RAAE

Review of Agricultural and Applied Economics
The Successor of the Acta Oeconomica et Informatica
ISSN 1336-9261, XVIII (Number 2, 2015): 51–56
doi: 10.15414/raae/2015.18.02.51-56

REGULAR ARTICLE

SCALE EFFICIENCY IN EUROPEAN PORK PRODUCTION

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ABSTRACT

The paper analyses scale efficiency in European pork production. The analysis shows significant differences in the exploitation of economies of scale among EU member states. In particular, old member states exhibit increasing returns to scale whereas most new member states show either constant or decreasing returns to scale. The differences among old and new member states are also pronounced from a dynamic perspective: whereas the old member states improved their productivity in pork production through scale efficiency, its impact in new member states was rather negative.

Keywords: pork production, scale efficiency, total factor productivity, metafrontier analysis, SFA
JEL: D24, O12, P27

INTRODUCTION

The agricultural sector in new member states (NMS) of the European Union (EU) experienced significant changes in the period immediately preceding and after accession into the European Union. We can observe, among other things, changes in farm size. Since scale efficiency is an important factor in determining productivity change, the analysis of economies of scale has been a fundamental subject in agricultural economics in recent decades.

An optimal scale of production was defined by **Frisch (1965)** as an input bundle where scale elasticity equals one. That is, a farm operates under constant returns to scale. One can measure how close an observed farm is to the optimal scale using scale efficiency. According to **Försund (1996)** and **Ray (1998)**, scale efficiency measures the average productivity at the observed input scale with respect to the optimal scale. Moreover, **Coelli et al. (2005)** consider scale efficiency to be a component of productivity change.

The calculation of scale efficiency can be done either non-parametrically, especially using Data Envelopment Analysis (DEA) (e.g., **Fandel, 2003; Bielik and Rajčániová, 2004; Blažejcyk-Majka et al., 2011; Ohlan, 2013; Wang et al., 2013**), or parametrically, especially through Stochastic Frontier Analysis (**Ray, 1998**). **Madau (2012)** provides a comparison of these approaches.

Studies on scale efficiency in European agriculture are numerous. For example, **Mathijs and Swinnen (2001)** analyzed the scale efficiency of East German farms; **Bielik and Rajčániová (2004)** did the same for farms in the Slovak Republic; **Karagiannis and Sarris (2005)** measured the scale efficiency of Greek farms; **Latruffe et al. (2005)** did the same for Poland; **Madau (2012)** calculated the scale efficiency of Italian farms; and **Cechura (2014)** and **Cechura et al. (2014)** did the same for Czech farms. A comparison of the EU countries was done by **Blažejcyk-Majka et al. (2011)** and more recently by **Blažejcyk-Majka and Kala (2015).** Their results (based on DEA and Farm Accountancy Data Network (FADN) data on average farms in EU regions for the period 2004 – 2009) showed that livestock and mixed farms in NMS as well as old member states (OMS) enlarged their total agricultural area and animal stocks. However, scale efficiency increased only for mixed farms in the new regions. Our research complements current knowledge by comparing economies of scale and the contribution of scale efficiency to productivity changes in EU member states, for the time period 2004 – 2011, by employing a translog stochastic meta-frontier model. In particular, the paper addresses questions related to the exploitation of economies of scale from a static as well as dynamic perspective. The aim is to evaluate differences, by country, in returns to scale and in the role played by scale efficiency in productivity changes in EU pork production. The paper is organized as follows: first, an estimation strategy and data set are described; next, the results of the stochastic metafrontier multiple output distance function estimate are presented and the estimated technology is discussed; and finally, the impact of scale efficiency on productivity change is analysed.

