Productivity of Estonian dairy farms decline after the accession to the European Union

Nikolay VASILIEV[1], Elsa SUUSTER[1], Helis LUIK[2], Rando VÄRNIK[2], Eduard MATVEEV[3], Alar ASTOVER[1]

[1]Department of Soil Science and Agrochemistry, Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences, Tartu, Estonia
[2]Institute of Economics and Social Sciences, Estonian University of Life Sciences, Tartu, Estonia
[3]Rural Economy Research Centre, Jäneda, Estonia

Abstract: The aim of the study was to analyze the productivity change of Estonian dairy farms before and after the accession to the European Union. The Malmquist productivity index was measured and separated into the technical and efficiency change using the data envelopment analysis for the pre-accession period (years 2001–2003) and the post-accession period (2004–2006). Second-stage regression was applied to estimate the possible variables determining the productivity and efficiency change. Productivity growth of Estonian dairy farms was negative for both observed periods; the mean annual growth rate of the Malmquist productivity index was –0.7% in 2001–2003 and –2.6% in 2004–2006. The share of farms with declining productivity increased from 36% to 50% after the accession to the EU and is induced mainly by a significant deterioration in the efficiency change. Remarkable changes in the line-up of most efficient dairy farms occurred between 2000 and 2006, producers with greater initial efficiency have experienced significant regress, with efficiency score decreasing from 0.842 in 2000 to 0.608 in 2006 and the new front-runners, forming the efficiency frontier, have emerged. Capitalization was positively related with the cumulative technical change. Nevertheless, increasing investments and assets have not affected efficiency change and investments have often not been harnessed in the best possible way.

Key words: Malmquist productivity index (MPI), data envelopment analysis (DEA), bootstrapping, dairy farms

Agriculture in the Central and Eastern European Countries (CEEC) has undergone rapid changes during the last two decades. Several studies have analyzed farm productivity and efficiency in the CEECs (i.e. Mathijs and Swinnen 2001; Mathijs and Vranken 2001; Brümmer et al. 2002; Gorton and Davidova 2004; Latruffe et al. 2005, 2008), but an analysis of the Baltic countries is still rare (Vasiliev et al. 2008; Luik et al. 2009). The previous studies mainly cover the period prior to the accession to the European Union (EU). Since Estonia became a full member of the EU in 2004, the process of transition from the ultra-liberal economic policy of the 1990s to the EU Common Agricultural Policy (CAP) has been ongoing. The changes in the productivity and efficiency of farming before and after the accession have not been analyzed. There are only a few studies available that describe the effects of the accession to the EU on the overall economic characteristics of farms or on the macro-economic aspects in the CEECs (Matejkova et al. 2008; Foltyn et al. 2009). The accession to the EU has increased agricultural income in the new member states (Swinnen and Vranken 2005), but how it has altered productivity, is unknown.

Dairy farming has a key role in European agriculture and also in Estonia, since milk production makes the highest contribution to the Estonia's total agricultural output (29% in 2004–2006). The dairy farming leading role in Estonia's agriculture remained after the independence was regained in 1991, although milk production decreased to 50% of the previous level (Astover et al. 2006). Estonia changed from being a net exporter to a net importer of most major agricultural products over a short period of time (Yao 2005), although the milk sector is still an exception – the national self-sufficiency in milk and milk products is still about 130–140%. Sustainability of dairy farming must be estimated in the context of ecological, social and economic aspects. Therefore, the up-to-date information on farming productivity and efficiency is important at various scales (from the micro-economic to the EU's agro-environmental policy). Boussemart et al. (2006) studied the economies of scale for the years 2000–2003, but no other comparative econometric analysis for Estonian dairy farms has been available.

The aim of the current study was to assess the Malmquist productivity index and its components of technical and efficiency change in Estonian specialized dairy farms before and after the accession to the EU. The time horizon 2001–2006 was divided into the pre-accession period (years 2001–2003) and the post-accession period (2004–2006). Second-stage regression was applied to estimate the possible variables determining the productivity and efficiency change in Estonian dairy farms.

MATERIAL AND METHODS

Malmquist productivity index

For estimating the productivity change in Estonian dairy farms, the Malmquist productivity index (MPI) was measured using the data envelopment analysis (DEA). The MPI was first introduced by Caves et al. (1982) defined in terms of distance functions. Färe et al. (1992) integrated the MPI evaluation to the DEA framework. The MPI does not require input prices or output prices, which makes it particularly useful in situations where prices are misrepresented or non-existent.

