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TECHNICAL, SCALE, ALLOCATIVE AND ECONOMIC EFFICIENCIES IN THE SLOVENIAN FARMS

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ABSTRACT

This paper analyzes technical, scale, allocative and economic efficiency for Slovenian farms during the transition period 1994-2003, with a Farm Accountancy Data Network (FADN) sample. Such studies of various components of economic efficiency are rare in transitional agriculture, especially in Slovenia. The research contributes crucial issue of whether small family farms might be able to compete on international markets, as Slovenian agriculture is characterized by such structures.

Data Envelopment Analysis (DEA) models are used with an output-orientation, three outputs and four inputs. This non-parametric approach is compared with applied parametric stochastic frontier approach and cluster analysis is used to identify three different farm groups. The data used in the empirical analysis are the data averages for 13 farm production branches from the FADN sample of Slovenia.

The average technical, scale, allocative and economic efficiencies for the whole FADN sample over the whole analyzed period are relatively high (around or over 0.90), suggesting that, although the FADN sample contains very different farm production types, farms have similar management practices, and are similarly able to make the best use of the existing technology. Five farm branches (crop, dairy, livestock using own feed, fruit, and forestry farms) are fully efficient with respect to all calculated efficiencies (technical, scale, allocative, and economic), suggesting these specializations have the best chance to compete on the European and world markets.

Keywords: economic efficiency, data envelopment analysis (DEA), stochastic frontier, cluster analysis

INTRODUCTION

A key question in managerial economics is economic efficiency of production, based on well known mini-max principle achieving maximum output at given costs or producing output at minimum costs, in order to maximize economic efficiency as the difference between revenues and costs (e.g. Heather 2002, Allen 2005). Economic efficiency has several components: technical, scale and allocative efficiencies. In this paper, all components are analyzed for Slovenian farms during the transition period from the previous socialist system to a market economy and adjustments to the European Union (EU) membership, with a Farm Accountancy Data Network (FADN) database to investigate the performance of the Slovenian farms in the FADN sample.

Different performance measurement systems and models have been developed in the literature. Among a range of most recently published research studies, Rao (2006) introduced a performance evaluation system using a profit-linked multi-factor productivity measurement model on spreadsheet-based multi-period operational-level accounting data for a government-run water utilities enterprise to provide performance feedback for financial managers. Takala et al. (2006) proposed a structured framework as the multi-dimension measurement process that is compared with some other techniques to be used to measure and capture work performance of white-collar workforce using data on outputs/outcomes, skills, behaviour, and organizational goals for appraisal purposes. Choy et al. (2006) examined criteria for measuring knowledge management performance outcomes in organizations based on data from case studies in two organizations, researching the relationships between knowledge management efforts and organizational performance outcomes for business success. Phusavat and Photaranon (2006) investigated productivity and financial performance at the production operational level with application to the government pharmaceutical organization. They applied the multi-factor productivity measurement model on existing data from the accounting department, raising needs for better technical database management and better managerial performance-analysis capability by staffs in the organization to ensure success and sustainability. Hou and Lin (2006) proposed quantitative models of patent appraisal performance employing multiple regression model for patent trading system appraisal and price determination mechanism on a case study basis. Antoncic (2007) evaluated intrapreneurship construct predictors and consequences across firms in two countries (the USA and Slovenia) using comparative structural equation modelling. The author examined levels and patterns of relationships among environmental, organizational characteristics, intrapreneurship, and performance on firm's growth and profitability by testing zero-means model and latent-means model. Žižmond and Novak (2007) investigated controversies of technology convergence within economies of the EU employing frontier production functions on Eurostat data base. They argued that technical inefficiency is the main impediment to spill-over effects of technology convergence. Bojnec and Xavier (2007) analyzed the determinants of firm exit at micro firm-level in the Slovenian manufacturing sector on the basis of the Slovenian firm registry panel data set complemented with sector level trade data. They estimated pooled and panel probit models focusing on the effect of firm specific characteristics, domestic sector and import competition, and financial variables on firm exit to derive findings on the relationships between firm exit and firm specific characteristics, competition and finance.

