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Efficiency of Estonian grain farms in 2000–2004

Nikolay Vasiliev, Alar Astover, Mati Mõtte, Merrit Noormets, Endla Reintam, Hugo Roostalu
Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences, Kreutzwaldi 64, 51014 Tartu, Estonia, email: nivas@emu.ee
Eduard Matveev
Rural Economy Research Centre, Jäneda, Lääne-Virumaa, 73602, Estonia

The aim of this study is to analyse the efficiency of Estonian grain farms after Estonia's transition to a market economy and during the accession period to the European Union (EU). The non-parametric method Data Envelopment Analysis (DEA) was used to estimate the total technical, pure technical and scale efficiency of Estonian grain farms in 2000–2004. Mean total technical efficiency varied from 0.70 to 0.78. Of the grain farms 62% are operating under increasing returns to scale. Solely based on the DEA model it is not possible to determine optimum farm scale and the range of Estonian farm sizes operating efficiently is extensive. The most pure technically efficient farms were the smallest and the largest but the productivity of small farms is low compared to larger farms because of their small scale. Therefore, they are the least competitive. Since pre-accession period to the EU, large input slacks of capital have replaced the former excessive use of labour and land. This raises the question about the effects on efficiency of the EU's investment support schemes in new member states.

Keywords: Data Envelopment Analysis, scale efficiency, technical efficiency, farm size, grain farms, transition economies

Introduction

Estonian agriculture has overcome the major challenges of a transition economy in the last fifteen years; the Soviet-period subsidies that underpinned agricultural products in both production and the market place were almost wholly removed at Estonia's re-independence. Acting within the concept of free-market economies Estonia opened its markets and applied a liberalized trade policy at a time when the loss of the former regional markets in Russia were not immediately replaced by access to the EU market; in 1995 Estonia became a food importer.

Since Estonia became a full member of the EU in May 2004, the process of transition from

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the liberal economic policy of the 1990s to the EU Common Agricultural Policy (CAP) has been ongoing. The pre-accession program SAPARD (Special Accession Program for Agriculture and Rural Development) was launched successfully in Estonia in 2001. Subsidies under the SAPARD programme were aimed at improving the competitiveness of agriculture, rural development and entrepreneurship, and rural infrastructure so as to help the agriculture sector adjust to EU requirements and solve rural development problems. However, pre-accession subsidies may have induced inefficient investments through decisions to purchase machinery and equipment irrespective of farm size. Latruffe et al. (2005) have found overcapitalization of Polish farms but there is a lack of comparative evidence for excessive use of capital in other new EU member states.

The efficiency and productivity of grain production affects the national food supply (Vasiliev et al. 2006); in 2000–2004, Estonian farms supplied only 75% of the demand of the domestic cereal market. One of the key factors that determine the efficiency of a farm is the land area (Lund and Price 1998). An on-going trend throughout Europe is a decrease in the number of all farms with an increase in their average size (Stoate et al. 2001). This is also true of Estonia where the average size of agricultural holdings has increased from 21.5 ha in 2003 to 29.9 ha in 2005. While these figures may seem small, the increase in the dominance of holdings greater than 50 ha is quite striking, moving from 56% of all agricultural land in 2001, through 66% in 2003 to 73% in 2005. This trend is set to continue: according to the Estonian Agricultural Registers and Information Board database of agricultural subsidies, the average cereal growth area per farm was 68 ha in 2004. The transitional process and structural changes of Estonian farms have highlighted the need for econometric analysis of optimal farm size. Previous farm size-efficiency studies have shown that there are no uniform cross-national results (Gorton and Davidova 2004) and therefore the efficiency analysis of Estonian farms is justified not only at local scale but might be useful for concluding synthesis of size-efficiency relationship in other transitional economies.

Several authors have analysed general farm efficiency in the post-transition period in Central and Eastern European Countries (Mathijs and Swinnen 2001, Brümmer 2001, Latruffe et al. 2005) but, other than an analysis of the efficiency of Estonian dairy farms (Boussemart et al. 2006), comparative data for Estonian farms has not been available. Indeed Gorton and Davidova (2004), while showing that the link between deterministic factors and farm efficiency is dependent on the country of location and product specialisation, emphasized an absence of farm efficiency analysis in the Baltic States. A country-specific analysis of Estonian grain farms is therefore crucial for both an improvement in decision making at macro and microeconomic levels and for estimating the competitiveness of the Estonian grain sector. The aim of the present study is to analyse the total technical, pure technical and scale efficiency of Estonian grain farms following Estonia's transition to the market economy and during the accession period to the EU.

