IDM. This approach would however lead the IDM ad absurdum, because it is its idea to document consumers' information search trace which would be made impossible if the complete information was visible. Further, in the real purchasing environment, information on several products are not simultaneously visible either. Since today's consumers are used to online shops and (online) product test reports which have a similar design and structure like the IDM, the critique of little correspondence to reality can be rejected to some extent. Further critique towards the method is the high amount of information participants have to deal with (Arch et al. 1978) which was in this study encountered via offering participants the possibility to mark interesting fields. Further, participants in a pre-test explained that they did not face problems with the quantity of information.

The IDM is suitable to apply on non-daily products, where a conscious and targeted information uptake is necessary (Schopphoven 1996, Kuß 1987). Usually, food purchase is characterized by limited information search, since purchases are habituated. Ethical products, and thus Fair Trade coffee, however are an exception. A study of Bezençon and Blili (2010) has shown that the higher the involvement in the Fair Trade purchase decision, the greater is the information search.

2.2 Research design

In this study, participants' task was to choose from nine different Fair Trade coffees, equipped with different ethical attributes representing the Fair Trade idea: protection of children (such as tackling the problem of child labour), producer income (such as a price which secures producers standard of living), trade relations (such as a guaranteed purchase of harvest) and social projects (such as the establishment of a health center), a Fair Trade-label, plus information on prices[2] and production method (organic or conventional). A 7x9-matrix was designed, see Figure 1. The products were equipped with information on attributes given in the rows. Information on ethical attributes varied in two manners, or the field contained no information. Further, different prices according to the quality of information given were designed. Four products were equipped with a faked label and five with the common Transfair-label. Regarding the production method, products were either organic or no information was given on the production method (=conventional). The combination of the different attribute specifications resulted in 18 different products which were designed based on considerations as regards content. The 18 different products were spread across two different 7x9-matrices. Consequently, two different groups of participants existed which were chosen randomly in each point of purchase category. Each set of products contained a product which only consisted of a Fair Trade-label declaration and a price. The attributes and products were ordered randomly in order to avoid distortions due to European reading habits from top left to bottom right. Participants were introduced into their task to decide for one of the coffees and buy it (supported by a monetary incentive): They were allowed to access as much information on the product as they wanted, in the order they preferred, by clicking on a field which opened subsequently and contained the specified attribute information (see Figure 2). Repeated field access was possible, too. Only one field at a time was accessible, and the fields needed to be closed before opening the next, but participants had the possibility to mark interesting attribute specifications. Finally, consumers placed their preferred product into the virtual shopping basket. Before the experiment started, participants were explained that their

[2] Prices range from 4.99 € till 6.49 € per 500g in supermarkets and organic food stores and per 250g in worldshops due to an approximately doubled price level of coffee.

purchase decision was binding. Also, they were informed that they receive the incentive of 5 € at the end of the survey.

Figure 1: IDM

Source: own depiction

Figure 2: Opened field

Source: own depiction

The questionnaire basically contained questions on consumers' motivations to purchase Fair Trade-products, on their information search behaviour, shopping behaviour and socio-demographics in order to be able to further describe participants.

The survey was conducted in five retail stores in Germany in 2011: Two conventional retail stores, two world stores and one organic food shop were involved. Prior to the survey, consumers answered a few screening questions: In order to participate, consumers needed to purchase Fair Trade-products at least occasionally. Totally, 389 consumers took part in the survey. Table 1 gives an overview on participants' socio-demographics.

Table 1: Sample description

		% of participants	AM	SD
			39,97	12,08
Age (n=389)	18- 25	11,1		
	25-34	31,6		
	35-44	16,7		
	45-54	25,7		
	55-64	13,1		
	65-75	1,8		
	Male	35,2		
Gender (n=389)	Female	64,8		
	none	0,0		
Education (n=389)	Certificate of Secondary Education	1,3		
	General Certificate of secondary education	10,3		
	University entrance diploma	27,5		
	University degree, Polytechnic degree	60,9		
	Yes	75,8		
Employment (n=389)	No	24,2		
			1,98	1,22
Household size (n=389)	1	44,2		
	2	33,2		
	3	10,0		
	4	7,7		
	5	3,1		
	6	1,3		
	7	0,3		
	8	0,3		
			1963,56*	1201,70*
Net household income (N=389)	<600 €	10,8		
	600 - 1200 €	21,9		
	1200 - <1800 €	13,6		
	1800 - <2400 €	16,7		
	2400 - <3000 €	8,5		
	3000 - <3600 €	11,3		
	3600 - <4200€	6,9		
	4200 - <4800€	4,1		
	>4800 €	5,1		
	Not specified	1,0		

*classified mean, highest income group excluded.

Source: own calculations

3 Results

Results are described in two parts: First, insights into the extent of information search and search strategies are given. Second, consumer preferences for attributes in Fair Trade-products are displayed.

3.1 Search behaviour and strategies

In order to measure the extent of information search, the time participants needed to make a purchase decision was measured, as well as the number of accessed fields and the size of the submatrix[3].

In average, participants needed 4 min 43 sec in order to reach a purchase decision. In order to decide on a product, participants averagely accessed 51.45 fields out of an unlimited number of accessions, since fields could be accessed repeatedly. At the same, the SD is quiet high. The size of the submatrix is 55.36 in average of all participants. This corresponds to an average utilisation level of 88% of the total matrix (9 products and 7 attributes = 63 fields).

Table 2: Measures of search extent

Measure	AV	SD
Decision time (min)	04:43	02:40
Number of accessed fields	51.45	26.70
Size of submatrix	55.36	-

Source: own calculations

As shown above, participants averagely searched for information to a large extent. On the other hand, descriptive analysis has shown that there are few participants who hardly searched for information and many participants who opened almost all fields at least once. With the help of a regression analysis, the factors which led to differences in information search extent were tried to be explained. It was hypothesized that consumers who are more concerned with ethical products are searching for information more intensively (cp. Beatty/Smith 1987). Further, it was hypothesized that age, gender and education have effects on the intensity of information search. A regression model was calculated based on the above mentioned socio-demographic data, factors on the motivation to buy Fair Trade-products and variables regarding consumers' attitudes towards information search in ethical products. However, the regression model could not explain the variations in information search extent.