This paper aims to investigate management data systems and particularly managing enterprise performance focusing on effective farm performance management within the broader context of farm performance management. Bose (2006) underlined that managing enterprise performance is an important but difficult process due to its complexity monitoring strategic focuses of an enterprise and performances from a wide range of interrelated business activities at different levels within the enterprise as challenges the business managers for gaining competitive advantage for their businesses. Seydel (2006) applied a modified Data Envelopment Analysis (DEA) approach with weight constraints to provide decision makers data management support for addressing problems involving alternative sets and multicriteria decision problem. Wong and Wong (2007) illustrated the use of DEA modelling in measuring internal supply chain performance measurement system. They developed two DEA models (a technical efficiency model and a cost efficiency model) with scenario analysis to identify operations inefficiencies and derive business insights for managers' decisions making actions for improvements on resource allocations.

In this paper we apply the DEA approach as a tool used for performance evaluations and for decision supports (e.g. Seydel 2006, Wong and Wong 2007), as well as a stochastic frontier analysis approach. Therefore, we investigate the performance, in terms of economic efficiency and its components technical, scale and allocative efficiencies, in a dynamic environment to provide a decision-making tool and managerial implications in the measurement of farm performance and efficiency. These research objectives are motivated by two main reasons. First, efficiency has rarely been studied for transition agriculture in Central and Eastern European (CEE) countries, as research mostly concentrated on technical efficiency (see Gorton and Davidova 2004, for a review of literature). Our focus is on Slovenia, where even studies on technical efficiency are rare. Only Brümmer (2001) and Bojnec and Latruffe (2007) contributed to this issue. Second, Slovenian agriculture has a specific small-scale family farm structure, which differs from western countries and from most of the other CEE countries, due to the failed communist agricultural collectivization, to the institutional limitations on individual farms during the communism and, later during transition, to the more modest process of farm restructuring and farm concentration. Whether small family farms might be able to compete on international markets is a crucial research and managerial question that this paper will contribute to. Therefore, our objective is to investigate which farm branches performed best during the period studied. Several DEA models are developed to evaluate technical, scale, allocative and economic efficiencies, in order to derive insights for farm managers to identify possible sources of inefficiencies and to make business decisions that would improve efficiency on resource allocations and international competitiveness. The rest of the paper is structured as follows. In the next section, Section 2, we explain the methodology. Section 3 presents the data used. In Section 4 the empirical results are described, whereas Section 5 derives main conclusions and implications for data management systems and for managers' decision making.

METHODOLOGY

Investigating efficiency in our case means evaluating how farms perform under an existing technology. Technical efficiency is the performance of farms as regard to the quantity produced in comparison to the quantities of inputs used. It can be measured within two main frameworks: output-oriented framework and input-oriented

framework. In an output-oriented framework, technical efficiency gives information about the potential output increase that a firm could implement without increasing its use of inputs, while in an input-oriented framework, it gives the potential input reduction that a firm could apply without having to reduce its output level. By contrast to technical efficiency, allocative efficiency accounts for the respective prices of inputs. Economic efficiency is the product of technical and allocative efficiency. It can be interpreted as the potential reduction in production costs (and is thus named cost efficiency) or the potential increase in revenue (named revenue efficiency) that a firm could apply in order to operate at the point of technical and allocative efficiency. As for scale efficiency, it enables to draw conclusions on whether farms operate at optimal or suboptimal size. Scale efficiency is a component of technical efficiency, the other component being pure technical efficiency, evaluating management practices only, that is to say without considering the size. Figure 1 summarises the concepts of technical, allocative and economic efficiencies in an output-oriented framework, adapted from the input-oriented case introduced firstly by Farrell (1957).

Figure 1
Illustration of the concepts of technical, allocative and economic efficiencies

