Technical efficiency of Polish farms: Estimation according to specialisation and lessons from confidence intervals [1]

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Abstract

The technical and scale efficiency of Polish farms is analysed, using Data Envelopment Analysis. Efficiency differences are measured according to farm specialisation, in crop or livestock, at two points in time during transition, 1996 and 2000. The statistical variability of efficiency estimates is investigated. The efficiency results are reviewed in the light of confidence intervals provided by bootstrapping and of a summary measure introduced in this study 'the coefficient of separation'. The inference analysis suggests that farms might be less efficient than revealed by the point estimates alone, and that they might not be clearly different from each other.

Keywords: Poland, farms, technical efficiency, specialisation, bootstrapping

Introduction

Poland is a frontrunner for accession to the European Union (EU) and the largest of the ten Central and Eastern European countries (CEECs) that are candidates for EU membership. Its vast agricultural sector plays a crucial role in land use and in the employment of the rural population. As structural change has been slow, agriculture's share of rural employment remains high and agricultural employment has not fallen by as much as was expected (OECD, 1995). Agricultural labour productivity is low and in 1998 it was estimated to be only 8.4 per cent of the EU average (Pouliquen, 2001). In addition, according to this indicator, Poland is lagging behind most of the other CEECs. This suggests overmanning and disguised agricultural unemployment. At the same time, Polish farms seem to be significantly more capitalised than farms in the Czech Republic or Hungary (Davidova et al., 2002). All these facts raise questions about the efficiency of factor use in Polish farms.

Post-transitional efficiency studies on Polish agriculture have concentrated mainly on the relationship between efficiency (productivity) and size in individual private farms. Van Zyl et al. (1996) and Munroe (2001) reported a negative size-efficiency relationship. In addition, van Zyl et al. also argued that differences in scale efficiency between size groups were not statistically significant. Mech (1999), Davidova et al. (2002) and Lerman (2002) argued that larger farms were more efficient (productive). Obviously, even narrowing the discussion to the size-efficiency (productivity) relationship, the results are not consistent, and in addition, with the exception of Davidova et al. (2002) and Lerman (2002), they were based on data from the early stages of transition process.

This paper attempts to build on the existing studies in three ways. First, by providing estimates of technical and scale efficiency using the latest available data from 2000, and with data from an earlier stage in transition, 1996. Second, by investigating separately the efficiency of crop and livestock farms as there is not a detailed study analysing the efficiency variations in Polish farming according to specialisation. Third, by investigating the statistical variability of the efficiency estimates and reviewing them in the light of confidence intervals.

The paper is structured as follows. The next section provides a brief explanation of the methodology and data sets. Section three presents the results and section four discusses the methodological and policy conclusions.

Methodology and data sets

Polish farm efficiency in 1996 and 2000 was estimated by employing the non-parametric method Data Envelopment Analysis (DEA) (for more details see Färe et al. 1994; Thiele and Brodersen, 1999). An input-oriented single-output multi-input model was applied at the farm level using accountancy data similar to FADN. Total output in value was used as a single output variable. Four inputs were included: utilised agricultural area (UAA) in hectares as a land factor, annual work units (AWU) as a labour factor, depreciation plus interest as a capital factor, and intermediate consumption as a variable input factor. For

2000, all nominal values were deflated to adjust for the substantial inflation that persisted in Poland during the analysed period. Output was deflated by the index of agricultural output prices, depreciation and intermediate consumption by the index of agricultural input prices, and interest by the consumer price index.[2]

The analysis accounts for the sampling noise in the efficiency estimates ignored in previous studies about farm efficiency in CEECs, with the exception of Brümmer (2001). It investigates the sampling variability of DEA point estimates by correcting for bias inherent in the DEA procedure and by providing confidence intervals. Ninety-five per cent confidence intervals were constructed using bootstrapping. The smoothed homogenous bootstrap and the procedure proposed by Simar and Wilson (1998, 2000) were applied. The bandwidth parameters were chosen according to the normal reference rule (Simar and Wilson 2000) and 2000 bootstrapping iterations were performed.

