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REGULAR ARTICLE

PRODUCTIVITY AND EFFICIENCY DIFFERENCES BETWEEN CZECH AND SLOVAK MILK PRODUCERS

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ABSTRACT

The paper deals with the analysis of productivity and efficiency differences between Czech and Slovak milk producers. The estimate of stochastic metafrontier multiple output distance function revealed that both Czech and Slovak milk producers highly exploit their production possibilities. On the other hand, productivity differences were pronounced. The Slovak regions were found being falling behind. Only the West Slovak regions can keep pace with competitors. The Central Bohemia and Moravian-Silesian regions are the most productive regions. We found that technical efficiency and management component are the most important factors determining the regional differences.

Keywords: milk production, productivity, efficiency, metafrontier analysis, SFA
JEL: D24, O12, P27

INTRODUCTION

Productivity and efficiency as important indicators of the competitiveness have got a prominent attention of agricultural research in last two decades. The Czech and Slovak agriculture were not exceptions. The authors addressed questions especially related to the EU enlargement and CAP or to the specific factors determining technical efficiency and total factor productivity (e.g. **Machek (2013), Machek and Špička (2013), Čechura (2012), Curtiss and Jelínek (2012), Bielik and Hupková (2011), Malá (2011), Sojková, Kropková and Kováč (2008), Latruffe et al. (2008), Davidová et al. (2003)**). The authors predominantly oriented on one country, either the Czech Republic or Slovakia, and if the comparison among countries were carried out, it was based on the country specific model estimate. The reliable comparison among the countries is missing.

This paper complements the research on productivity and efficiency by the metafrontier analysis of Czech and Slovak milk production. In particularly, the paper addresses two research questions. The first questions relates to the technical efficiency. The aim is to assess whether there are significant differences in efficiency of input use. The second questions concerns total factor productivity. The aim is to evaluate regional differences in productivity and their sources. In particularly, we will analyse if there is an indication of falling behind or catching up processes on the regional level.

The paper is organized as follows: Chapter Material and Methods contains the theoretical framework, presents the estimation strategy and describes the data set; Chapter Results and Discussion presents results of stochastic metafrontier multiple output distance function estimate, discusses estimated technology and technological change and compares technical efficiency and total factor productivity. Chapter Conclusions contains concluding remarks.

MATERIAL AND METHODS

Theoretical framework

The research questions will be addressed by the estimation of multiple output distance function. First, the stochastic frontier multiple output distance function for each country will be estimated. These estimates will serve for the calculation of efficient outputs which we use for the estimation of stochastic metafrontier multiple output distance function. The metafrontier analysis provides unbiased comparison of the efficiency and productivity level of Czech and Slovak milk producers.

We assume that the production possibilities can be well approximated by the translog multiple output distance function. We use a translog functional form since it is flexible and provides well approximation of the production process. Moreover, it permits the imposition of homogeneity (**Coelli and Perelman, 1996**). The translog output distance function for 3 outputs and 5 inputs, as it is the case in our empirical application, is:

$$D_{Oit} =$$
$$\alpha_0 + \sum_{m=1}^{3} \alpha_m ln\, y_{mit} +$$
$$\frac{1}{2}\sum_{m=1}^{3}\sum_{n=1}^{3} \alpha_{mn} ln y_{mit} ln y_{nit} + \sum_{k=1}^{5} \beta_k ln\, x_{kit} +$$

$\frac{1}{2}\sum_{k=1}^{5}\sum_{l=1}^{5}\beta_{kl} lnx_{kit} lnx_{lit}$ +
$\frac{1}{2}\sum_{k=1}^{5}\sum_{n=1}^{3}\gamma_{km} lnx_{kit} lny_{mit}$ (1)

where subscripts i, with $i = 1,\ldots,N$, and t, with $t = 1,\ldots,T$, refer to a certain producer and time (year), respectively. $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$ are vectors of parameters to be estimated.

Following Lovell at al. (1994) we impose the homogeneity by choosing y_{1it} and dividing by it other outputs. Moreover, we introduce statistical noise, v_{it}, and associate $-lnD_{Oit}$ with inefficiency term, $u_{it} = -lnD_{Oit}$. Finally, we capture the effect of technological change by a trend variable (t). The resulting stochastic frontier multiple output distance function is:

$$-lny_{1it} = \alpha_0 + \sum_{m=2}^{3}\alpha_m ln\, y_{mit}^{*} + \frac{1}{2}\sum_{m=2}^{3}\sum_{n=2}^{3}\alpha_{mn} lny_{mit}^{*} lny_{nit}^{*} + \sum_{k=1}^{5}\beta_k ln\, x_{kit} + \frac{1}{2}\sum_{k=1}^{5}\sum_{l=1}^{5}\beta_{kl} lnx_{kit} lnx_{lit} + \frac{1}{2}\sum_{k=1}^{5}\sum_{m=2}^{3}\gamma_{km} lnx_{kit} lny_{mit}^{*} + \delta_t t + \frac{1}{2}\delta_{tt}t^2 + \sum_{m=2}^{3}\alpha_{mt} t lny_{mit}^{*} + \sum_{k}^{5}\beta_{kt} t ln\, x_{kit} + u_{it} + v_{it}\ . \quad (2)$$

where we assume that $v_{it} \sim N(0,\sigma_v^2)$, $u_{it} \sim N^{+}(0,\sigma_s^2)$, and they are distributed independently of each other, and of the regressors (**Kumbhakar and Lovell, 2000**).