DATA AND METHODS

Theoretical framework

Productivity changes and the effects of economies of scale can be analysed by non-parametric or parametric methods. **Kimura and Sauer (2015)** represent the non-parametric approach based on the Fisher index. **Bojnec and Latruffe (2013)** used another non-parametric method: data envelopment analysis. An example of a parametric method is **Piesse and Thirtle (2000),** who applied stochastic frontier analysis. These methods have their pros and cons, e.g. **Van Beren (2007)** mentioned that the parametric method can lead to a bias in total factor productivity change, due to a selection bias connected with the construction of a balanced panel or with the endogeneity of inputs. This could be resolved by using a semi-parametric approach, which was used by **Rizov et al. (2013)**, **Mary (2013)** and others. Our research is based on a parametric approach applied on unbalance panel data, and the endogeneity is resolved through random parameter model specification.

Specifically, the research questions will be addressed by the estimation of multiple output distance functions (ODF) for EU member states. To provide a coherent comparison of the contribution of scale efficiency to total factor productivity (TFP), we use the efficient outputs from the multiple output distance function country estimates in the estimation of a metafrontier multiple output distance function. Both the country and metafrontier models are formulated as translog multiple output distance functions with three outputs and five inputs:

$$-lny_{1it} = \alpha_0 + \sum_{p=2}^{3} \alpha_p ln\, y_{pit}^* + \frac{1}{2}\sum_{p=2}^{3}\sum_{q=2}^{3} \alpha_{pq} lny_{pit}^* lny_{qit}^* + \sum_{k=1}^{5} \beta_k ln\, x_{kit} + \frac{1}{2}\sum_{k=1}^{5}\sum_{l=1}^{5} \beta_{kl} lnx_{kit} lnx_{lit} + \frac{1}{2}\sum_{k=1}^{5}\sum_{p=2}^{3} \gamma_{kp} lnx_{kit} lny_{pit}^* + u_{it} + v_{it} \quad (1)$$

where $y_{mit}^* = \frac{y_{mit}}{y_{1it}}$, v_{it}, is statistical noise and $u_{it} = -lnD_{Oit}$ represents an inefficiency term. The subscripts *i*, with *i*=1,2,…,N, and *t*, with *t =1,…,T*, refer to a certain producer and time (year), respectively. $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$ are vectors of the parameters to be estimated. Moreover, we assume that $v_{it} \sim N(0, \sigma_v^2)$, $u_{it} \sim N^+(0, \sigma_s^2)$, and that they are distributed independently of each other, and of the regressors (**Kumbhakar and Lovell, 2000**).

In all models we assume that agricultural production possibilities are significantly affected by firm heterogeneity, which affects the level as well as the shape of the production possibilities. The heterogeneity is captured by the fixed management model introduced by **Alvarez et al. (2004)**. Moreover, it is assumed that the distribution is the same for all random parameters. That is, the model specification which is estimated in the empirical part (country-specific models as well as the metafrontier model) has the form:

$$-lny_{1it} = \alpha_0 + \sum_{p=2}^{3} \alpha_p ln\, y_{pit}^* + \frac{1}{2}\sum_{p=2}^{3}\sum_{q=2}^{3} \alpha_{pq} lny_{pit}^* lny_{qit}^* + \sum_{k=1}^{5} \beta_k ln\, x_{kit} + \frac{1}{2}\sum_{k=1}^{5}\sum_{l=1}^{5} \beta_{kl} lnx_{kit} lnx_{lit} + \frac{1}{2}\sum_{k=1}^{5}\sum_{p=2}^{3} \gamma_{kp} lnx_{kit} lny_{pit}^* + \alpha_{m*} m_i^* + \frac{1}{2}\alpha_{m*m*} m_i^{*2} + \delta_{tm*} m_i^* t + \sum_{k=1}^{5} \beta_{km*} m_i^*\, lnx_{kit} + u_{it} + v_{it} \quad (2)$$

where m_i^* represents an observed heterogeneity. $m_i^* \sim \bullet(0,1)$ could possess any distribution with zero mean and unit variance and determines the level of the fitted parameters as well as the level of technical efficiency.