Methods and materials

Farm efficiency

The non-parametric method DEA was used to estimate the efficiency of Estonian grain farming in 2000–2004 (for more details about DEA see Färe et al. 1994). DEA application for efficiency analysis in agriculture and corresponding methodology has recently been described in numerous studies (Gorton and Davidova 2004, Lartuffe et al. 2005, Davidova and Latruffe 2007, Hansson 2007). DEA uses mathematical programming to produce a linear best practice frontier over the data and then calculates efficiency measures relative to this frontier. The objective of DEA is to determine the relative efficiency of each farm. DEA has two alternative orientations: input and output. The input-orientation model measures the proportional decrease in the use of inputs as output remains unchanged. The output-orientation model measures the proportional increase in output that can be attained with constant input.

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Efficiency measures, total technical efficiency, pure technical efficiency, scale efficiency, and input slacks were calculated using the software DEAP Version 2.1 (Coelli 1996). A farm achieves total technical efficiency if it produces on the boundary (frontier) of production possibility. Total technical efficiency (estimated under a constant return to scale) can be split into two scores, pure technical efficiency (estimated under a variable return to scale) and scale efficiency. Pure technical efficiency usually relates to management practices while scale efficiency is the ratio between total technical and pure technical efficiency. A total technical efficiency score of less than 1 indicates to what extent a farm can proportionally reduce all inputs and still produce the same level of output. Farms achieving total technical efficiency are assumed to operate at optimal scale. In the case of the input-oriented DEA model slacks indicate the excessive use of each input. A farm can un-proportionally reduce particular input by the amount of slacks without reducing output.

The sampling variability may lead overestimation of the DEA point estimates but sampling errors can be evaluated by using bootstrapping (Brümmer 2001). Ninety-five percent confidence intervals for DEA point estimates were constructed using the smoothed homogeneous bootstrap method proposed by Simar and Wilson (1998, 2000). The bandwidth parameters were chosen according to the normal reference rule (Simar and Wilson 2000) and 2000 bootstrap iterations were performed. A similar approach has been applied in several studies for the agricultural division of the DEA (Brümmer 2001, Latruffe et al. 2005, Hansson 2007). The programme FEAR (Wilson 2007) which works in the R software was used for bootstrapping procedure in this study.

Data used

An input-oriented model with a single-output but multiple inputs was applied using the Farm Accountancy Data Network (FADN) unbalanced panel data for each separate year (2000–2004). The Rural Economy Research Centre is responsible for the FADN survey in Estonia. Farms selected for the FADN database were those where grain production (cereals, legumes and oilseed crops) contributed more than 75% to the farm's total output. The analysed sample consisted of 338 such units – 62 farms in 2000 and 64, 78, 67 and 67 farms respectively in 2001, 2002, 2003 and 2004. Only 28 farms participated in each year. The dependent variable in the input-oriented DEA model was the total output in Euros (€). Four factors were included as inputs: Labour in the form of annual work units (AWU), land in the form of utilised agricultural area (UAA) in hectares, capital in the form of the value (€) of the total assets, and a variable factor in the form of the value (€) of intermediate consumption. The monetary values for both input and outputs were adjusted downward to 2000 values to reflect the substantial inflation that persisted in Estonia during the analysed period. The value of the total output was deflated by the index of agricultural output prices while the values of the capital and intermediate consumption were deflated by the index of agricultural input prices. Descriptive statistics for the output and inputs used are shown in Table 1. All the input values (except labour) and the total output value have increased 2–3 fold during the analysed period. The highest increase (3.2 fold) is the capital value.

Results

The mean total technical efficiency for all farms varied from 0.70 to 0.78 during the analysed period 2000–2004 (Table 2) with the lowest score of 0.18 occurring in 2002. The high variation in the total technical efficiency values indicates an unequal distribution of total technical efficiency throughout the sample. Mean total technical efficiency was lowest in 2000 and increased in the following years. The mean pure technical efficiency score has not significantly changed during these five years. The proportion of pure technically efficient farms was highest in 2003 when the mean pure technical efficiency was 0.86

Table 1. Descriptive statistics for variables applied in DEA.