Heterogeneity in technology is captured using a Fixed Management model. **Álvarez et al. (2003 and 2004)** specified the Fixed Management model as a special case of Random Parameters model in the following form:

$$\ln TE_{it} = \ln f\left(\mathbf{y}_{it}^{*}, \mathbf{x}_{it}, t, m_i; \boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\gamma}, \boldsymbol{\delta}\right) - \ln f\left(\mathbf{y}_{it}^{*}, \mathbf{x}_{it}, t, m_i^{*}; \boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\gamma}, \boldsymbol{\delta}\right) \le 0$$

$$\ln TE_{it} = -u_{it}, \quad (3)$$

and

$$-lny_{1it} = \alpha_0 + \sum_{m=2}^{3}\alpha_m ln\, y_{mit}^{*} + \frac{1}{2}\sum_{m=2}^{3}\sum_{n=2}^{3}\alpha_{mn} lny_{mit}^{*} lny_{nit}^{*} + \sum_{k=1}^{5}\beta_k ln\, x_{kit} + \frac{1}{2}\sum_{k=1}^{5}\sum_{l=1}^{5}\beta_{kl} lnx_{kit} lnx_{lit} + \frac{1}{2}\sum_{k=1}^{5}\sum_{m=2}^{3}\gamma_{km} lnx_{kit} lny_{mit}^{*} + \delta_t t + \frac{1}{2}\delta_{tt}t^2 + \sum_{m=2}^{3}\alpha_{mt} t lny_{mit}^{*} + \sum_{k}^{5}\beta_{kt} t ln\, x_{kit} + \alpha_{m*}m_i^{*} + \frac{1}{2}\alpha_{m*m*}m_i^{*2} + \delta_{tm*}m_i^{*}t + \sum_{k=1}^{5}\beta_{km*}m_i^{*}\, lnx_{kit} + u_{it} + v_{it} \quad (4)$$

Technical efficiency, $TE_{i(t)}$, with $0 < TE_{i(t)} < 1$, captures deviations from the maximum achievable output. $m_i^{*} \sim \bullet(0,1)$ represents unobservable fixed management. The symbol $\bullet$ expresses that m_i^{*} might possess any distribution with zero mean and unit variance. u_{it} is estimated according to **Jondrow at al. (1982)**. Fixed management model is used for the estimation of stochastic metafrontier multiple output distance function. Total factor productivity is calculated in the form of the Törnqvist-Theil index (TTI) (see, e.g., **Cechura and Hockmann, 2010**).

All the calculations are carried out in the econometric SW NLOGIT 5.

Data

The panel data set is drawn from the FADN database provided by the European Commission. The data set covers the period from 2004 to 2011. We estimate multiple output distance function with 3 outputs (y_1 milk production, y_2 other animal production, y_3 plant production) and 5 inputs (x_1 labour, x_2 land, x_3 capital, x_4 specific material and x_5 other material).

Labour is represented by the total labour measured in AWU. Land is the total utilised land. Capital is a sum of contract work and depreciation. Specific material in milk production creates cost on feed for grazing livestock.

Outputs as well as inputs (except for labour and land) are deflated by country price indexes on each individual output and input (2005 = 100). The country price indexes are taken from the EUROSTAT database.

The multiple output distance function is estimated only for specialized producers. The specialization is defined as at least 50 % share of dairy production on total animal production. Moreover, we excluded observations with negative and zero values. Finally, we involved in the estimation producers with 5 and more observations to eliminate the problem with entry and exit of producers from the database.

Sample descriptive statistics are provided in the Table 1.

Table 1: Sample descriptive statistics

Variable	Country			
	Czech Republic		Slovakia	
	Mean	Std.Dev	Mean	Std.Dev
y1	512.6173	463.5051	432.405	434.9009
y2	185.9992	235.7986	148.8387	188.8775
y3	526.4729	568.6988	562.9835	622.645
x1	40.4917	35.90233	54.87934	40.75965
x2	1099.362	915.5908	1583.842	1048.619
x3	177.1352	173.1129	387.0065	380.4519
x4	265.0414	234.04	263.9446	280.6434
x5	736.4364	726.1223	784.612	736.1076
Cases		2600		1447

Note: y1 – milk 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 own calculations

RESULTS AND DISCUSSION

Table 2 provides parameter estimate of stochastic metafrontier multiple output distance function. As was expected, the first order parameters standardly discussed in production function estimate as well as the majority of parameters on unobservable fixed management are highly significant. This also holds for majority of second order parameters.