If bulky information needs to be processed, theory has shown that different search strategies are applied (e.g. Payne et al. 1978, Sauermann 2004, Ball 1997, Beatty and Smith 1987). If the strategy leads to ignoring part of the information, either consciously or unconsciously, heuristics are applied, in difference to decisions based on logic or statistics (rational decisions) (Gigerenz and Gassmeier 2011). The analysis of search strategies was performed visually with the help of a tool that visualises the fields that the participants opened. Participants' search strategies were basically assigned to the search patterns described by Ball (1997). The largest part of participants (63%) applied attribute-wise strategies, whereas about 20% of participants applied alternative-wise strategies. 18% of participants could not be assigned to any of those strategies, either because the search was random or because shifts in search pattern took place that could not be explained and did not seem to follow any rule. Totally, 16% of all participants mixed search patterns, which means that more than one search pattern was detectable. Interestingly, 70% of consumers mixed alternative-wise and attribute-

[3]The submatrix corresponds to the number of regarded attributes, multiplied with the number of regarded products which were at least accessed one time and serves as an indicator for participants' interest in the diversity of information offered in the IDM. A submatrix receives the value 9 if all attributes of a product were opened, but also if only 3 attributes, spread on 3 products were regarded.

wise search strategies. In 36% of all cases, purely (ignoring the mixed strategies) compensatory strategies were applied. Compensatory strategies comprise that trade-offs between attributes can be performed (Payne et al. 1993).

3.2 Attribute preferences

According to economic theory, information that is accessed first and more frequently is most decisive for the purchase decision. Analysis has shown that the two examinations did not come to the exactly same results on attribute preference. However, it can be stated that the Fair Trade-label, production method (organic or conventional), protection of children and product price are the four most important of the tested criteria when purchasing a Fair Trade-product. It is conspicuous that among those four attributes, only one is an ethical attribute.

Table 3: Most important attributes

Attribute	**Number of total views** (% of all clicks)	**Number of first views** (% of all first clicks)
Fair Trade-label	15,36%	24,94%
Production method	16,23%	21,08%
Protection of children	14,00%	16,20%
Product price	17,29%	11,05%
Social projects on-site	11,96%	11,05%
Trade relations	12,32%	9,25%
Producer income	12,84%	6,43%

Source: own calculations

The attributes which were most rarely not regarded at all were product price, production method and Fair Trade-label, which argues again for the importance of those attributes.

Taking a look at the single arguments, it is striking that within one attribute category, they were all almost equally often repeatedly accessed. A domination of any of the arguments could not be elaborated except for the price of 5.99 € whose accession accounts for half of the views in the attribute 'price'. A depiction of the first accessed attributes does not make sense, since the fields were closed and participants could not see which argument covers behind the closed field.

Totally, coffee A was bought most often (44.7%). Coffee A is a product alternative which informs the consumer about Fair Trade aspect in an unspecific manner. The product carries the Transfair-label and the German organic label as well. The price is 5.99 € per 500g[4]. Thereby, it is the second most expensive product and simultaneously above the 5 € incentive participants were informed about prior to the experiment. From this, it can be concluded that it is not the cheapest product which was bought most frequently, even though results have shown that price is an important attribute for the purchase decision. However, it should be mentioned that the overall price level of the products in the experiment was lower than real

[4] 5.99€ per 250g in worldshops.

market prices at that time. As mentioned above, two groups with products which are congruent regarding the principle design of the products but with slight differences when it comes to the attributes in the matrices were formed. The analysis shows that both groups selected coffee A most often. The difference between coffee A in the two groups lies in the arguments, the principle design of the products is congruent. Therefore, it can be presumed that no clear preference structure for specific attributes is detectable since consumers seem to have a clear preference for one product regarding its general design; the specific attributes are not very relevant. Nevertheless, information on the product that goes beyond the label seems indeed to be important: The product which only carries a Transfair-label but does not offer any other information was purchased very rarely (3.1%), even though it has the lowest price of all products. However, it needs to be stated that the effect of the organic label which was not displayed here and the missing ethical attributes cannot be divided since the product misses both the organic label and ethical attributes. The product which does not carry an organic label was bought least often, independent of the price. 82% of participants selected a product with the organic logo. The two products which were bought most often carry a Fair Trade-label, but products with a faked logo were purchased by around 25% of consumers as well.

4 Conclusions

Results offer insights into consumers' information preference and the quantity of information they retrieve when purchasing Fair Trade coffee. Regarding information search extent, analysis showed that consumers tend to search for information on product packages quite intensively, even though the experiment took place in a real shopping environment. Thus, the first conclusion is that information on product packages is relevant to consumers. However, it needs to be recalled that not only ethical attributes were included into the survey, but in order to design the experiment realistic and to gain insight into their importance, price, production method and Fair Trade-label were integrated as well. In fact, analysis showed that price, organic certification and Fair Trade-label are important information. Due to the high importance of the organic attribute, combined with a positive willingness to pay, marketers should further integrate the organic quality into Fair Trade products. Amongst the most important attributes, there is only one ethical attribute, protection of children. On the other hand, the product which was equipped with no ethical attributes was purchased very rarely, even though it was the cheapest one. This could refer to an importance of further description of Fair Trade characteristics. However, this product was also not endowed with an organic logo. Consequently, the fact that this product was rarely bought cannot be traced back to the non-existence of ethical attributes. Thus, the question of the importance of specific ethical attributes should be further explored in future research. So far, it can be stated that also in a mainstream market, information on ethical attributes that go beyond the label are regarded. Concerning the Fair Trade-label, which is important especially in mainstream markets (Moore 2004), marketers should be aware of the fact that almost 25% of participants purchased the product with the faked label. That means that label contents values are not communicated strong enough. On the other hand, it means that new labels still have the opportunity to enter the market. The price also turned out to be worth regarding. However, it was not one of the cheapest products which was purchased most often. This displays the importance of other product attributes. It can be concluded that price is, amongst other attributes, paid attention to, but further studies should discover the actual willingness to pay. Marketers should further be aware of the high importance of an organic logo for consumers, which consumers are also willing to pay for.

On the information search strategy, it could be shown that participants indeed applied strategic approaches, whereof attribute-wise strategies were applied most prevalently (as also detected by Zander and Hamm 2012). Generally, the information search was performed rather extensively. Very reduced search heuristics were applied in only few cases, as well as random search on the other hand. It can be concluded that consumers were not overburdened with information, even though the matrix was quite bulky, which could be traced back to the fact that participants had the opportunity to mark interesting fields, as already documented by Zander and Hamm (2010). That means that many consumers applied a search strategy, but did not feel the need to strongly reduce the amount of information to be considered to click on. It could also be shown that attribute-wise strategy was preferred over alternative-wise ones, since they are cognitively easier to apply, as Russo and Dosher (in Payne et al. 1987) explain.