Year	Mean	Standard deviation	Minimum	Maximum
Total output, €				
2000	44165	47694	4347	267928
2001	51062	58058	4612	312263
2002	73423	75982	2548	398065
2003	85493	78591	5753	377322
2004	96039	95866	7170	589195
Intermediate consumption, €				
2000	28105	33020	2681	165695
2001	35567	40695	3021	227599
2002	46869	51376	3433	323938
2003	58385	56772	4019	328214
2004	82443	82575	6716	481773
Total assets, €				
2000	91926	91287	6166	477442
2001	104826	111370	14038	659475
2002	171553	209629	7573	1233833
2003	230214	199784	7492	895977
2004	295475	252403	11571	1151937
Utilized agricultural area, ha				
2000	180	165	29	757
2001	179	150	31	820
2002	227	188	31	1133
2003	298	253	31	1444
2004	341	264	39	1441
Labour input, annual working units				
2000	2.4	2.9	0.5	19.3
2001	1.9	1.7	0.5	10.5
2002	2.6	2.4	0.7	13.3
2003	2.5	2.1	0.7	12
2004	2.6	2.1	0.7	12.6

Table 2. Descriptive results of efficiency estimates.

	Mean	Standard deviation	Minimum	Proportion of efficient farms (%)
Total technical efficiency				
2000	0.70	0.17	0.39	11
2001	0.77	0.16	0.42	14
2002	0.73	0.22	0.18	13
2003	0.78	0.19	0.37	18
2004	0.76	0.18	0.37	16
Pure technical efficiency				
2000	0.84	0.15	0.51	31
2001	0.85	0.15	0.43	33
2002	0.84	0.17	0.41	31
2003	0.86	0.15	0.54	37
2004	0.85	0.14	0.50	31
Scale efficiency				
2000	0.85	0.14	0.49	11
2001	0.90	0.12	0.59	17
2002	0.87	0.18	0.22	15
2003	0.90	0.14	0.42	18
2004	0.90	0.15	0.39	16

Table 3. The proportion (%) and size (ha) of farms according returns to scale – Constant, Increasing and Decreasing – as an average 2000–2004.

	Returns to scale		
	Decreasing	Constant	Increasing
Share of farms, %	23	15	62
Size, ha			
Mean ± Standard deviation	433±202.4	290±279.8	165±134.6
Confidence intervals ±95%	391–476	239–341	140–191
Minimum	120	39	29
Maximum	1444	842	769

with a standard deviation of 0.15. About 31–37% of the farms were identified as pure technical efficient and although the average score for scale efficiency was 0.90, fewer than one-fifth of the samples were operating at optimal scale.

The proportions of farms operating under increasing, constant or decreasing returns to scale (Table 3), indicate that those 62% of the grain farms operating under increasing returns to scale are nevertheless below their optimal scale. This in-

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fers that the majority of farms could gain efficiency by increasing size. The results also indicate that 23% of the farms are operating above their optimal scale and could therefore increase their efficiency through a size reduction. The mean size of farms differs significantly depending on the returns to scale. Farms operating under decreasing returns to scale have the widest range in size. The size of farms operating at constant returns to scale ranges from 39 to 842 ha.

To visualise the size-efficiency relationship of the pure technical and scale efficiency scores the grain farms were allocated to one of nine sequential size intervals; in principal that interval consisted of at least three farms each year. Grain farms with less than 100 ha have the lowest scale efficiency which increases sharply to around 100–150 ha and stabilises thereafter (Fig. 1). Pure technical efficiency and size have a shallow U-shape relationship. The highest scores for pure technical efficiency are to be found in farm sizes at opposite ends of the spectrum – the smallest and the largest – with a farm size of 300–400 ha being critical for low pure technical efficiency scores.

To estimate sampling variability of DEA point estimates the bootstrapping was performed according to the Simar and Wilson (2000) approach. The confidence intervals of point estimate of pure technical efficiency scores for size intervals are presented in Table 4. Point estimates of pure technical efficiency are higher than the upper bound of confidence intervals, which indicates that point estimates overstate the efficiency. The confidence intervals are relatively wide in all size groups but the highest width bounds are in the smallest farms. Based on the point estimate of pure technical efficiency, farms could reduce inputs by 15% on average, without reducing output. Confidence intervals indicate that an average of total sample inputs