As far as theoretical consistency of the estimate is concerned the model should inherit properties of multiple output distance function, i.e. being non-decreasing, positively linearly homogenous and convex in outputs, as well as decreasing and quasi convex in inputs. Both monotonicity requirements as well as requirements on convexity in outputs and quasi convexity in inputs are met, evaluated on the sample mean.

Since all variables are normalised in logarithm by their sample mean, the first-order parameters of outputs represent the shares of outputs y_2 and y_3 in the total output and parameters of inputs can be interpreted as elasticities of production on the sample mean. That is, the share of other animal production is about 6 % and the share of plant production is 32 %. This holds on the sample mean. As was expected the highest elasticity of production is for material inputs. Labour and land have a considerable effect on the production as well. On the other hand, capital elasticity is lower than expected. This suggests that the milk producers might have faced capital market imperfections.

Since the sum of production elasticities is -0.9516 slightly decreasing returns to scale were estimated. However, since the sum is closed to one the impact of scale efficiency on a productivity change will not be large on the average. The decreasing returns to scale are more pronounced in Slovakia (-0.9254) as compared to the Czech Republic (-0.9571). Moreover, the impact might be large for individual milk producers since the returns to scale differ significantly in the sample.

The parameters on unobservable management are highly significant except for labour and other material inputs which suggest that the chosen specification well approximates the estimated relationship and that heterogeneity among producers is an important characteristic of farmers with milk specialisation in the Czech Republic and Slovakia. The unobservable management contributes positively to the production and the impact accelerates over time. The increase in management has a positive impact on production elasticities of specific material inputs and negative on land and capital. The impact of technological change on technical efficiency is negative.

Table 2: Parameter estimate

Means for random parameters				Coefficient on unobservable fixed management			
Variable	Coef.	SE	P [|z|>Z*]	Variable	Coef.	SE	P [|z|>Z*]
Const.	-0.1146	0.0043	0.0000	Alpha_m	-0.2692	0.0024	0.0000
Time	-0.0284	0.0007	0.0000	Time	-0.0056	0.0010	0.0000
X1	-0.2073	0.0047	0.0000	X1	0.0083	0.0056	0.1365
X2	-0.2437	0.0057	0.0000	X2	-0.0749	0.0070	0.0000
X3	-0.0247	0.0029	0.0000	X3	-0.0073	0.0033	0.0259
X4	-0.2476	0.0039	0.0000	X4	0.0653	0.0045	0.0000
X5	-0.2283	0.0056	0.0000	X5	0.0093	0.0071	0.1886
				Alpha_mm	-0.0475	0.0040	0.0000
Variable	Coef.	SE	P [|z|>Z*]	Variable	Coef.	SE	P [|z|>Z*]
TT	0.0002	0.0008	0.7812	X13	-0.0227	0.0062	0.0003
Y2	0.0612	0.0023	0.0000	X14	0.0418	0.0087	0.0000
Y3	0.3225	0.0025	0.0000	X15	0.0668	0.0122	0.0000
Y2T	-0.0047	0.0009	0.0000	X23	-0.0038	0.0072	0.5983
Y3T	0.0088	0.0011	0.0000	X24	0.0958	0.0113	0.0000
Y22	0.0189	0.0020	0.0000	X25	-0.0148	0.0161	0.3581
Y33	0.1440	0.0031	0.0000	X34	0.0156	0.0046	0.0006
Y23	-0.0062	0.0025	0.0121	X35	0.0287	0.0076	0.0002
X1T	0.0009	0.0017	0.6148	X45	-0.0145	0.0101	0.1540
X2T	0.0025	0.0027	0.3569	Y2X1	-0.0186	0.0056	0.0008
X3T	-0.0052	0.0014	0.0002	Y2X2	-0.0283	0.0058	0.0000
X4T	0.0002	0.0017	0.9005	Y2X3	0.0100	0.0033	0.0025
X5T	-0.0004	0.0026	0.8754	Y2X4	0.0167	0.0041	0.0000
X11	-0.1118	0.0082	0.0000	Y2X5	0.0134	0.0060	0.0249
X22	-0.0389	0.0209	0.0624	Y3X1	-0.0119	0.0054	0.0261
X33	-0.0148	0.0049	0.0025	Y3X2	-0.0202	0.0058	0.0005
X44	-0.1194	0.0045	0.0000	Y3X3	-0.0366	0.0031	0.0000
X55	-0.0884	0.0209	0.0000	Y3X4	0.0147	0.0041	0.0003
X12	0.0085	0.0126	0.5009	Y3X5	-0.0074	0.0058	0.2027
Sigma	0.1157	0.0020	0.0000				
Lambda	1.4372	0.0877	0.0000				