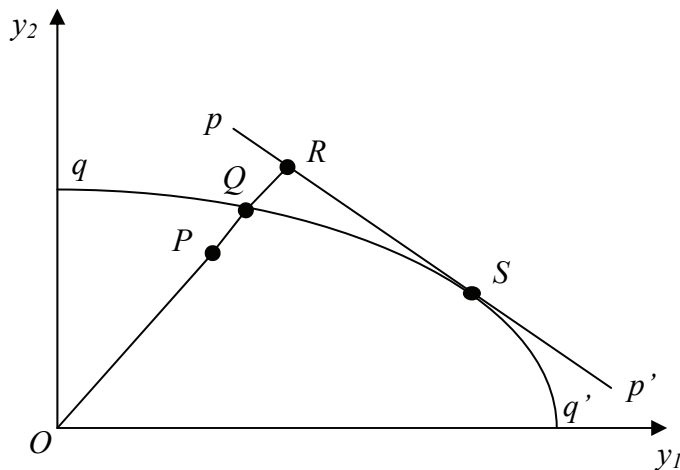


Figure 1 depicts a production possibility curve (qq') for firms producing two outputs (y_1 and y_2) with one input. Firms lie on the curve (such as firms Q and S), and in this case they are fully efficient, or below the frontier, and in this case they are inefficient (such as firm P). The technical efficiency measure for firm P is found with the radial output ratio line, so that P is projected on the frontier, the projection being Q. The distance PQ represents the proportional amount by which both outputs could be increased, and the ratio OP/OQ gives the technical efficiency score of firm P. Allocative efficiency can be calculated with the help of the output price line (pp'), whose slope is the ratio of output prices ($-p_1/p_2$), and of the projection of technical efficient firms on this line: the allocative efficiency score of firm P (and of firm Q) is OQ/OR . Finally, full economic efficiency is achieved for firms operating at the tangency point between the production possibility curve and the price line, such as firm S. Firm P's economic efficiency score is given by the ratio OP/OR and thus by the product of technical efficiency and allocative efficiency. All scores are bounded between 0 and 1, with 1 indicating full efficiency and with lower scores indicating lower efficiency.

In order to empirically investigate and calculate these efficiency scores, two main streams of approaches compete in the literature: non-parametric and parametric approaches. Both have advantages and drawbacks, and for this reason it is not clear which one is superior. Thus, in this paper we use both types of methods to calculate the various efficiencies. The first main method that we apply is the non-parametric method Data Envelopment Analysis (DEA). Closely related to the explanations given above for Figure 1, the method, proposed by Charnes et al. (1978) and later developed further by Färe et al. (1994), uses linear programming to construct a piece-wise efficient frontier with the best performing farms of the sample used. Under the assumption of constant returns to scale (CRS) technical efficiency is calculated, while scale efficiency can be obtained by the residual between efficiency under CRS and efficiency under variable returns to scale (VRS). The DEA linear programming models used to calculate technical efficiency scores and economic efficiency scores are presented in Appendix 1. Once these scores are obtained, allocative efficiency is calculated by the ratio between economic efficiency and technical efficiency. The second main approach is the parametric stochastic frontier approach, which estimates parameters of a production function with the help of econometrics. Introduced simultaneously by Aigner et al. (1977) and Meeusen and van den Broeck (1977), the method relies on estimating a production function with two error terms, one for noise and one for inefficiency, as shown in Appendix 2. This method thus has the advantage of accounting for noise, while DEA, being a non-parametric method, assumes that all deviations from the efficient frontier are due to inefficiencies, and not due to measurement errors. DEA's second main drawback is that its results are very sensitive to outliers, as observations from the sample are used to construct the frontier. However, DEA has the main advantage of avoiding assumptions regarding the production function and the disturbance terms' distribution, and thus of avoiding misspecification errors. Thus it enables to disentangle scale efficiency from technical efficiency. Moreover, it can consider several outputs simultaneously.

Regarding DEA, an output-oriented model is used in this paper, allowing assessing the potential output increase that farms could apply keeping the same input quantities¹. In both DEA and stochastic frontier methods, the four standard inputs in agriculture are used: utilised agricultural area (UAA) in hectares as the land factor, total labour used aggregated in Annual Working Units (AWU²), the value of assets as the capital factor, and the value of variable inputs. The stochastic frontier method accounting for only one output, the total output in value is used. However, in DEA this total output is decomposed into three outputs in value (crop, livestock and other output), which allows to better represent the different technologies between branches. Finally, in order to calculate economic and allocative efficiencies, total cost of the farm and input prices are used. Land prices are farm land rentals, labour prices are farm hired labour's wages, and capital prices are depreciation costs. Thus, these three input prices are specific to each farm and calculated from the existing FADN database. In opposite, prices of variable inputs are not available in any FADN database. Therefore we assume that all farms face the same prices for such inputs. However, these prices vary across the years. Thus we employ the input price index

¹ The choice between input- and output-orientation depends on whether farms may be constrained in their input reduction or in their output expansion. But in general, both orientations give extremely close results (Coelli et al. 2005). We chose output-orientation for DEA in the view of comparison with the results from the stochastic frontier, whose orientation is by construction an output-orientation.