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The Influence of Communication Frequency with Social Network Actors on the Continuous Innovation Adoption: Organic Farmers in Germany

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Abstract: This study investigates previously experienced farmers' adoption behavior of Agri-Environmental Measures (AEM) in Central Germany. We consider organic farmers as previously experienced with AEM as they already have practiced the environmental management standards for organic farming. The logit model is used to explain the influence of communication frequency on the probability of adoption of other environmental measures as a continuous innovation. Social network analysis is carried out to investigate the role of attitudes towards information sources. Our findings demonstrate the influence of communication frequency with interpersonal network actors (agricultural organizations and neighborhood farmers) on continuous innovation adoption in three ways: First, the communication frequency of organic farmers with both agricultural organizations and neighborhood farmers does not influence the original farmer's decision to adopt AEM. Second, a higher education level of frequently communicated neighborhood farmers increases the probability of farmers' AEM adoption, while the innovativeness of frequently communicated farmers does not. Third, inside the population of frequently communicated organic farmers, formal information sources (agricultural organizations) are considered as more important information sources about agricultural issues than are informal sources (other farmers).

Key words: Interpersonal communication network, communication frequency, innovation adoption, agri-environmental measures

1 Introduction

Agri-Environmental Measures (AEM) are the key instruments of European agricultural and rural policy. To reinforce environmentally friendly farming practices, significant parts of the Common Agricultural Policy (CAP), as well as national funding, are dedicated to supporting agri-environmental (AE) practices. This AE support is paid annually to farmers, who decide voluntarily to carry out their activities in a manner that goes beyond usual good farming practices and is deemed environmentally beneficial (Article 248(4) of the EC Treaty). Most importantly, since 2005 these supports have introduced cross compliance conditions linking direct payments with standards concerning the environment, food safety, and animal and plant health. These voluntary and cross compliance measures promote adoption through raising awareness of the importance of the environment amongst farmers. Within this context, more farmers adopted AEM.

To explain the adoption behavior, many studies have investigated the farmer's decision-making process by focusing on innovation and the adoption of technology. The study done by Ryan and Gross (1943) is generally accepted as the starting point of research on innovation diffusion in rural areas; their study describes "diffusion" as a process that aims to reduce uncertainty among potential users. According to Rogers (2003), adoption begins with sharing information with potential users through two main channels: mass media and interpersonal communication channels. Interpersonal communication channels represent information sharing by people in a face-to-face situation.

In the research field of innovation adoption, there is an increasing number of studies that recognize the importance of social networks, particularly the influence of interpersonal communication channels on farmer's behavior (Conley and Udry 2001; Bandiera and Rasul, 2006; Matusche and Qaim, 2009; Hartwich, Fromm and Romero, 2010). The main research

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works in this field have highlighted the importance of the interpersonal communication network actors on information support. Only few studies on the adoption of AEM were published that investigate the influence of being previously experienced on environmental practices (Vanslembrouck, Van Huylenbroeck and Verbeke, 2002; Defrancesco et al, 2008). To our knowledge, the influence that communication frequency with a network has on continuous innovation behavior[3] actors has not yet been studied.

This study investigates the adoption of AEM to illustrate the adoption of innovation among previously experienced farmers. We consider organic farmers as being previously experienced with AEM as they already practice the environmental management standards for organic farming. In our study, a closer look at organic farmers located in Central Germany is carried out. The main aim of the study is to contribute to understanding the influence different aspects of communication with interpersonal communication actors has on adoption decisions. First, we analyze the influence of communication frequency with interpersonal network actors on the continuous adoption of AEM among organic farmers. Second, we study the influence of communication partner characteristics such as education and innovativeness on AEM-adoption decisions. Third, we analyze the question of whether there is a correlation between communication frequency and considering the communication partner as an important source of information on agricultural issues.

The paper is structured into six sections. In the following section, we develop the research framework on the role of interpersonal communication networks in adoption behavior. Detailed information on the studied data set is provided in the third section. Sections four and five describe the methods applied (logit model and social network approach) and the results, respectively. The results are discussed and conclusions are derived in the last section.

2 Review

Adopting AEM is a complex decision process. Previous studies show that many factors can influence the process of adoption, for example: characteristics of farm and farmers (Crabtree, Chalmers and Barron, 1998; Wynn, Crabtree and Potts, 2001; Polman and Slangen, 2008), the influence of a person that promotes innovation (Chatzimichael, Genius and Tzouvelekas, 2011), environmental influences (Morris and Potter, 1995; Sutherland et al, 2012), the design and requirements of policy measures (Dupraz, Latouche and Turpin, 2009; Beckmann, Eggers and Mettepenningen, 2009; Fraser, 2012; Vanslembrouck, Van Huylenbroeck and Verbeke, 2002), and communication networks (Lowe and Cox, 1990; Black and Reeve, 1993; Morris and Potter, 1995; Skerratt, 1998; Deffuant et al, 2001; Prager, 2007).

Environmental conservation can be seen as an innovation by farmers (Black and Reeve 1993; Deffuant et al, 2001). Valente (1995) defines diffusion of innovation as the “spread of new ideas, opinions, or products throughout a society, thus diffusion is a communication process in which adopters persuade those who have not yet adopted to adopt.” This definition is mostly used in the adoption of AEM studies as an idea that shows the relevance of innovation diffusion theories.

Interpersonal influence is defined by Cartwright (1965, p.3) as the “modification of one person responses by the action of another.” In that perspective, interpersonal influence is one of the most important variables explaining the importance of communication flows in the diffusion of innovation in rural areas.

[3] In the study we accepted the concept of continuous innovation as a continuous improvement on AE farming practices by adopting the definition of “continuous innovation builds on previous knowledge without massive amounts of new knowledge,” (Sonnino et al, 2009).

Interest in studying interpersonal communication started in the early 1950s with Barnes (1954). The main aim of subsequent studies was to analyze how relations between actors influence their behavior. The concept of interpersonal network was broadly applied in studies on innovation diffusion. Indeed, a number of studies were published analyzing who influences whom within the community about innovation adoption (Rogers and Beal, 1958; Coleman et al, 1966; Valente and Rogers, 1995; Nutley, Davies and Walter, 2002; Albronda, Langen and Huizing, 2011). An interpersonal network unites actors who frequently communicate in ways that allow them to achieve a common purpose (Chassagnon and Audran, 2010).