The MPI measures the productivity change between two data points by calculating the ratio of the distances of each data point relative to a common technology. Following Färe et al. (1994), the output-orientated MPI between period t and period $t + 1$ is given by

$$M_o(Y_{t+1}, X_{t+1,} Y_{t,} X_t) = \left[\frac{d_o^t(Y_{t+1}, X_{t+1})}{d_o^t(Y_{t,} X_t)} \times \frac{d_o^{t+1}(Y_{t+1}, X_{t+1})}{d_0^{t+1}(Y_t, X_t)} \right]^{1/2} \quad (1)$$

where the notation d_o represents the distance function and the value of M_o is the MPI. The first ratio represents the period t index. It measures the productivity change from period t to period (t + 1) using the period t technology as a benchmark. The second ratio is the period (t + 1) index and measures productivity change from period t to period (t + 1) using period (t + 1) technology as a benchmark. A value of M_o greater than one (i.e. $M_o > 1$) denotes productivity growth, while a value less than one ($M_o < 1$) indicates productivity decline, and $M_o = 1$ corresponds to stagnation.

The output-based MPI between time periods t and (t + 1) can be separated into two components, efficiency change (EffCh) and technical change (TechCh), as follows:

$$M_o(Y_{t+1,} X_{t+1,} Y_{t,} X_t) = \frac{d_o^{t+1}(Y_{t+1,} X_{t+1})}{d_0^t(Y_{t,} X_t)} \left[\frac{d_o^t(Y_{t+1,} X_{t+1})}{d_o^{t+1}(Y_{t+1}, X_{t+1})} \frac{d_o^t(Y_{t,} X_t)}{d_o^{t+1}(Y_t, X_t)} \right]^{1/2} \quad (2)$$

where

$$\text{EffCh} = \frac{d_o^{t+1}(Y_{t+1,} X_{t+1})}{d_0^t(Y_{t,} X_t)} \quad (3)$$

and

$$\text{TechCh} = \left[\frac{d_o^t(Y_{t+1,} X_{t+1})}{d_o^{t+1}(Y_{t+1}, X_{t+1})} \frac{d_o^t(Y_{t,} X_t)}{d_o^{t+1}(Y_t, X_t)} \right]^{1/2} \quad (4)$$

The EffCh shows how much closer (or farther away) a farm gets to the frontier made up of the 'best practice' farms and measures the change in the ability to make the best use of the available technology. On the other hand, the TechCh component measures the shift in the frontier over time and refers to an improvement or worsening of the state of technology. It can be interpreted as providing evidence of innovation for the farm considered.

Bootstrapping

One of the main drawbacks of the DEA is that its results may be affected by the sampling variation meaning that distances to the frontier are likely to be underestimated if the best performers in the population are not included in the sample. In order to assess the sampling variability of the results, confidence intervals were constructed using the homogenous bootstrap procedure (Simar and Wilson 1998, 2000). The bandwidth parameter was chosen according to the normal rule: 2000 bootstrap iterations were performed and the 95% confidence intervals ($CI_{95\%}$) were constructed. Bootstrapping for the DEA scores with farming datasets have previously been used in several studies (Brümmer 2001; Hansson 2007; Latruffe et al. 2008; Odeck 2009) and they conclude that the discovered differences based on the conventional DEA methods without bootstrapping may not be significant. The basic idea of the bootstrap method is that if the data are viewed as a set of random draws from an underlying population, random draws from the sample are also random draws from the population. Therefore, the known bootstrap distribution will mimic the original unknown distribution if the known data generating process is a consistent estimator of the unknown data generating process. After many simulations, a distribution of efficiency scores is obtained and represents an estimate of the true distribution. Based on the lower and upper bounds of

Table 1. Descriptive statistics of the data used for the productivity change calculation