Furthermore, **Alvarez et al. (2004)** showed that u_{it} can be estimated according to **Jondrow et al. (1982)**. Total factor productivity is calculated in the form of the Törnqvist-Theil index (TTI) (**Diwert, 1976** and **Caves et al., 1982**) and decomposed into its components: scale effect, technological change, technical efficiency and management effect (**Cechura et al., 2014)**.

All calculations are carried out using the econometric software NLOGIT 5.

Data

We use the Farm Accountancy Data Network (FADN) dataset provided by the European Commission. Every year, the FADN collect accountancy data from a sample of farms in the European Union. The survey covers farms which could be considered commercial, due to their size. The annual sample covers approximately 80,000 holdings, which represents approximately 90% of the total utilised agricultural area and accounts for about 90% of total agricultural production.

Our dataset consists of 24 EU member states (only Croatia, Cyprus, Luxemburg and Malta are missing) and covers the period from 2004 to 2011 (except for Austria (2005 – 2011), Bulgaria and Romania (2008 – 2011)).

The variables we use in the analysis are as follows: y1 pork production, y2 other animal production, y3 plant production, x1 labour, x2 land, x3 capital, x4 specific material and x5 other material.

Labour is represented by the total labour, measured in average working unit (AWU). Land is the total utilised land. Capital is the sum of contract work and depreciation. Specific material in pork production represents feed costs for pigs and poultry. Outputs as well as inputs (except for labour and land) are deflated by country price indices on each individual output and input (2005 = 100). The country price indices are taken from the EUROSTAT database.

The multiple output distance functions are estimated only for specialized producers. Specialization is defined when pork production represents at least a 50 percent share of total animal production. Sample descriptive statistics, which are provided in Table 1, show that the major differences in the mean values of inputs (specific material is the exception) based on a country comparison are in the Czech Republic, Slovakia and Hungary. A higher mean value of plant production can also be observed in these countries compared to the rest. Farms in these countries have more diversified production. However, this also holds for the majority of new member states.