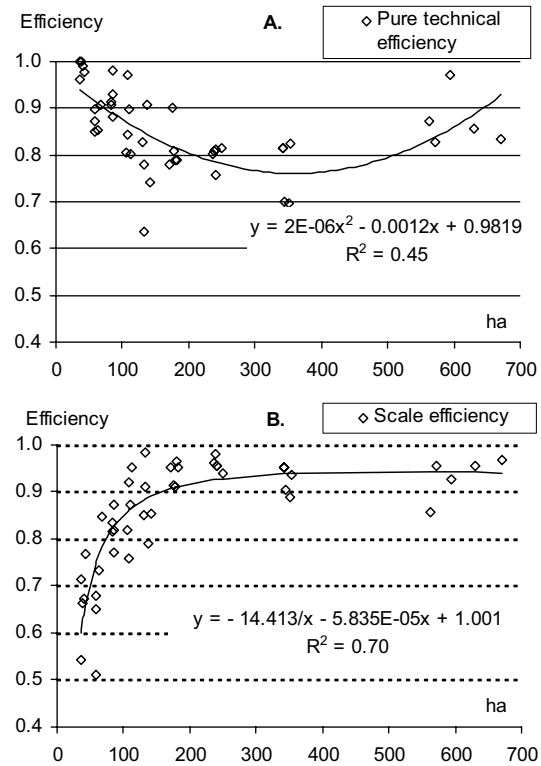

Fig. 1. Pure technical efficiency (A) and scale efficiency (B) as the function of arable land area of grain farms in 2000–2004.

Table 4. Mean point estimates and confidence intervals for pure technical efficiency of grain farms in 2000–2004 according to size (ha).

	Size intervals, ha									
	<50	50–75	75–100	100–125	125–150	150–200	200–300	300–400	>400	Total
Point estimate	0.98	0.88	0.92	0.86	0.76	0.82	0.80	0.80	0.85	0.85
Lower bound	0.74	0.73	0.75	0.72	0.65	0.69	0.68	0.68	0.67	0.70
Upper bound	0.97	0.87	0.92	0.85	0.76	0.81	0.80	0.79	0.85	0.84
Average width	0.23	0.14	0.17	0.13	0.11	0.12	0.12	0.11	0.18	0.14

could be reduced by between 16% and 30%.

Input slacks in DEA may essentially be handled as allocative inefficiency (Ferrier and Lovell 1990) and indicates spare capacity to use inputs in optimal proportions. A high slack-input ratio may imply a large potential to reduce input non-proportionally or a large variability of input quality (Thiele and Brodersen 1999). The highest slack-input ratio of labour during the study period was during 2000–2003 (Fig. 2) and although the slack-input ratio of labour has decreased from 12.2% to 4.3% throughout the period, land slack-input ratio has decreased 3.5-fold. The changes in the ratio of intermediate consumption were minimal but the slack-input ratio of capital has increased from 1.9% to 10.5%. The lowest ratio of input-slacks was for intermediate consumption.

To determine whether efficiency scores depend on soil quality, the sample farms were divided to two groups: low soil quality or high soil quality (Table 5). These sub-samples have mean value of soil quality respectively 37 and 46 points. In Estonia, the assessment of the soil quality of arable land is performed on a 100-point scale, an indicator that describes the productivity of soils. The higher value of soil quality is related to higher crop yield (Astover et al. 2006b). The FADN database does not include values for soil quality so weighted soil quality of arable fields for a given farm according to rural municipality location was used in dividing the farms. The Kolmogorov-Smirnov test indicates that only pure technical efficiency is significantly different distributed between soil quality groups (Table 5). Higher soil quality ensures better pure technical efficiency of grain farms.

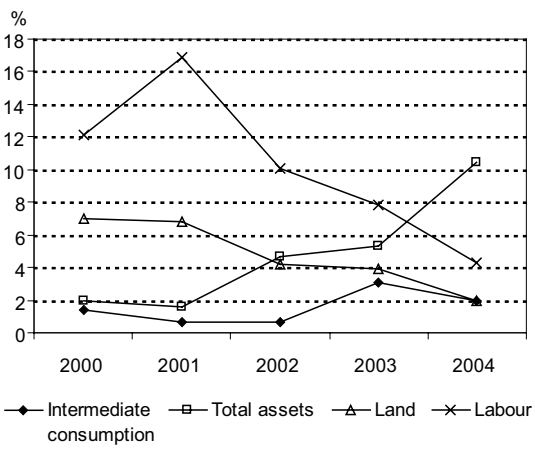

Fig. 2. Ratio (%) between DEA input slacks for total technical efficiency and average input level in 2000–2004.

Table 5. Mean efficiency scores in of grain farms located in municipalities with low and high soil quality in 2000–2004.