Year	Mean	SD	Minimum	Maximum
		Total output (EEK)		
2000	926 525	1 411 603	116 987	9 423 062
2001	955 757	1 463 058	98 286	9 250 498
2002	1 188 897	1 988 300	113 345	13 981 680
2003	1 292 599	1 916 203	123 551	12 063 443
2004	1 471 518	2 308 904	117 042	14 060 065
2005	1 661 463	2 847 731	112 064	19 827 269
2006	1 803 298	3 462 636	106 314	24 662 529
		Intermediate consumption (EEK)		
2000	535 690	754 850	63 958	4 768 805
2001	644 707	957 104	60 908	5 791 644
2002	864 690	1 340 154	70 282	9 065 599
2003	934 666	1 528 262	78 992	9 910 573
2004	1 163 651	1 908 244	101 564	12 958 170
2005	1 412 425	2 618 746	115 566	18 405 482
2006	1 417 439	2 753 811	93 695	20 431 374
		Total assets (EEK)		
2000	1 658 400	2 468 495	182 468	18 092 228
2001	1 667 272	2 409 460	187 110	17 710 173
2002	2 772 608	4 863 697	251 784	35 050 108
2003	2 913 304	5 008 176	271 724	35 286 392
2004	3 637 622	8 046 319	269 043	61 900 314
2005	3 898 225	8 251 123	251 626	63 112 296
2006	4 245 475	9 359 528	276 737	71 942 806
		Dairy cows and other cattle (livestock units)		
2000	87	146	9	940
2001	88	142	9	927
2002	95	159	9	1 081
2003	99	162	11	1 108
2004	101	162	10	1 114
2005	111	184	12	1 257
2006	115	193	9	1 343
		Labour input (annual working units)		
2000	6.2	8.1	1.0	41.0
2001	5.8	8.0	1.0	43.0
2002	5.8	7.7	1.0	43.0
2003	5.7	7.4	1.0	43.0
2004	5.5	7.3	1.0	44.0
2005	5.5	7.3	1.0	43.0
2006	5.6	8.1	1.0	53.0

the confidence intervals derived with bootstrapping, farms were grouped into three classes: (1) decline (upper $CI_{95\%} < 1$), (2) stagnation (lower or upper $CI_{95\%}$ covers 1), and (3) growth (lower $CI_{95\%} > 1$). Differences in the distribution of farms between the given classes before and after the accession to the EU were estimated with χ^2-test.

Second-stage regression

The dependent variables applied in the ordinary least square (OLS) regression were the cumulative Malmquist indices. The cumulative MPI was calculated as follows:

$$M_{oc} = \sum_{i} (M_{oi} - 1) \qquad (5)$$

where M_{oc} is the cumulative MPI, M_{oi} is the MPI in a certain year and i denotes the total time period (years 2001–2006). Cumulative efficiency and technical change values were calculated with a similar approach. The selection of independent variables for the second-stage regression was limited by the data availability and therefore mainly the farm internal factors were included: the initial DEA score, livestock units (LU) as a size variable, the land and LU ratio as the land use intensity variable, the total assets and the LU ratio as the capital intensity variable, the LU and annual working unit ratio as the labour use efficiency variable, the intermediate consumption and LU ratio as the variable cost indicator, and the annual milk yield per cow.

Data

An output-oriented model with a single output but multiple inputs was applied using the Farm Accountancy Data Network (FADN). The Rural Economy Research Centre is responsible for the FADN survey in Estonia. Dairy farms, where livestock production contributed more than 50% to the farm's total output, were selected for the FADN database (according to the FADN typology). The study used panel data on 63 such units for the period 2000–2006. Conditionally for the Malmquist index, time scale was divided into the pre-accession period (years 2001–2003) and the post-accession period (years 2004–2006).

The output factor in the output-oriented DEA model was the total output in Estonian Crowns (EEK). Four factors were included as inputs: labour in the form of annual work units (AWU), dairy cows and other cattle in the form of livestock units (LU), capital in the form of the value (EEK) of the total assets, and a variable factor in the form of the value (EEK) of intermediate consumption. The monetary values have been deflated, using the indices (output and input price indices) based on the year 2000 according to national statistics. Descriptive statistics were calculated for the outputs and inputs used in analyses for the sample farms (Table 1). The size of dairy farms has increased from 87 to 115 livestock units in 2000–2006, however, the use of labour decreased 10%. The total assets and intermediate consumption have increased even by a factor of 2.6, but the growth of the total output has been lower (by a factor of 1.9).

Table 2. Mean values and 95% confidence intervals (lower and upper bound in parantheses) of Malmquist indexes before (2001–2003) and after (2004–2006) the accession to the EU

Time period	MPI	EffCh	TechCh
2001–2003	0.993 (0.950–1.043)*	1.029 (0.917–1.135)	0.964 (0.887–1.071)
2004–2006	0.974 (0.938–1.012)	0.974 (0.884–1.083)	1.000 (0.908–1.093)

*Mean values are geometric means and confidence intervals at 95% were derived with bootstrapping