Table 1: Sample descriptive statistics

	y1		y2		y3		x1		x2		x3		x4		x5		
EU member country	Mean	Std.Dev	Mean	Std.Dev	Mean	Std.Dev	Mean	Std.Dev	Mean	Std.Dev	Mean	Std.Dev	Mean	Std.Dev	Mean	Std.Dev	Cases
Austria	48.82	55.22	4.59	9.42	23.62	22.57	1.60	0.69	36.83	23.26	22.21	11.29	19.05	18.92	35.26	18.68	665
Belgium	260.33	197.48	57.39	66.16	39.49	74.74	1.99	0.92	38.52	28.17	41.14	29.52	148.76	126.87	83.90	59.89	540
Bulgaria	8.28	14.49	3.18	8.27	51.80	143.42	5.54	10.44	150.56	408.76	14.47	42.99	4.78	9.13	43.79	107.99	65
Czech Republic	184.35	271.07	572.79	651.57	618.82	680.42	45.48	44.95	1224.58	1064.63	194.37	201.57	124.84	190.96	1008.48	992.68	2609
Germany	200.33	189.55	14.73	24.38	42.35	47.47	1.89	1.63	61.24	68.29	36.77	33.39	85.57	85.18	89.34	88.45	2700
Denmark	610.39	480.68	53.78	102.27	144.42	116.36	3.47	2.32	190.90	125.20	113.68	76.04	312.45	222.29	209.37	140.82	1465
Estonia	160.97	381.80	14.75	51.47	56.81	91.45	5.58	9.36	232.94	290.96	29.02	45.37	80.16	181.82	90.56	188.46	123
Spain	149.12	363.98	14.52	29.30	17.70	28.40	1.68	1.44	63.27	76.85	10.96	24.22	86.48	233.29	32.98	56.42	1052
Finland	122.33	122.61	4.15	8.56	22.93	16.73	1.77	0.83	74.93	36.64	43.70	31.64	68.98	65.87	66.25	40.14	179
France	256.69	234.48	58.16	53.93	40.32	52.66	2.37	1.32	85.01	59.36	65.74	42.72	137.59	122.22	122.66	79.15	928
United Kingdom	373.37	526.82	47.43	116.54	63.96	128.03	3.72	4.11	94.15	129.96	45.08	57.26	192.75	280.01	159.90	192.94	334
Greece	34.42	91.00	4.29	9.13	13.02	18.06	1.50	0.63	17.42	32.03	4.68	5.64	19.63	56.05	10.59	15.76	79
Hungary	244.48	916.83	87.15	471.57	164.95	808.41	13.22	50.79	314.90	1140.75	57.49	263.82	133.04	525.24	276.68	1309.92	607
Ireland	214.79	112.39	128.27	55.56	18.85	11.99	2.36	1.29	73.47	22.61	34.02	5.73	146.45	65.16	113.90	51.79	11
Italy	463.53	1083.61	48.23	140.31	49.15	74.16	3.18	4.01	44.11	63.17	27.84	39.87	226.31	606.03	92.60	217.16	721
Lithuania	28.67	137.80	5.26	21.67	33.22	67.22	2.69	3.89	104.72	192.60	7.17	14.55	12.51	50.63	29.94	60.32	313
Latvia	90.47	461.40	11.09	55.16	22.38	49.52	4.66	14.77	119.51	173.73	15.54	54.26	53.68	291.38	44.60	120.04	394
Netherlands	601.36	519.31	65.43	83.19	23.56	83.04	2.14	1.41	21.13	24.68	66.59	55.79	286.56	233.19	184.80	151.61	543
Poland	20.57	52.86	3.92	15.08	16.17	45.41	1.94	2.18	33.45	62.82	5.72	9.36	11.74	33.17	15.68	53.87	14437
Portugal	122.32	314.53	15.95	36.97	17.27	44.61	2.57	2.08	109.59	225.67	11.70	23.83	60.81	171.19	36.46	62.75	153
Romania	23.86	177.94	5.17	35.40	10.24	33.02	3.33	12.74	24.90	105.07	2.58	13.28	7.56	55.06	16.00	84.55	360
Sweden	173.65	223.07	5.06	17.00	55.40	72.54	1.86	1.37	96.62	101.45	48.76	47.56	98.26	120.79	92.73	84.69	1161
Slovenia	21.56	46.27	4.24	7.35	17.16	20.19	2.06	1.01	23.96	33.00	12.55	12.36	12.52	23.68	18.88	19.69	218
Slovakia	314.48	630.90	134.38	306.05	444.31	604.63	38.36	49.35	1087.57	1364.76	288.28	398.93	157.14	353.34	641.38	860.57	238

Note: y1 – pork production (ths. EUR), y2 – other animal production (ths. EUR), y3 – plant production (ths. EUR), x1 – labour (AWU), x2 – land (ha), x3 – capital (ths. EUR), x4 – specific material (ths. EUR) and x5 – other material (ths. EUR).
Source: FADN and author’s own calculations

RESULTS AND DISCUSSION

First, we start with a general discussion of the fitted country-specific stochastic frontier models. Then, we will concentrate on a discussion of economies of scale. The complete results, together with a discussion, are provided in **Cechura et al. (2014)**.

The majority of estimated parameters are significant at the 1% significance level. The parameter estimates of the multiple output distance function meet monotonicity requirements for all outputs and inputs. Land in Belgium, Great Britain and Slovakia, and capital in Bulgaria are exceptions. However, except for the case of Belgium, these parameters are not significant at the 5% significance level. In addition, the convexity of ODF in inputs holds for almost all countries evaluated on the sample mean. More about the properties of ODF can be found in **Coelli et al. (2005).**

The first-order parameters of outputs represent the share of outputs y2 (other animal production) and y3 (plant production) in total output. Pork producers with a higher share of other animal production can be found in the Czech Republic and Finland, where the parameter of y2 exceeds 0.15. In the majority of the analysed countries, producers specialized in pork can also be characterized by quite a large share of plant production. The share is higher than 30 % in 15 countries, namely in Austria, the Czech Republic, Germany, Denmark, Estonia, Finland, Hungary, Italy, Lithuania, Latvia, Poland, Portugal, Sweden and Slovenia. On the other hand, the share of plant and other animal production in total output is around 10% in the United Kingdom (UK) and the Netherlands, pointing to the high specialization of UK and Dutch farms.