Studies that recognize the importance of communication networks have analyzed the social influence of communication network actors by providing information in rural areas. In the context of delivering information to potential adopters, some studies point out that interpersonal communication channels[4] (oral, visual, written, etc.) most likely influence attitudes about innovation adoption in rural areas (Thomas, Ladewig and McIntos, 1990; Daberkow and McBride, 2001; Deffuant et al, 2001). Longo (1990) found out in his study on the influence of different communication channels in Brazil that while media created awareness about agricultural innovation, interpersonal information become important when transferring more (adoption promoting) technical information.

To clarify the importance of interpersonal communication channels, aside from the network approach, a number of studies on social capital investigate factors that influence a farmer's decision about collaborative activities (Morris, C. et al, 1995; Potter, C. et al, 1998; Wilson and Hart, 2000). In the social capital literature, greater participation in agricultural organizations is the important index that shows higher levels of social capital (Beugelsdijk, 2003; Sobels, Curtis and Lockie, 2001). Social capital could lead to lower transaction costs and influences the behavior of farmers (Polman and Slangen, 2008).

In addition to the presented approaches on the importance of communication network actors on the adoption of innovation in the agricultural sector, we also considered literature on the influence of communication frequency on innovators in other sectors (Lewicki and Bunker, 1996; Harhoff et al, 1999; Paruchuri, 2010; Chassagnon and Audran, 2011). The main studies in this field stress the role of repeated collaboration and cooperation between network actors to increase innovativeness. Based on the previous studies, the following assumption is derived for this study: high-frequency communication with interpersonal network actors is an important approach for understanding new ideas that reduce uncertainty.

Thus, our first tested three hypotheses are:

H1: The higher the interpersonal communication frequency on agricultural topics, the higher the probability of adoption of other AEM by organic farmers.

H1a: The higher the interpersonal communication frequency with agricultural organizations, the higher the probability of adoption of other AEM by organic farmers.

H1b: The higher the interpersonal communication frequency with other farmers on agricultural topics, the higher the probability of adoption of other AEM by organic farmers.

Studies on the adoption decision of AEM show the important influence of neighborhood farmers' attitudes, not only for passive adopters – those who enter AEM mainly for financial reasons – but also for active adopters – those who voluntary adopt AEM for both environmental protection and financial reasons (Deffuant et al, 2001; Defrancesco et al, 2008). A study by Deffuant et al (2001) on decision-making found that for France, Italy and

[4] We use the definition of interpersonal communication as a "process of message transaction or transmission between people to create and sustain shared meaning." Examples for each interpersonal communication channel are given as: oral communication (speaking face-to-face or on the phone), written communication (e-mails, letters, instant messaging and texting), and visual communication (body language or sign language).

the UK, given categories of “family” and “colleagues” are the most-cited answers by AEM adopters as being factors that influence their decisions (relative to the categories of institutions, other and nobody). Defrancesco et al (2008) carried out a study in Italy and found a positive influence of neighboring farmers on the opinion of AEM for both passive and active farmers.

Research on characteristics of innovation promoters (Kautz and Larsen, 2000; Rogers, 2003; Nutley, Davies and Walter, 2002; Guerin 2001) points out that promoters, characterized as having higher status or being more innovative (called also opinion leaders), have a vital role in the adoption of innovation. The following hypotheses on regularly communicated farmer’s characteristics are tested:

H2: The higher the education of regularly communicated farmers, the higher the probability of adopting other AEM.

H3: The higher the innovativeness of regularly communicated farmers, the higher the probability of adopting other AEM.

In addition to the frequency of interactions between actors and the characteristics of informing actors, attitudes towards identifying actors as interpersonal information sources can be seen as a complementary process when understanding innovation adoption. Weimann (1982) defines the strength of communication links by a measure composed of contact frequency and contact importance. A relation is defined as strong if actors have high rates for both contact frequency and contact importance. The relationship between contact frequency and contact importance is tested using the following hypotheses:

H4: The higher interpersonal contact frequency with interpersonal communication actors, the higher the probability of considering that actor as an important source of information.

H4a: The higher participation frequency in agricultural organizations, the higher probability of considering that actor as an important source of information.

H4b: The higher communication frequency with other farmers on agricultural issues, the higher probability of considering that actor as an important source of information.

3 Data

The dataset available for the analysis consists of 52 organic farmers located in Central Germany. The data were collected during face-to-face interviews with farm managers within the EU-funded FOODIMA Project (EU Food Industry Dynamics and Methodological Advances) in 2008. The survey provides farms’ and farmers’ characteristics and interpersonal communication relations (formal and informal network). The descriptive statistics for the data used for estimations are given by the two-sample t-test results in Table 1. In that table, variables related to characteristics of regularly communicated farmers (age, education, farm size and innovativeness) represent the average number of three different regularly communicated farmers given by respondents.

Table 1. Characteristics of Organic Farmers (n=52)
Central Germany, 2008 (two-sample t-test results)

Variables	Mean AEM Adopters (n=36/70%)	Mean Non-Adopters, (n=16/30%)	P-Value
Farmer Characteristics			
AGE	50.600	48.611	0.531
EDUCY	15.867	15.972	0.872
Farm Characteristics			
FARM_SIZE	231.313	145.358	0.300
FSOILQ	2.313	2.917	0.054*
INCOME	2.313	2.917	0.193
Informal Network			
AGE_RCF	44.692	49.727	0.134
EDUC_RCF	16.846	15.469	0.077**
FARMSIZE_RCF	270.769	173.900	0.372
INNOV_RCF	7.423	7.068	0.540
CFREQ	50.313	57.857	0.280
Formal Network			
MAO	0.813	0.861	0.661
PFREQ	2.000	1.833	0.561

Significant levels: * = $p < 0.10$, ** = $p < 0.05$
Description of variables:

AGE: Age of surveyed farmer (years).
EDUCY: Education of surveyed farmer (years).
FARM_SIZE: The sum of arable and grass land: Total Land (ha).
FSOILQ: German Soil Value for Farmland (Bodenwertzahl 1-100) (Ordinal Scale 1-5).
Low=1 for "< 25", 2 for "26-45", 3 for "46-65", 4 for "66-85" and High=5 for "> 85".
INCOME: Share of income from farm activities (Ordinal Scale 1-4).
1 for "<50 %", 2 for "=50%", 3 for "<50%" and 4 for "=100%".
AGE_RCF/EDUC_RCF/FARMSIZE_RCF: Age, education and farm size of regularly communicated farmer.
INNOV_RCF: Innovativeness of regularly communicated farmers (Ordinal Scale 1-10).
1 for "hardly accept an innovation" and 10 for "easily accept an innovation".
CFREQ: Communication frequency with other farmers (%).
0 for "not at all" and 100 for "very frequently".
MAO: Membership in agricultural organizations (1=Member, 0=Non-Member).
PFERQ: Participation frequency in agricultural organizations[5] (Ordinal Scale 0-4)
0 for "not at all" and 4 for "very frequently".