² One AWU corresponds to 2,200 hours work per year.

over 1994-2003 with base in 1994, provided by the Statistical Office of the Republic of Slovenia (SORS).

Our objective is to investigate which farm branches performed best during the period studied. As several efficiency scores will be calculated for each branch, in order to see more clearly which farm branches are superior, we will use a cluster analysis to classify branches into a limited number of groups. We employ a two-step cluster analysis based on the log-likelihood distance between observations (Hair et al. 1998).

DATA USED

The Slovenian FADN dataset provided by the Ministry of Agriculture, Forestry and Food (MAFF) of Slovenia is used. The dataset includes individual family farms only, which represent the great majority of the Slovenian farming structures (e.g. Bojnec and Latruffe 2007). The farms are classified according to socio-economic type, by different types of areas according to factors of agricultural production and by production types according to the shares of revenue. The data used in the empirical analysis are the data averages for 13 production farm branches, over a 10-year period 1994-2003. Thus in total, 130 observations are included in the empirical analysis. The nominal output data were deflated by the agricultural producer price index and the nominal input data were deflated by the agricultural input price index, which were provided by the SORS.

The consequence of the small number of family owned and operated farms in Slovenian FADN data is that there are only a few farms per production type in the country. Therefore, for confidentiality reasons, only data averages per production types can be provided by the MAFF. The 13 branches are the following: crop; dairy using own feed; cattle using own feed; pigs using own feed; sheep using own feed; other livestock using own feed; livestock using purchased feed; fruit; grape and wine; mixed; vegetables; forestry; and combined. Farms are classified in farming branches according to the shares of revenue. The share of a specific farm production in the total farm revenue is greater than fifty percent for the first ten branches of farms (from crop to grape and wine). The revenue structure of the mixed farms consists of a combination of revenues from crop revenues, own feed, livestock, fruit, grapes and wine and hops, where a single product contribution in total revenue is less than 50 percent. In the case of vegetables and forestry, the single revenue criteria are set as greater than 75 percent of total farm revenue. The combined farm in its revenue structure has incomes from crop and livestock using own feed, where the single production contribution in total revenue is less than 75 percent (Pajntar 1997).

The FADN sample gives a good representation of the small-scale farming structures prevailing in Slovenia. Table 1 presents summary statistics of the sample in more detail. In value terms, farms specialised in pig or in fruit produce the most in total, while the lowest output in value is attained by sheep and cattle farms. All farm branches in the FADN sample are on average larger in terms of land per farm than the average size of the family farm population in Slovenia (about 6.3 hectares of utilized agricultural area per farm) as on average farms in the FADN sample have a size of 12 ha, except in the last years of the period where it approaches 20 ha. The farms in the FADN sample are economically more viable farms that represent a future in the Slovenian farming structures. Regarding the other factors used, dairy farms have a

huge labour use compared to the other branches, vegetable farms use very little capital, and variable inputs are used primary in pig production.

Table 1: Summary statistics by individual farm branches in current prices, averages for 1994-2003