Despite the pronounced differences in technology among the countries, some common patterns can be found. The elasticities for material inputs (specific and other material) with respect to outputs have the highest values, and the elasticities for capital are the lowest. Estonia is an exception. In Estonia, land has the highest elasticity (0.60), and the sum of material elasticities (specific and other) is the lowest (0.47) of all countries. That is, the impact of material inputs on production is the greatest among the analysed inputs. The same results can be found in **Rizov et al. (2013)**, who analysed European old member states. Only in Estonia does an increase in agricultural land imply a higher increase in production than in material. The elasticity of capital is the highest in Italy (0.17). A high value for capital elasticity can also be found in France (0.15), Finland (0.13), Portugal (0.12) and Austria (0.11). However, there are no similarities in the impacts of other inputs (land, labour) in these five countries. For example, labour elasticity in Portugal is the highest of the analysed countries (0.26), while labour elasticity in France (0.06) has the second-lowest value. For Italian farms, on the other hand, land has the highest impact (0.28).

Table 2 provides estimates of the returns of scale. No indication of economies of scale (the sum of the elasticities is about one) was found for the average farm in the Czech Republic, Finland, France, Hungary, Lithuania and Slovenia. Bulgaria, Latvia and Romania are characterized by decreasing returns to scale. The other pork producers experienced increasing returns to scale. Thus scale efficiency has a large impact on productivity change in most member states.

Moreover, we can observe differences between OMS and NMS. Whereas OMS are characterized by increasing returns to scale (on average 1.08), the estimates indicate either constant or decreasing returns to scale for most NMS. According to **Coelli et al. (2005)**, constant returns to scale are equivalent to the most productive scale size. That is, from a static point of view the farmers in OMS have a less-than-optimal size, and farmers in NMS are characterized by either an optimal or greater-than-optimal size. However, significant differences among farmers in most member states can be found. The highest standard deviations were calculated for Finland, Italy, Portugal, Bulgaria, Estonia, Lithuania and Slovenia.

Table 2: Returns to scale in EU pork production

EU member country	Returns to Scale (RTS)			
	Mean	St. Dev.	Min.	Max.
Austria	1.0958	0.1141	0.6105	1.5435
Belgium	1.0273	0.1071	0.7682	1.5325
Germany	1.0654	0.0434	0.8580	1.2009
Denmark	1.0891	0.0378	0.9910	1.2609
Spain	1.0446	0.0729	0.5771	1.2886
Finland	1.0289	0.2330	0.2005	1.7170
France	1.0071	0.0599	0.7651	1.2641
United Kingdom	1.1270	0.1035	0.9321	1.4158
Greece	1.1798	1.9199	-1.7761	7.3627
Ireland	LNO	LNO	LNO	LNO
Italy	1.0440	0.2513	0.1740	1.6704
Netherlands	1.0903	0.0820	0.8343	1.3612
Portugal	1.0865	0.3730	0.3394	2.0006
Sweden	1.1124	0.1172	0.8856	1.5774
OMS	1.0768	0.2704	0.4738	1.9381
Bulgaria	0.9038	0.5086	-0.1084	2.1215
Czech Republic	1.0145	0.0501	0.6907	1.4647
Estonia	1.2900	0.2147	0.8622	1.7994
Hungary	1.0249	0.0262	0.9515	1.1157
Lithuania	1.0123	0.3678	0.0431	1.9265
Latvia	0.9463	0.1026	0.6751	1.2521
Poland	1.0790	0.0365	0.9292	1.2495
Romania	0.9600	0.0691	0.6955	1.2017
Slovakia	1.0477	0.1044	0.7402	1.3336
Slovenia	1.0083	0.2510	0.2538	1.7715
NMS	1.0287	0.1731	0.5733	1.5236
EU	1.0559	0.2281	0.5171	1.7579