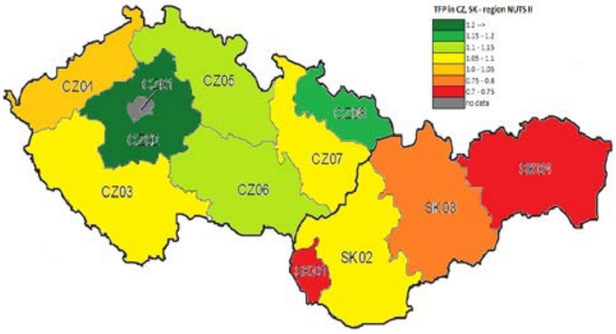
Source: own calculations

Technological change has a significant positive contribution (β_T < 0) to the production and the impact does not change over time (β_{TT} is not significant). The biased technological change is pronounced only for capital. The technological change is capital using. This direction of the technological change corresponds to our expectations. The adoption of innovations leads to the situation where capital becomes more abundant. Moreover, the direction of biased technological change does not support the above stated implication that the milk producers face the capital market imperfections. Instead of that, the low capital elasticity and direction of biased technical change suggest that the producers have the access to the financial resources (subsidies can play an important role) and become less undercapitalized

Parameter λ is highly significant and higher than one. That is the variation in u_{it} is more pronounced than the variation in the random component v_{it}. The estimates indicate that efficiency differences among milk producers are important reasons for variation in production. However, the estimate did not reveal significant differences among countries not even among regions. The results show that milk producers in the Czech Republic and Slovakia highly exploit their production possibilities (evaluated on the sample mean). The averages of technical efficiency calculated on regional level (NUTSII) are in the interval 0.92 and 0.94.

On the contrary to the technical efficiency TFP differences among countries as well as among regions are significantly pronounced. Table 3 provides the figures on TFP (calculated as a Tornqvist-Theil index /TTI/) and its components – technical change, scale efficiency, technical efficiency and management. Figure 1 provides the graphical illustration of regional TFP differences. The estimate revealed significant regional differences. The highest productivity is in Central Bohemia (CZ02) and Moravian-Silesian region (CZ06 and CZ08). On the other hand, Bratislava region (SK01) and East Slovak regions (SK03 and SK04) have the lowest productivity. The results suggest that Slovak regions are falling behind in milk production. Only the West Slovak region (SK02) can keep a pace with competitors. However, the productivity is on the same level as the worst performing regions in the Czech Republic.

Figure 1: Regional TFP



Source: own calculations

Table 3 indicates that technical change and management are the most important determinants of TFP. The scale and technical efficiency effects are less pronounced. The huge differences among Czech and Slovak regions are due to the management component. Since the management variable can be associated with inputs quality and suitability of regions for milk production. We can conclude that these factors are the most important reasons determining the productivity differences among Czech and Slovak regions.

Table 3: Total factor productivity

Country	NUTSII	TFP	Components of TFP:			
			TCH	SE	TE	MAN
The Czech Republic	CZ02	1.2065	1.0449	0.9939	1.0018	1.1638
	CZ03	1.0535	1.0026	1.0013	0.9988	1.0481
	CZ04	1.0260	0.9651	0.9881	0.9992	1.0751
	CZ05	1.1001	0.9809	1.0205	1.0040	1.1034
	CZ06	1.1406	1.0033	0.9926	0.9968	1.1416
	CZ07	1.0881	0.9811	0.9980	0.9966	1.1075
	CZ08	1.1535	1.0155	1.0056	1.0009	1.1307
Slovakia	SK01	0.7382	0.9837	0.9900	1.0062	0.7627
	SK02	1.0558	1.0794	0.9832	0.9985	0.9933
	SK03	0.7922	0.9815	0.9934	1.0011	0.8133
	SK04	0.7281	0.9861	0.9955	1.0008	0.7423

Source: own calculations

CONCLUSIONS

In this section we will concentrate on the questions raised in the introduction, namely the ones regarding technical efficiency and productivity differences between the Czech Republic and Slovakia.

As far as the technical efficiency is concerned no significant differences between the Czech Republic and Slovakia were revealed by the estimate. On average, the milk producers highly exploit their production possibilities.

On the other hand, productivity differences were highly pronounced. The results suggest that Slovak regions are falling behind in milk production. Only the West Slovak region (SK02) can keep a pace with competitors. Technical change and management component were found being the most important factors determining the productivity differences among the Czech and Slovak regions.

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