RESULTS AND DISCUSSION

Productivity growth was negative for both periods and the decline was even larger after the accession to the EU (Table 2). The mean annual growth rate of the MPI was -0.7% in 2001–2003 and –2.6% in 2004–2006. Productivity decline in the pre-accession period was mainly induced by the technical component and by the efficiency component in the post-accession period. The EffCh was positive in the first period, with the annual growth rate of 2.9%. The decline in the TechCh halted in 2004–2006. This result is in accordance with the fast growth in investments to dairy farm assets (Table 1). Comparative studies about farm productivity changes in the transition period to the EU membership are still rare and Bielik et al. (2010) found no clear trend in the MPI change for the Trnava region in Slovakia in 2002–2006. We found narrow confidence intervals for the MPI (mean width 0.07–0.09) compared to 0.48 reported by Balcombe et al. (2008) for Polish agriculture and compared to 0.22 found by Olson and Vu (2009) for farms in the USA. The confidence intervals were remarkably larger for the EffCh and the TechCh than for the MPI. A similar tendency is found also by Olson and Vu (2009). A conclusion based purely on mean estimates may still be biased. Consideration of the confidence intervals reveals that in the case of all three presented indices, regress, stagnation or progress is possible for both periods. The previous studies have also highlighted that the differences found without bootstrapping may be non-significant (Brümmer 2001; Hansson 2007; Latruffe et al. 2008; Olson and Vu 2009). Confidence intervals derived with bootstrapping give the statistical evidence if the farm productivity indexes are significantly different from unity and make it possible to determine the actual decline or growth for each single farm. This information can not be gleaned from the aggregated data with the mean values for all farms (Table 2).

To make more reliable conclusions about the productivity change, we grouped the studied Estonian dairy farms according to confidence intervals as (i) declining, (ii) stagnating, and (iii) growing. Farms whose 95% confidence interval included unity were classified as being in stagnation. Distribution of farms according to the MPI and the EffCh for the pre- and post-accession periods was significantly different (Table 3). The share of farms with the productivity decline has increased from 36% to 50% in transition to the EU membership. This is induced mainly by a significant deterioration in the EffCh. Only less than 1/3 of dairy farms experienced efficiency growth and their proportion decreased in the post-accession period. Most of the farms have stagnated in the TechCh and differences between the compared periods have been insignificant.

Determinants of productivity change

To interpret the possible determinants of changes in the MPI and its components, we used cumulative indices (i) for grouping the dataset and (ii) for ap-

Table 3. Farm distribution (%) according to productivity change before and after accession to the EU

Farm group	MPI		EffCh		TechCh	
	2001–2003	2004–2006	2001–2003	2004–2006	2001–2003	2004–2006
Decline	36	50	22	37	27	21
Growth	41	33	32	24	14	17
Stagnation	23	17	46	39	59	62
	$\chi^2 = 8.2$; $p = 0.016$		$\chi^2 = 12.9$; $p = 0.002$		$\chi^2 = 2.4$; $p = 0.306$	

Table 4. Determinants of productivity change grouped by the cumulative MPI

Criteria	Cumulative MPI in 2001–2006			
	≤0.2 (–0.388)[a]	–0.2–0 (–0.099)	≥0–0.2 (0.101)	≥0.2 (0.346)
Farms (%)	16	40	25	19
DEA score in 2000	0.842	0.796	0.796	0.668
DEA score in 2006	0.608	0.756	0.865	0.902
Milk per cow, annual change (%)	–0.2	4.3	5.5	7.0
Milk per cow in 2006 (kg)	4 724	6 074	6 528	6 894
Livestock units (LU)	48	88	96	169
Land per LU (ha)	2.8	2.6	2.7	2.2
Costs per LU (EEK)	11 914	13 256	14 001	14 651
Assets per LU (EEK)	33 254	31 126	3 0695	39 553
LU/AWU	13.3	16.3	17.3	16.9
Net investment per LU (EEK)	1 156	1 791	2 023	2 277

[a]group mean cumulative MPI is in parentheses

plying the second-stage regression. Dairy farms with the highest cumulative MPI can be called innovators and their proportion was 19% (Table 4). Innovators had the lowest initial DEA efficiency score and the highest score in 2006. This result is supported by the regression analysis – the initial efficiency score had a significant negative impact on the cumulative MPI and the efficiency change (Table 5).

A remarkable shift in the ranking of efficient dairy farms has happened in 2000–2006. Producers with a greater initial efficiency have undergone a significant regress and new "front-runners" have emerged. Odeck (2009) also found the correlation between the initial efficiency and the Malmquist index for Norwegian cereal growers, but with a reverse relation. Estonian dairy farms with the highest cumulative MPI had the fastest growth in milk yield per cow. Milk yield is the most frequently used indicator for dairy farms and it faithfully reflects the changes in farm productivity (Hansson 2007; Moreira et al. 2010). Milk yield had a significant positive relation with all three cumulative indices. Effective use of labour, expressed in livestock units per annual working unit, has been the second important success factor for the productivity and efficiency change. A frequently debated question in agricultural economics is optimal farm size. Most of studies reveal that it is not possible to determine the optimal farm size purely based on the efficiency and productivity indices since efficiently operating farms may range widely in size (Førsund and Hjalmarsson 2004; Vasiliev et al. 2008). In the current study, the innovators group had the largest herd (farm) size and the most efficient land use, but according to regression estimates both these factors were insignificant.