Additionally, adopted AEM by surveyed organic farmers in Central Germany between 2000-2008 is given by the division of states in Table 2.

[5] Agricultural organizations that represent professional farmers use "Berufsständische Vertretungen" in the administrative terminology (Prager, 1999). In our study, agricultural organizations relevant for and involved with AEM are mainly translated into English by using the study of Prager, 1999; these are farmers' associations Landesbauernverband, LBV; Landvolk, Farmers' Association Coalition for Organic Farming Associations, APOL; Demeter, International Branch of Demeter International e.V and Gäa

Table 2. Adopted Agri-Environmental Measures (AEM)
by Organic Farmers (N=52), Central Germany, 2000-2008

1. Saxony-Anhalt (n=26)
Crop diversification (Fruchtartendiversifizierung)
Mulch seeding (Mulchsaat)
Nature conservation (Naturschutz)
Land cultivation adapted to market and location (Markt-undstandortangepasste Landbewirtschaftung, MSL)
2. Saxony (n=13)
Cultural landscape program (Kulturlandschaftsprogramm, KuLap)
Environmental protection, Forestry (Agrarumwelt Maßnahmen und Waldmehrung, AuW)
Nature conservation (Naturschutz)
Environmentally friendly crop production (Umweltgerechter Ackerbau)
3. Nordrhein Westfalen (n=6)
Solid manure program (Festmistprogramm)
Wetland protection (Feuchtwiesenschutz)
Diversified crop rotation (Vielfältige Fruchtfolgen)
Grazing dairy cows (Weidehaltung v. Milchkühen)
4. Thuringia (n=7)
Cultural landscape program (Kulturlandschaftsprogramm, KuLap)

4 Logit Model

4.1. Method

A number of studies on AEM adoption analyze the choice problem using a logit or probit model. These studies consider the adoption decision to be a dichotomous problem (1=adopters and 0=non-adopters) for estimation (Crammer, 1991; Crabtree, Chalmers and Barron, 1998; Wynn, Crabtree and Potts, 2001; Vanslembrouck, Van Huylenbroeck and Verbeke, 2002; Polman and Slagen, 2008; Hurle and Goded, 2007).

The difference between a logit and probit model lies in the distribution function of the error term. While in the logit model errors are assumed to follow the standard logistic distribution, in the probit model errors are assumed to be based on standard normal distribution. Having applied both models, the choice of which to use in the study is derived by the results of models' (R-squared) explanatory power (Collet, 1991). Since the R-square is lower in the probit model, an error term can be assumed to be distributed logistically, and the logit model is selected for analysis. The employed dependent variable is described as:

Yi =1 is assigned to organic farmers that adopt a minimum of one other AEM by the survey date.

Yi =0 is assigned to organic farmers that did not adopt any other AEM by the survey date.

The logit model used in this study is specified as:

$$Yi = \beta\ Xi + ui \quad \textbf{(1)}$$

Where β = vector of parameters, Xi = vector of independent variables, ui = error term.

To estimate the probability of organic farmer i adoption of other AEM, our research uses the following variables. First, based on the results of previous studies on the influence of farmers' characteristics (Bonnieux, Rainelli and Vermersch, 1998; Vanslembrouck, Van Huylenbroeck and Verbeke, 2002), we included age and education as the estimation factors. To avoid the dummy variable trap (Greene, 1997), AGE1 and EDUC2 are used as reference categories and dropped from the model.

Second, by taking into account the studies that investigate the importance of farm characteristics (Wynn, Crabtree and Potts, 2001), farm size, share of farm income of total income and farm soil quality are tested as estimation factors.

Third, interpersonal communication characteristics are included as an estimation factor. We consider the communication frequency of surveyed farmers with other farmers on agricultural issues and characteristics of regularly communicated farmers. We test regularly communicated farmers' age, education, and innovativeness as perceived by surveyed farmers. Furthermore, we include membership in agricultural organizations and participation frequency to organizations' events.

The probability of being an adopter is given by:

$$\Pr (Yi =1| Xi) = F (\beta Xi) = \exp (\beta Xi)/ 1+ \exp (\beta Xi). \quad \textbf{(2)}$$

Tested independent variables are:

Xi= (AGE2, EDUCY2, FARM_SIZE, FSOILQ, INCOME, CFREQ, AGE_RCF2, AGE_RCF3, EDUC_RCF, INNOV_RCF, PFREQ, MAO). **(3)**

To avoid the multi-collinearity between the 10 tested independent variables in the model, we checked this potential problem by applying two common used tests. Firstly, using the approach by Menard (2002), we calculated the variance inflation factor (VIF) by constructing an ordinary least squares (OLS) regression with the same variables in the equation. Results show the mean VIF value of 1.49. As the accepted upper critic limit is 10.0 (Chatterjee and Hadi, 2006), we consider that there is no correlation between variables. Secondly, we checked the pairwise correlation coefficient between explanatory variables. Inside the total coefficient values of the model, the indication of values ranged from 0.003 to 0.41. No coefficient values larger than 0.5 indicates weak correlation between variables. Relying on the results of two tests, we conclude that there is no multicollinearity problem in the model.

4.2. Results

Table 3 reports the results of the logit model estimation for Adopters and Non-Adopters of other AEM within the group of organic farmers. Due to missing values, the total number of observations decreases to 43 farmers. In the model, a likelihood ratio test is used to compare the fit of null and alternative models, that is, 32.96, with nine degrees of freedom (LR chi2 (9): 32.96). By observing the associated p-value, that is, $p < 0.001$, we conclude that the used model with all predictors provides a significant fit to the data. Tested predictors were treated as significant when p-value was lower than 0.10.

Adoption of other AEM by organic farmers is significantly influenced by a farmer's age, farm soil quality, and education of regularly communicated farmers. A positive coefficient sign for the age variable reveals that adopting AEM increases with the increasing age of an organic farmer. The negative sign for soil quality means that farms located in less favored areas have a greater likelihood of adopting other AEM.