Farm branches	Total revenue (mio SIT)	Crop revenue (mio SIT)	Livestock revenue (mio SIT)	Other revenue (mio SIT)	Land (UAA in ha)	Labour (AWU)	Capital (mio SIT)	Variable inputs (mio SIT)
1 – crop	4.02	1.71	2.12	0.19	12.6	1.55	12.35	2.66
2 – dairy	6.10	0.55	5.17	0.37	16.7	11.23	22.12	3.20
3 – cattle	2.97	0.55	1.90	0.52	16.7	1.69	17.67	1.94
4 – pigs	7.63	1.23	6.13	0.27	17.6	1.85	26.44	5.29
5 – sheep	2.32	0.19	1.49	0.64	25.0	1.44	12.42	1.36
6 – other livestock using own feed	4.96	0.35	4.00	0.62	12.1	1.78	23.99	2.86
7 – livestock using purchased feed	3.52	0.84	2.20	0.48	9.4	1.32	11.07	1.96
8 – fruit	7.28	6.76	0.16	0.36	7.9	2.47	22.50	3.37
9 – grape and wine	5.06	4.37	0.42	0.27	8.8	2.11	16.77	2.74
10 – mixed	6.52	2.12	3.82	0.57	15.8	4.69	29.46	3.43
11 – vegetables	5.25	4.55	0.41	0.29	8.1	2.27	8.15	2.99
12 – forestry	4.43	0.85	1.60	1.98	21.9	2.12	17.06	2.88
13 – combined	5.19	1.59	2.55	1.06	14.0	1.99	18.36	2.51
Sample's average	5.02	1.97	2.46	0.59	14.37	2.81	18.33	2.86

Note: Slovenian tolar (SIT), the national Slovenian currency between October 1991 and 1 January 2007, when Euro was introduced in Slovenia in place of SIT.

EMPIRICAL RESULTS

Using DEA, the average technical efficiency for the whole farm sample over the whole analyzed period is calculated at 0.965, which is relatively high indicating a homogenous sample (Table 2). This suggests that, although the sample contains very different production farm types, farms have similar management practices, and are similarly able to make the best use of the existing technology. This is also true for scale efficiency, which is evaluated at 0.971 on average for the whole farm sample and the whole analyzed period. Farms in the sample are also relatively efficient in terms of allocative efficiency (0.924) and economic efficiency (0.894). Moreover, the empirical results show that both technical and scale efficiencies tend to increase in the period 1994-1996. In 1996, the measures of technical and scale efficiency are the greatest.

Regarding the differences between farm branches, five farm branches are fully efficient with respect to all four calculated efficiencies measures (technical, scale, allocative, and economic efficiencies): crop, dairy, livestock using own feed, fruit, and forestry farms. This result suggests that these farm specializations have the best chance to compete on the EU and world markets. Two farm branches, namely

vegetables and livestock farms using purchased feed, have full technical and scale efficiency, but not full allocative and economic efficiencies. This indicates that these two farm branches are able to maximise their output with existing input quantities, but do not account for respective input prices in their input use decisions. As for the other farm branches (cattle; pigs; sheep; other livestock; grape and wine; mixed; and combined), they need to improve their management practices in order to remain competitive.

Table 2: Technical, scale, allocative and economic efficiencies using non-parametric DEA approach; averages for 1994-2003

Farm branches	Technical efficiency		Scale efficiency	Allocative efficiency		Economic efficiency	
	Under CRS	Under VRS		Under CRS	Under VRS	Under CRS	Under VRS
1 – crop	1	1	1	1	1	1	1
2 – dairy	1	1	1	1	1	1	1
3 – cattle	0.855	0.958	0.892	0.996	0.922	0.851	0.884
4 – pigs	0.98	0.982	0.998	0.916	0.931	0.898	0.915
5 – sheep	0.896	1	0.896	0.42	0.621	0.376	0.621
6 – other livestock using own feed	1	1	1	1	1	1	1
7 – livestock using purchased feed	1	1	1	0.942	1	0.942	1
8 – fruit	1	1	1	1	1	1	1
9 – grape and wine	0.942	1	0.942	0.995	1	0.938	1
10 – mixed	0.935	0.972	0.961	0.928	0.917	0.868	0.891
11 – vegetables	1	1	1	0.855	0.941	0.855	0.941
12 – forestry	1	1	1	1	1	1	1
13 – combined	0.933	1	0.933	0.954	0.947	0.89	0.947
Sample's average	0.965	0.993	0.971	0.924	0.945	0.894	0.938

Note: CRS = constant returns to scale. VRS = variable returns to scale.

Results from the stochastic frontier approach are lower than the ones obtained with DEA (Table 3). This is due to the fact that stochastic frontier accounts for noise, and thus, the deviation from the frontier (i.e. the difference between 1 and the efficiency score) is not only attributed to inefficiency but to measurement errors as well (Latruffe et al. 2004). The highest economic efficiency is achieved by crop and vegetable farms, which does not fully confirm results from DEA. This shows how important it is to not use one efficiency approach only, but to compare several approaches.