	Total technical efficiency	Pure technical efficiency	Scale efficiency
Low soil quality	0.74	0.82	0.90
High soil quality	0.76	0.88	0.87
Significance*, *p*	>0.1	<0.01	>0.1

* The Kolmogorov-Smirnov test was used to determine significant differences

Discussion

This is the first time that efficiency estimates of Estonian grain farms during the post-Soviet transition period have been calculated and published. This enables comparisons to be made with existing efficiency estimates for the majority of the Central and East European Countries that have undergone a similar transition. As a result of applying DEA to FADN data, Estonian grain farms can, when adopting best practice, proportionally reduce their input by 22–30% without decreasing output. This confirms the results by Boussemart et al. (2006) who found a similar potential for Estonian dairy farms to improve total technical efficiency by 23%. Gorton and Davidova (2004) suggest two explanations for the variations in farm efficiency: (i) the internal structure and agency factors and (ii) the inter-organisational arrangements. Pure technical inefficiency is often explained as a result of poor management practices. The slightly lower scores

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for pure technical efficiency than those for scale efficiency (Table 2) indicate that inefficiencies are more likely due to poor management practices than farm size. There is clearly a considerable unpredictability in efficiency among farms and this relatively high deviation points to a high diversity of management practices and skills between farms. Thiele and Brodersen (1999) discovered that the variance of farm efficiencies was higher in the former East Germany than in West Germany in 1995–1997 and argued that this was due to the greater inconsistency of management skills in the east during the transition period.

Optimal size varies depending upon each farm's particular input-output configuration (Jaforullah and Whiteman 2000). Kislev and Peterson (1996) pointed out that scale economies are short-term disequilibrium phenomena and appear only under certain circumstances. Studies concerning optimal farm size and size-efficiency relationship state that there are no uniform cross-national findings (Gorton and Davidova 2004). In our study the most pure technically efficient farms were the smallest and the largest. The small farms are pure technically efficient but their productivity is low compared to larger farms because of their small scale. Therefore, they are the least competitive. Latruffe et al. (2005) argued that knowing of the variability of point estimates is useful for detecting actual impact of farm size on efficiency. The widest width of confidence intervals in small farms (Table 4) affirms that point estimates are overstating mainly the efficiency of small grain farms but on average, the confidence intervals are also remarkable in other size intervals. High variability of point estimates for transitional countries is confirmed as well in previous studies (Brümmer 2001, Davidova and Latruffe 2007).

Only 15% of the farms with a mean size of 290 ha are operating at their optimal scale. Efficient farms can be found in each size interval (Fandel 2003) however Førsund and Hjalmarson (2004) have recommended that before any conclusions are made about optimal scales, based on DEA models, additional information should be taken into account. An earlier study of Estonian FADN grain farms (Vasiliev et al. 2006) has shown that profitability is negative for the smallest farms and highest in the size range from approximately 150 to 400 ha. The U-shape graphic depicting the relationship between size and pure technical efficiency in Estonian grain farms is also detected in other post-Soviet countries, specifically in Slovakia (Fandel 2003) and Poland (Lerman 2002, Latruffe et al. 2005). Small farms usually rely on labour intensive technology and use little capital (Allen and Lueck 1998). In developing countries where land and capital are scarce compared with labour, the higher pure technical efficiency of small farms is the result of the greater abundance of family labour (Hazell 2005). Furthermore family labour is usually more motivated and easier to manage than hired workers. For developed countries efficiency gains of small farms are less important. Munroe (2001) supposed that reliance on family labour – low capital input - allowed Polish farms to maintain agricultural output during transition periods. The relatively low cost of labour compared to other input factors during the study period was evident also in Estonia. Whereas small farms have a low intensity of labour usage and rely on low cost family labour, larger farms predominantly use relatively costlier hired labour. Estonian FADN grain farms that employ more than 2.6 workers per 100 ha are unprofitable (Vasiliev et al. 2006). As the current low level of wages in the agricultural sector is increasing, optimal use of labour will increasingly affect the competitiveness of grain producers. Despite the fact that the smallest farms have good pure technical efficiency scores, they have a low competitive ability in the Estonian grain sector.

Osborne and Trueblood (2006) recommended that Russian corporate farms should replace old machinery-intensive technology with more labour-using technology to improve farm efficiency. This kind of recommendation does not reflect the situation of Estonian grain farms. The pre-accession period to the EU has resulted in a sharp increase in capital investments (primarily machinery) and during the study period, labour use efficiency has improved by 10.2% a year ($r = 0.93$; $p < 0.01$). This result is supported also by decreased labour input-slacks (Fig. 2). In this study, we were unable to factor in differences in the quality of labour as an input variable although Thiele and Brodersen (1999) argue such

differences could result in higher input slacks.