Table 3. Results of Logit Analysis,
Organic Farmers, Central Germany, 2008

Parameters	Coef.	Std Error	P>|z|
AGE2	0.384	0.209	0.066*
EDUCY2	-0.631	0.905	0.486
FARM_SIZE	0.003	0.008	0.724
FSOILQ	-2.119	1.261	0.093*
INCOME	-1.139	0.834	0.172
CFREQ	0.014	0.037	0.712
AGE_RCF2	-10.026	6.905	0.147
AGE_RCF3	-2.338	2.542	0.358
EDUCY_RCF	1.695	0.835	0.043*
INNOV_RCF	0.171	1.075	0.874
PFREQ	2.501	1.966	0.203
MAO	-3.461	3.293	0.293
CONSTANT	-33.209	27.41	0.226

Number of Observations: 43 / LR chi2(9): 32.96 /Prob > chi2: 0.001 / Pseudo R2: 0.6253
Significant levels: * = p < 0.10
Definition of used categorical variables[6]:

AGE: AGE1 for "<35 years", AGE2 for "35-60 years" and AGE3 for ">60 years".
EDUCY: EDUCY1 for "<16", EDUCY2 for "17 or >17 years of education".
AGE_RCF: Age of regularly communicated farmers.
AGE_RCF1 for "<35", AGE_RCF2 for "35-60" and AGE_RCF3 for ">60 years".
EDUC_RCF: Years of education, regularly communicated farmers.
EDUC_RCF1 for "<16 years", EDUC_RCF2 for "17 years" or ">17 years of education".
INNOV_RCF: Innovativeness of regularly communicated farmers, (ordinal scale 1 to 3). The value of 1 represents "Hardly accept an innovation", and 3 represents "Easily accept an innovation".

With respect to interpersonal communication, both hypothesis H1a (The higher the interpersonal communication frequency with agricultural organizations, the higher the probability of adoption of other AEM by organic farmers) and H1b (The higher the interpersonal communication frequency with other farmers on agricultural topics, the higher the probability of adoption of other AEM by organic farmers) were rejected (Table 3). Communication and participation frequencies are found to be insignificant when explaining the adoption behavior of organic farmers in Central Germany.

Regarding H2 (The higher the education of regularly communicated farmers, the higher the probability of adopting other AEM), a positive sign of estimates for the education variable of regularly communicated farmers confirmed that farmers that communicate regularly with more educated farmers have a greater likelihood of adopting AEM. Thus, H2 was corroborated.

Hypothesis H3 (The higher the innovativeness of regularly communicated farmers, the higher the probability of adopting other AEM) was rejected. Innovativeness of regularly communicated farmers is not a significant variable for explaining the adoption behavior of organic farmers in Central Germany. Finally, we conclude that it is not interpersonal

[6] As opposed to the given description variables in table 2, here we provide the categorical variables created by the user in order to estimate the results of categorical predictors' interactions.

communication frequency that increases the probability of adoption, but the attributes of regularly contacted actors in the network.

5 Social Network Analysis

5.1. Method

In addition to modeling the effect of communication frequency and communication partner characteristics in the acceptance decision by using logit analysis, the relationship between contact frequency and contact importance was examined using Social Network Analysis (SNA). “Social network analysis in general studies the behavior of the individual at the micro level, the pattern of relationships at the macro level, and the interactions between two,” (Stokamn, 2001, p. 509). In a network, social entities are referred to as actors that are discrete individual, corporate, or collective social units (Wasserman and Faust, 1994). SNA allows a number of analytical tools to measure the relational aspects of social structure. In our study, we use an ego-centered network and reciprocity analysis, respectively.

An ego-centered network is defined as a network (personal network) that consists of focal actors (called ego) and a set of nodes (called alter) to whom the ego is directly connected (Wasserman and Faust, 1994). There are several approaches that allow us to study the relations in ego-centered social networks. Our study uses personal interviews where each respondent (alter) reports to whom (ego) it is tied (Burt 1984, 1985). While here alter represents organic farmers, two interpersonal communication actors (agricultural organizations and other farmers) represent egos in the network. The measurement of such personal, ego-centered networks can be found in studies from fields such as anthropology, psychology, medicine and sociology (Bott, 1957; Wellman, 1993; McCarty et al, 2001).

Ego-centered networks are mostly used in studies on social support that refer to social relations that help to increase an individual’s well-being (Wasserman and Faust, 1994). In our study, we use the reference definition of Cohen and Wills (1985), which distinguishes between four types of support: instrumental, informational, emotional and social support. Our study focuses on informational support that refers to social relations providing assistance with knowledge, information and skills (Cobb, 1976). The objective of this study is to examine the degree of reciprocity within the informational social support in the organic farmers’ network.

Reciprocity means that a positive action of one individual provokes a positive action towards that individual (Katz and Powell, 1955), and is mostly studied using the question of “How strong is the tendency for one actor to choose another, if the second actor chooses the first,” (Weiligmann, 1999). Several studies have interpreted the strong tendency of reciprocity as the stability of a social system (Gouldner, 1960; Allen, 1977). The stronger the tendency of reciprocity in the social network, the stronger will be the social ties and cooperation in interpersonal networks (see the literature review of Chassagnon and Audran, 2011). In our study, a reciprocity analysis is carried out with the Ucinet software package to answer the question, “How strong is the contact importance with the second actor for the first actor if the first actor has high communication frequency with the second actor?” The examined social network indices are detailed in Table 4.

Table 4. Indices used to measures interpersonal communication structure

Indices	Definitions and Measure
Network Level	
Network Size (n)	Number of actors in the network.
Isolator	Actors that have neither in nor out-degree ties with a single actor.
Relational Ties	Social ties that link actors to the other actors.
Ego-Centered Network Level	
Connectedness	A ratio between the number of actual ties and the maximum number of possible ties that an actor could have.
Undirected Actors	Actors that are connected to and from ego actor.
In-Neighborhood Actors	Actors with a tie to ego.
Out-Neighborhood Actors	Actors with a tie from ego.
Out-degree ties	Ties from ego to out-neighborhood actor.
In-degree ties	Ties from in-neighborhood actor to the ego.
Connectedness	A ratio between the number of actual ties and the maximum number of possible ties that an actor could have.
Undirected Actors	Actors that are connected to and from ego actor.
Reciprocity Analysis	
Reciprocity	Proportion of dyads (actors) that are reciprocated.
Non-Symmetric In-Neighborhood Ties	Proportion of ego's incoming ties that are not reciprocated.