Table 3: Technical, allocative and economic efficiencies using parametric stochastic frontier approach; averages for 1994-2003

Farm branches	Technical efficiency	Allocative efficiency	Economic efficiency
1 – crop	0.539	0.575	0.938
2 – dairy	0.519	0.656	0.792
3 – cattle	0.471	0.616	0.765
4 – pigs	0.520	0.790	0.658
5 – sheep	0.607	0.719	0.845
6 – other livestock using own feed	0.520	0.691	0.752
7 – livestock using purchased feed	0.496	0.563	0.880
8 – fruit	0.562	0.643	0.874

9 – grape and wine	0.556	0.620	0.896
10 – mixed	0.517	0.673	0.768
11 – vegetables	0.589	0.609	0.967
12 – forestry	0.548	0.623	0.880
13 – combined	0.605	0.692	0.875
Sample's average	0.542	0.652	0.938

Tables 2 and 3 showed some discrepancies between results from DEA and from stochastic frontier. Therefore, in order to group farm branches according to their performance calculated with both approaches, a cluster analysis was carried out on all efficiency scores displayed in Tables 2 and 3. Three clusters were identified. Table 4 presents the average efficiencies for the obtained clusters. In general, Cluster 3 is the best performing on average, while Cluster 1 as the worst performing according to average scores. The latter includes only branch 5 – sheep. Finally, Cluster 2 is composed of branches 3 – cattle, 4 – pigs and 10 – mixed farms. Thus, it seems that livestock branches (that mainly compose Clusters 1 and 2) are on average the least efficient in Slovenia.

Table 4: Averages technical, allocative and economic efficiencies for the three clusters

	Data Envelopment Analysis (DEA)								Stochastic frontier		
	TE CRS	TE VRS	SE	AE CRS	AE VRS	EE CRS	EE VRS	TE	AE	EE	
Cluster 1	0.896	1	0.896	0.420	0.621	0.376	0.621	0.607	0.719	0.845	
Cluster 2	0.923	0.971	0.950	0.947	0.923	0.872	0.897	0.503	0.693	0.730	
Cluster 3	0.986	1	0.986	0.972	0.988	0.958	0.988	0.548	0.630	0.873	

TE: technical efficiency. AE: allocative efficiency. SE: scale efficiency. EE: economic efficiency. CRS = constant returns to scale. VRS = variable returns to scale.

CONCLUSION

Globalisation of economies has brought significant changes in economic structures that are exposed to international competition and management challenges. The traditional farming sector, which has been one of the most protected economic sectors during the last decades, has undergone similar liberalisation processes than other economic sectors. Trade and market liberalisation have encouraged forces and pressures for farm and agricultural sectors restructuring to improve micro-economic farm and agro-food sector efficiency. However, the farming sectors are facing some country-specific constraints that are caused by different natural and factor endowments production conditions and inherited different farm structures as a reason for a persistence of government policy and subsidy measures. At the same time, further trade and market deregulation processes and global market integration require appropriate monitoring of this sensitive restructuring and efficiency improvements processes, based on appropriate farm data management practices for managerial decisions and on accurate and reliable evidences. This is one of the reasons that FADN has been introduced in the EU countries, including in Slovenia before accession to the EU in 1994. This data set has shown to be in our empirical analysis a proper database to conduct sophisticated empirical analysis employing non-parametric DEA approach and parametric stochastic frontier approach, as well as cluster analysis

to identify different groups of farms according to their performance. The obtained results have unique research relevance as such study so far has not been conducted for the country analyzed. However, they are also of special practical farm managerial and broader policy measures relevance for improvements in managerial decisions on micro-levels of farms by different farm production branches and for economic policy measures in the agricultural and food sector.