Note: LNO – low number of observations; the parameter estimates for some countries were negatively influenced by a low number of observations – see sample descriptive statistics in Table 1 – as is the case for Greece, for example. OMS – old member states (EU – 15), NMS – new member states.
Source: author's own calculations

Finally, Table 3 provides estimates of total factor productivity (TFP) indices and the contribution of the scale efficiency component to TFP change. TFP indices are calculated from the estimate of a metafrontier multiple output distance function for the analysed EU countries. As far as the level of total factor productivity is concerned, we can find significant differences among countries. In particular, OMS have a higher productivity level on average (1.12) compared to NMS (0.95). These results can also be affected by the Common Agricultural Policy (CAP), as mentioned by **Rizov et al. (2013)**. The study by the mentioned authors concludes that coupled payments had a negative impact on farm productivity; however, decoupled payments contributed positively to TFP growth. **Mary (2013)** divided CAP subsidies into selective (e.g. investment subsidies, environmental subsidies) and automatic (e.g. single area payment, set-aside premium, LFA) and found that automatic subsidies had a negative impact on TFP in France. Selective subsidies had no significant impact on production.

Table 3: Contribution of scale effect to TFP change

Country	TFP	Contribution of SE to TFP change (%)
Austria	0.9668	-4.94
Belgium	1.1313	12.26
Denmark	1.1557	14.37
Germany	1.1166	10.82
Greece	1.0349	1.88
Spain	1.5038	34.07
Finland	0.7752	-27.32
France	1.0844	7.88
Italy	1.4896	33.45
Netherlands	1.1379	11.95
Portugal	1.1832	12.91
Sweden	1.0540	4.39
United Kingdom	1.0522	4.75
OMS	1.1297	8.96
Bulgaria	0.9827	-2.30
Czech Republic	0.9427	-6.32
Estonia	0.8732	-14.84
Hungary	0.9726	-4.22
Lithuania	0.9249	-8.98
Latvia	0.8933	-12.55
Poland	0.9829	-2.58
Romania	0.9134	-10.06
Slovakia	1.0688	3.87
Slovenia	0.9202	-9.09
NMS	0.9475	-6.71

Source: author's own calculations

The contribution of scale efficiency to productivity change is also higher, on average, in OMS compared to NMS. Moreover, it holds true in the majority of cases that the effect of scale efficiency was positive in OMS and negative in NMS. Austria, Finland and Slovakia are exceptions. The contribution of scale efficiency in OMS and NMS to TFP was also evaluated by **Błażejczyk-Majka and Kala (2015)** on the basis of the Malmquist index. However, their scale efficiency indices for livestock farms, which were slightly higher in NMS than in OMS, were not statistically significant.

The highest positive contribution of scale efficiency to productivity change was estimated for Spain and Italy. On the other hand, the highest negative impact of scale efficiency was observed in Estonia, Latvia and Romania.

CONCLUSION

In this section we will concentrate on the questions raised in the introduction, namely those regarding the exploitation of economies of scale from a static as well as dynamic perspective. The results show significant differences in the exploitation of economies of scale among the EU member states. In particular, OMS are characterized by increasing returns to scale, indicating a production of less-than-optimal size, whereas most NMS have either an optimal or greater-than-optimal size from a static point of view.

The differences among OMS and NMS are pronounced from a dynamic perspective as well. Whereas OMS improved productivity through scale efficiency, the impact of scale efficiency on productivity change in new member states was rather negative.

The results suggest that the competitiveness of the EU pork production can be increased through the scale efficiency. However, as far as the institutional support is concerned, policy makers should produce country specific actions by the exploitation of economies of scale.

Acknowledgements

This paper was created within the project COMPETE – "International comparisons of product supply chains in the agro-food sectors: Determinants of their competitiveness and performance on EU and international markets". The project received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 312029 (www.compete-project.eu) and MSM 7E13038.

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