In the ego-centered network measures (table 4), all alters that represent farmers are undirected actors. While an in-neighborhood actor represents farmers that have high contact frequency with the studied ego, an out-neighborhood actor represents farmers that attach high contact importance to the ego actor. In the reciprocity analysis, proportions of the employed measure are given for each of the studied egos by considering the ties to and from that ego. A result for reciprocity gives the proportions from 0 to 1. If the value is equal to 1, this can be interpreted as a high tendency to make reciprocal choices. If the value is equal to 0, then there is no tendency to reciprocate. The non-symmetric in-neighborhood ties represent the proportion of farmers that have a high contact frequency with the ego, but did not cite the contact as an important information source.

In the interpersonal communication network, we incorporate reciprocity by assuming that farmer A is more likely to give importance to the information coming from farmer B if farmer A has already cited B as an actor that he communicates with frequently. Regarding that assumption, to test hypothesis H4, the average number of in-degree ties is accepted as the minimum expected number of reciprocal ties in the network. We then created a binary data as: 1 = farmers that have both in-degree and reciprocal ties; 0 = farmers that have in-degree ties but not reciprocal ties. The binomial probability test is used by the expected probability of success with 0.5. We test the statement of "at least 50% of population is coded as 1." If the probability is smaller than the significance level of 0.05, the hypothesis is rejected for the observed network.

After clarifying the study concept for the organic farmers' interpersonal communication network, we identify the role of actors in the communication structure. As opposed to network analyses that focus on characteristic of actors, network role analysis asks the question of

"How do relationships link the entire sum of actors throughout the network," (Wasserman and Faust, 1994). Based on the literature on communication roles and information exchange patterns, we distinguish between informal and formal communication structures (Allen, 1977). While a formal communication structure is formulated within the organizational structure, channels and rules, an informal communication structure works within social affiliations (Kilduff and Brass, 2001). In the examined network, we refer to the constructed ties between ego of an agricultural organization and surveyed farmers as formal networks, and ties between the ego of other farmers and the surveyed farmers as an informal network. A contact matrix that illustrates whether or not there exists any relation among actors has been designed for both networks. In the study, 50 organic farmers were surveyed with a contact matrix; due to missing values we eliminated 2 farmers from the matrix. Two main types of relations were considered: frequency of communication and importance of information sources. Measures that are used to construct communication structures are given as follows:

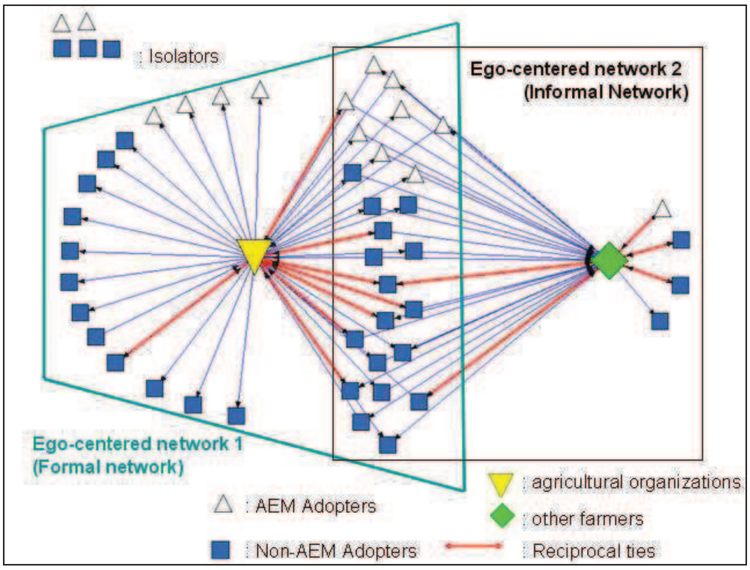
Communication frequency: Information exchange in the communication structure could be measured by several methods (Kyriazis and Massey, 2008). In our study, we use the amount of communication to represent the intensity of all available information flows. The question "How often do you communicate with other farmers on agricultural issues?" was asked of survey participants to describe their informal communication frequency. Additionally, the question "How often do you participate in the agricultural organization's events?" was asked of farmers to define formal communication frequency. For both questions, the degree of frequency was ranked on a percentage scale, in that the higher percentage indicates a higher frequency of communication. In the contact matrix, the threshold level of having high contact frequency is constructed by translating the top-half of the communication and participation frequency percentages (>50%) of farmers into 1's and the other half into 0's (≤50%).

Importance of information source: Information sources in rural areas are examined by several studies focusing on either the use of information (Ortmann et al., 1993), factors that influence attitudes toward information sources (Gloy, Akridge and Whipker, 2000), or information preferences of farmers (Pompelli et al, 1997; Schnitkey et al, 1992). In our study, we consider the importance of information from socio-informational network actors ranked by farmers. Farmers were asked to rate the importance of 15 information sources under three main titles: other farmers, agricultural organizations and media. The question posed was "What is the importance of the listed information sources on agri-environmental issues for you?" The degree of importance was ranked on a percentage scale that summed up to 100. Regarding the distribution of rankings in the matrix, a high percentage of responses (more than 33%) were translated into 1, and a low percentage (less than 33%) into 0. For the purpose of the study, the source of media was eliminated from the network, as this does not represent interpersonal communication.

5.2. Results

Figure 1 shows the information exchange in the structure of interpersonal communication network (n=52) for a sample of organic farmers in Central Germany in 2008. In the presented network, we observe organic farmers (n=50) who have a high communication frequency and/or contact importance with ego-central networks (n=2), as well as an interpersonal information source of agricultural organizations and other farmers.

Figure 1. Interpersonal Communication Network of Organic Farmers, Central Germany, 2008



Source: *FOODIMA Survey*

The figure shows that the number of reciprocal ties is far below the number of in-degree ties (ties from alters to the ego). For the whole network, hypothesis H4 (The higher the interpersonal contact frequency with interpersonal communication actors, the higher the probability of attributing importance to that actor as a source of information) is rejected with the significance level of $p < 0.05$ using a binomial probability test. The state of relationship between the variable of high contact frequency and high contact importance cannot be explained by a stable equilibrium of either reciprocity or mutuality.

In the further analysis on differences between informal and formal communication structures, the following hypotheses are tested by using ego-centered network analysis:

H4a: The higher participation frequency in agricultural organizations, the higher probability of considering that actor as an important source of information.

H4b: The higher communication frequency with other farmers on agricultural issues, the higher probability of considering that actor as an important source of information.