Studies in farm efficiency analysis lack data (Munroe 2001, Gorton and Davidova 2004) regarding quality of other environmental factors, however Latruffe et al. (2004) did find a positive effect of soil quality on the efficiency of Polish crop farms. Soil quality is widely variable in Estonia. This undoubtedly can have a great influence on farm efficiency but since the soil quality in our study has no farm-specific values the results must be interpreted with caution. Soil quality has a significant influence on pure technical efficiency but not total and scale efficiency scores. The study's finding that better soil fertility causes higher pure technical efficiency is in accordance with the study's size-efficiency relationships (Fig. 1) because in our data sample there was a negative correlation ($r = -0.67$; $p < 0.01$) between soil quality and farm size.

Arguments for pure technical inefficiency include incorrect management decisions (i.e. overestimated seed or fertiliser rate) and imperfect markets for certain inputs as well as for marketing products. The external economic environment can have a greater influence on a farm's efficiency than the internal organisation (Brada and King 1993) and farm inefficiencies of transitional economies have been explained as an effect of disordered market conditions (Mathijs et al. 2000). Considering the low intensity of crop production practices in Estonia (Astover et al. 2006a), it is highly unlikely that the excessive use of inputs like fertilisers and pesticides is the reason for inefficiency. Relatively small slack-input ratio for intermediate consumption (Fig. 2) supports the conclusion about the small allocative inefficiency of this input factor. Latruffe et al. (2005) researching Polish farms reached a similar conclusion, as did Thiele and Brodersen (1999) when analysing efficiency of farms in West and the former East Germany. Insufficient fertilisation of Estonian agricultural land has led to three clearly negative results: First, only around 40–50% of the real yield potential of cereals is currently being realised (Roostalu et al. 2001); secondly, the nutrient balances of arable soils are predominantly negative (Astover et al. 2006a) and thirdly, Estonia's farms produce the lowest average cereal yield (in studied farms on average 1.9–2.3 Mg ha^{-1}) in the EU25 countries. This has caused negative self-sufficiency for cereals and endangers the national food supply. The use of fertilisers and other crop production inputs should be optimised according to the pedo-climatic and economic conditions for increasing crop production (Astover et al. 2006b). Considering the potential and necessity in Estonia to increase national agricultural self-sufficiency further, the output-oriented farm efficiency analysis will be also valuable. While the objective of current EU agri-environmental policy is to achieve less intensive production (Zalidis et al. 2004) and all input factors with the exception of intermediate consumption have shown high slacks in the study period, the analysis of the input-oriented DEA model is justified.

Although EU pre-accession investment subsidies (SAPARD) have stimulated a greater than 3-fold increase in capital value since 2001, this change has not been followed by an increase in efficiency. During the 1990s, capital investments on Estonian farms were minimal. Most of the machinery was dilapidated and in need of renewal, thus, when capital became available, as it did with SAPARD, investments crucial to maintaining crop production were to be expected. The increased capital input-slack ratio during 2000–2004 and our analysis of inefficiency determinants raises a question about the over-capitalisation of Estonian grain farms. This finding indicates a necessity for further studies into the efficiency of EU investment support in new member states. In their study in Poland, Latruffe et al. (2005) have shown that the highest input-slacks are those of capital. Their argument, using the Polish example, is that subsidised credit might stimulate purchase of machinery irrespective of farm size. A similar trend is also possible for Estonian grain farms.

Conclusions

The majority of Estonian grain farms have an increasing return to scale: less than a fifth are operating at their optimal size. A comparison with

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other studies confirms that there is no cross-national optimum farm size and the range of Estonian farm sizes operating efficiently is extensive. Despite the fact that the smallest farms have the highest pure technical efficiency, they are also the least competitive. Efficiency scores during 2000–2004 were practically unchanged but the key determinants of inefficiency have changed: inefficiency caused by the input-slack of capital has replaced the excessive use of labour and the land area factor. Although there is an argument that DEA results will also be useful for farm extension services (Jaforullah and Whiteman 2000), the large variations in the efficiency scores for farms in transition economies resulting from DEA on the one hand and Stochastic Frontier Analysis on the other (Brümmer 2001, Latruffe et al. 2004) infers the necessity to also apply other techniques to estimate the efficiency of agricultural production units.

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