The FADN management practices have been adjusted to the EU requirements and currently this data set is used for both national and EU statistical purposes, as well as for monitoring of micro-managerial and management decisions and for national and EU policy formulations by individual EU members. Slovenia within the EU belongs to the group of countries with relatively small-scale family owned and operated farms that are currently in a process of restructuring from subsistence and part-time farming towards more commercial and market-oriented farms. The FADN sample covers economically more viable and by size above average farms that are expected to create farms that are likely to represent the future in the Slovenian farming sector. However, as our empirical analysis revealed, there are considerable differences in technical and particularly economic efficiency of farms by farm branches indicating that their competitiveness and expected survival vary according to their farm production orientation, farm and households specific characteristics. The results of technical, scale, allocative and economic efficiencies for Slovenian FADN farm sample suggest that several Slovenian family farms, although still relatively small, are growing over time and are becoming competitive in the EU and other international markets. Both farm concentration and efficiency improvements are factors making farm survival and growth in a certain farm production orientations. We have found that the Slovenian farms in the FADN sample are, in terms of the average technical, scale, allocative and economic efficiencies relatively highly efficient. Although the FADN sample contains very different farm production types, farms in the FADN have been found to have a similar management practices. This is consistent with traditional development of these farms, which faced similar constraints during the previous system and similar opportunities for their development during transition to a market economy and integration into the EU. The farms in the FADN sample have also been similarly able to make the best use of the existing technology. As the most striking, the FADN sample of farms in five farm branches (crop, dairy, livestock using own feed, fruit, and forestry farms) have been found fully efficient with respect to all four calculated efficiency measures (technical, scale, allocative, and economic). These findings suggest that these specializations have the best chance to compete on the EU and other world markets. Finally, the results also imply that farm specialization and their commercialisation are an ongoing processing leading to smaller number of farms, greater farm size and improved scale efficiency. With input market deregulation and liberalisation, farms are also becoming more economically efficient. This clearly suggests that the farming sector in Slovenia is shifting from traditional small scale subsistence and peasant farming practices towards family-owned and operated entrepreneurial activities, which managerial and management practices in this stage of their development are similar to behaviours for small family-run businesses and medium-sized family-owned and run enterprises and their spirits for growth and survival.

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APPENDIX 1

The output-orientated DEA linear programming models to calculate technical efficiency (equations (1) to (5)) and economic efficiency (equations (6) to (10)) are as follows (Coelli et al. 2005).

$$\max_{\theta, \lambda} \theta \tag{1}$$

$$\text{s.t.} \quad -y_i + Y\lambda \geq 0 \tag{2}$$

$$x_i - X\lambda \geq 0 \tag{3}$$

$$\lambda \geq 0 \tag{4}$$

$$I\lambda = 0 \tag{5}$$

where Y and X are respectively the output and input matrices of the sample; y_i and x_i are respectively the output and input matrices of the i -th farm; I is a vector of 1; λ is a matrix of parameters.

$1 \leq \theta \leq \infty$, $1 - \theta$ is the potential proportional increase in all outputs for the i -th firm, and $1/\theta$ defines the technical efficiency score that varies between 0 and 1.

$$\max_{\lambda, y_i^*} p_i y_i^* \tag{6}$$

$$\text{s.t.} \quad -y_i^* + Y\lambda \geq 0 \tag{7}$$

$$x_i - X\lambda \geq 0 \tag{8}$$

$$\lambda \geq 0 \tag{9}$$

$$I\lambda = 0 \tag{10}$$

where y_i^* is the revenue-maximising vector of outputs.

Economic efficiency is given by the ratio $p_i y_i / p_i y_i^*$.

The above models are under the assumption of VRS; the assumption of CRS holds when equations (5) and (10) are removed.

Allocative efficiency is given by the ratio of economic efficiency to technical efficiency.

APPENDIX 2

The stochastic frontier models to estimate technical efficiency (equation (11)) and economic efficiency (equation (12)) are as follows (Coelli et al. 2005).

$$\ln y_i = f(x_i) + v_i - u_i \quad (11)$$

where y_i and x_i are respectively the single output and the input matrix of the i -th farm; f is the production function; v_i is a symmetric random error accounting for noise; u_i is a non-negative random variable.

The technical efficiency score of the i -th farm is given by $\exp(-u_i)$.

$$\ln(c_i / w_i) = g(x_i) + v_i + u_i \quad (12)$$

where c_i and w_i are respectively the cost amount and the matrix of input prices of the i -th farm; g is the cost function.

The economic efficiency score of the i -th farm is given by $\exp(-u_i)$.

Allocative efficiency is given by the ratio of economic efficiency to technical efficiency.