Table 5 shows the characteristics of both studied ego-centered networks. Regarding the study question, contact matrix relations are designed with a star network structure, where all actors connect to a central actor. Hence, as expected, the proportion of actual ties to the possible ties that are given as connectedness is low for both the formal and informal network. Additionally, standard deviation provides low variance between actors in terms of the distribution of ties. It means that population in the both of the ego-centeraled network represent a homogeneous group that deviates low from the mean.

The whole network consists of 83 ties representing high communication frequency (in-degree ties from actors to two ego nodes) and high contact importance (out-degree ties from ego nodes to actors), with the division of 49 formal and 34 informal communication ties. This could be interpreted as those formal ties being more important than informal ties in promoting information exchange. In the informal network, the ego node of other farmers is an actor that provides information exchange mostly with actors that also have support from formal ties (Figure 1). The strength of informal ties in promoting information exchange lies not in the high number of ties, but in their number of reciprocity with the actors that have only one informal tie.

Table 5. Ego-Centered Network Analysis of
Organic Farmers (n=50), Central Germany, 2008

Characteristics	Formal Network	Informal Network
Connectedness	0.019	0.013
Std Dev	0.137	0.115
Sum of Ties	49	34
Undirected Actors	41(82%)	29(58%)
In-Neighborhood Actors	15(30%)	20(40%)
Out-Neighborhood Actors	34(68%)	14(21%)
Reciprocity	0.19	0.17
Non-Symmetric In-Neighborhood Ties	0.46	0.75

Source: *FOODIMA Survey* (Percentages within the parentheses show the proportion of related actors to the total number of whole network level alters that represent farmers (n=50)).

In the study, the percentage of undirected actors is given by the number of actors that are linked to both ego networks. The proportion of undirected actors varies between the two considered ego networks. While 82% of actors are connected to formal networks, 58% of actors are connected to informal networks (Table 5). The reason for more connected actors in the formal network is mostly the high group size of out-neighborhood actors. These actors represent farmers that place high importance on information distributed by agricultural organizations. In the formal network these actors are both AEM Adopters and Non-Adopters. Comparing to the informal network, we observe more AEM Adopters in the formal network (Figure 1).

As we can observe from the proportion of non-symmetric in-neighborhood ties, the reciprocity analysis based on in-neighborhood ties provides different results for the ego networks. Relative to the informal network, in the formal network, the proportion of an ego's in-degree ties that are not reciprocated is lower (0.46). This could be interpreted as follows: 46% of farmers that cite high participation in the agricultural organizations do not report these organizations as being a source of information on agri-environmnetal issues, which is highly important. A binomial probability test was used to test the statement "At least 50% of in-neighborhood ties are symmetric," for the two ego-centered networks. While for the formal network, Hypothesis H4a is accepted, for the informal network H4b is rejected with a significance level of $p < 0.05$. We conclude that at least half of the farmers who cited themselves as a frequent participant in agricultural organizations also place importance on the information distributed by these organizations. However, with the assumed success of 0.5, in the informal network, high communication frequency with actors is not the measure that provides the high degree of importance of that contact as a source of information.

6 Discussion and conclusions

This paper investigates whether significant differences exist between AEM adopters and AEM non-adopters amongst farmers previously experienced with environmental practices. The central aim of this research is to illustrate the relationship between interpersonal actors, communication frequency, and the adoption of AEM. Organic farmers from Central Germany that had practiced similar environmental management standards are examined by using Rogers (2003) diffusion of innovation as a theoretical basis. The logit and social network analysis was included to explain the influence of communication frequency on the probability of adopting other environmental practices as a continuous innovation, as well as the role of attitudes towards information.

Previous studies on the adoption decision did not investigate the adoption behavior of previously experienced (innovator) farmers. The studies considering conventional farmers' decision making on AEM adoption found that friends and colleagues opinion are the most important sources of information (Retter, Stahr and Boland, 2002; Drake, Bergström and Svedsäter, 1999). Furthermore, Polman and Slangen (2008) studied farmers' AEM behavior in the Netherlands, Belgium, France and Italy. The results show that farmers' (without the division of being experienced or not) participation in agricultural organization events focusing on improving farming practices frequently has a negative impact on the acceptance of all types of studied AEM. Our analysis shows different results. The employed logit models show that the frequency of participation in agricultural organizations' events, as well as communication with other farmers, has no (positive or negative) effect on AEM adoption.

Beside our results, these differences can be assumed to arise from being an experienced or inexperienced farmer, and by the expectation that farmers have regarding the received information. Organic farmers, similar to other economic actors, make their decisions after communication with their social network actors, and after having collected sufficient information about the beneficial points of the considered action. At that point, attitudes towards information coming from network actors guide their behavior towards or against continuing innovation. The survey conducted by Prager and Nagel (2005) in Germany shows that farmers especially contact agricultural organizations when they are looking for information on the application, scheme requirement and responsibility issues of AEM. Regarding the study on informal sources of information by Deffuant (2001), the most frequently discussed subjects between farmers are "weather", "price" and "whether to adopt AEM." Experienced farmers possess the basic knowledge on AEM adoption already and need to update formal information on political innovations (e.g. new measures or requirements).

Additionally, the result for regularly communicated farmers' characteristics is important in terms of the contribution to studies on innovation promoters. A high education level of regularly communicated farmers is found to be a significant determinant of an organic farmer's participation in AEM.

The results of the reciprocity analysis reveal that more than half of the active participants in agricultural organization events rate the information received from organizations as important. The main implications of this finding emphasize the importance of considering the frequency of participants' perceptions on agricultural organizations in the policy design. High frequency participants are important actors that help to improve information exchange within agricultural organizations. Formal information exchange has to be considered in the context of its high capacity to influence the frequent participants. Findings also confirmed that informal information flow is not the central, but a complementary information source for frequently communicated organic farmers. Additionally, results suggest that the high contact frequency with interpersonal network actors cannot be seen as a measure of high contact importance as a source of information on agricultural issues for farmers.

The number of observed organic farmers is rather small in our study. Three limitations and further research interests could be defined. Firstly, the present study does not focus on one type of AEM adopted by organic farmers. We included all accepted AEM by organic farmers without any division regarding their requirements. Secondly, investigations on the influence of network actors on organic farmers' behavior could be confirmed using an extended dataset with more actors. In this paper, we limited the studied actors on formal and informal interpersonal relations, and excluded the influence of the socio-informational media network on actors. Thirdly, in addition to our study on the relationships between high communication frequency and attitudes towards an information source, it would be interesting to complete the relationships by determining the differences between less frequently communicated farmers.

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