Capitalization (assets per livestock units) was positively related with the cumulative technical change.

Table 5. OLS regression results for the cumulative productivity, technical, and efficiency change

Variables	Cumulative MPI		Cumulative EffCh		Cumulative TechCh	
	coefficient	*t*-value	coefficient	*t*-value	coefficient	*t*-value
Intercept	0.095761	0.47	0.53334	2.54**	–0.431606	–3.94***
DEA score in 2000	–1.179923	–6.75***	–1.35648	–7.57***	–0.076983	–0.82
LU	0.000142	0.94	0.00003	0.20	0.000109	1.35
ha/LU	0.005981	0.19	0.01063	0.34	0.017443	1.06
Assets/LU	–0.000001	–0.44	–0.00000	–0.85	0.000002	2.01**
LU/AWU	0.006562	1.91*	0.00605	1.72*	0.002311	1.25
Milk per cow in 2006	0.000120	4.96***	0.00011	4.51***	0.000022	1.70*
Intermediate cons./LU	–0.000003	–0.21	–0.00001	–0.81	0.000012	1.73*

*, ** and *** significance at 90%, 95% and 99% respectively

This is a logical result since investments to assets are expected to promote technological advancement. Nevertheless, increasing investments and assets have not improved the MPI and efficiency change. Our result is supported by the study by Bielik et al. (2010) for Trnava region (Slovakia), where an increase in investments, a slight improvement in technical change (1.002) and a regress in efficiency change (0.994) were found after the accession to the EU.

The rapid increase in investments was fostered already by the support schemes (SAPARD program) in the pre-accession period and continued after the accession to the EU. The tendency that a fast increase in investments is not followed by the efficiency improvement has also been evident for Estonian cereal farms (Vasiliev et al. 2008). Latruffe et al. (2005), using the example of Polish farms, argued that subsidized investments might stimulate purchase of technology irrespective of farm size. It is possible to conclude that investments to Estonian dairy farms have often not been harnessed in the best possible way. The benefits from investments may emerge with a certain time lag, so analysis over a longer time period is needed in order to make more profound conclusions. The dynamic DEA model proposed by Färe and Grosskopf (1996) may provide new insights for further analysis. Low and negative impact of assets to the productivity and efficiency change may be due to the unbalanced (one-sided) investments and management decisions. Investments in Estonian dairy farms have been made mainly to the animal buildings and machinery, but the progress in capital assets are probably not supported by the farm operational decisions (feeding, grassland fertilization, etc.). Productivity of grasslands is for example very low in Estonia due to an insufficient fertilization (Roostalu et al. 2001).

In the current study, farm sub-grouping according to the cumulative MPI (Table 4) shows that farms with higher investments formed the group of the front-runners (highest MPI growth and highest efficiency score in final year). This conclusion is not apparent from regression analysis, which captures the general trend and does not reveal shifts between farms. The question of possible over-investments to farms in transition countries clearly needs a further study.

CONCLUSIONS

We detected a regress in productivity change of Estonian dairy farms in the studied period and the decline was greater after the accession to the EU. The share of farms with productivity decline has increased up to 50%. This was induced mainly by a significant deterioration in the efficiency component. Increased capitalization was not followed by the improvement in the MPI and the TechCh, which indicates that the investments have often not been used in the optimal way. A significant change in the group of farms forming the efficiency frontier has taken place during the transition to the EU membership. The farms with the highest cumulative MPI change had a lower initial efficiency score and the highest final year value. The initially efficient producers have undergone the opposite trend. Thus there have been structural changes in Estonian dairy farming and the new front-runners have emerged. The improvement in the milk yield, the efficient labour use, the high capitalization and investments were significant characteristics of the front-runners. Despite the mean negative trends in the MPI there have been very diverse changes on the farm level and only a minority showed good adoption ability in the transition period to the EU membership.

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Contact address:

Nikolay Vasiliev, Estonian University of Life Sciences, Institute of Agricultural and Environmental Sciences, Department of Soil Science and Agrochemistry, Fr. R. Kreutzwaldi 1, 51014 Tartu, Estonia
e-mail: nikolay.vasiliev@emu.ee