For both periods 1996 and 2000 crop and livestock farms were separated into two sub-samples and a frontier was estimated for each specialisation. Farm specialisation was determined as a prevailing share of crop or livestock in the total farm output. This avoided the separation of crop and livestock enterprises and the allocation of enterprise specific inputs that would have involved strong assumptions about factor allocation. The specialisation criterion employed in this study was a share of minimum 65 per cent of the value of crop or livestock production in the total output.

The study employed data from the annual panel of bookkeeping farms surveyed by the Polish Institute of Agricultural and Food Economics (IERiGZ). For the present study, those farms that participated in both 1996 and 2000 surveys were selected, resulting in a sample size of 914 farms for each year. From these 914 farms, two sub-samples were constructed according to farm specialisation in crop and livestock. In 1996, there were 216 crop and 107 livestock farms and in 2000, 222 and 250 respectively. Overall, between 1996 and 2000

[2] Indices published by the Central Statistical Office (GUS) were used (GUS, 2001).

more farms became specialised, particularly in livestock production. Some variables characterising the two specialisations are presented in Table 1.

(Table 1)

As in the overall IERiGZ sample, all four sub-samples were not representative of the Polish farm population since they were biased towards larger farms (the size distribution of sample farms is presented in Table 2). This bias was due mainly to the fact that only farms keeping accountancy books were surveyed. Studying larger farms is adequate for the present research, as the interest is in farms that have commercial activities and will have to compete in the market of the enlarged Union. The smallest farms that do not keep accounting books are likely to continue to produce for self-consumption and are not expected to be market integrated even after the EU accession.

(Table 2)

Results

Total technical, pure technical and scale efficiency

Estimates of total technical, pure technical and scale efficiency are presented in Table 3. For each of the three efficiencies, the maximum score found was unity within the samples, therefore only minimums are reported here. The percentage of efficient farms represents the share of farms with an efficiency score of unity. Livestock farms were on average more technically efficient than crop ones and a higher share of livestock farms had a score of unity. The mean efficiency scores for both specialisations were lower in 2000 than in 1996, with less farms being perfectly efficient.[3] The scale efficiency was high for both specialisations and at both points in time, with higher scores being recorded by livestock farms. In 2000, the gap between the two specialisations increased, as the mean scale

[3] One of the possible reasons for the decrease in the mean efficiency between 1996 and 2000, particularly for the crop farms, could have been the influence of weather conditions. Both studied years were not very favourable towards agriculture but without exceptional crop damages. According to GUS, yields in the two studied years were within the expected range, but slightly higher in 1996 than in 2000 (GUS, 2001).

efficiency of crop farms dropped, whilst for livestock farms it remained unchanged. Although both specialisations were clustered towards high efficiency, crop farms were spread over a wider range of efficiency intervals. The shares of farms operating under constant (CRS), increasing (IRS) and decreasing (DRS) returns to scale indicate that in both time periods crop farms mostly operated under IRS (Table 4). Thus, one of the important conclusions of these results is that, using 2000 as a reference point, the majority of the farms could gain efficiency by increasing in size.

(Table 3)

(Table 4)

Size-efficiency relationship

As underlined in the introduction, most of the studies about the performance of Polish farms during transition focused on the size-efficiency (productivity) relationship and the reported results have not been in agreement. Graph 1 depicts the pure technical efficiency scores for livestock farms in 2000 with respect to 7 size intervals. The curve is U-shaped; the most efficient farms were the smallest and the largest. The curve of pure technical efficiency for crop farms is not as clearly shaped as that for livestock farms, but once the largest size group (over 50 ha) is broken down by size intervals, then a U-shaped curve is also apparent in the crop sector. These results are similar to Lerman's (2002) findings about the low efficiency of mid-sized farms. The scale efficiency according to size for livestock farms in 2000 is depicted on Graph 2. The smallest farms (between 1-2 and 2-5 ha) were the least efficient. The same conclusion applies to crop farms and to both specialisations in 1996. The efficiency results concerning the smallest farms should be considered with caution because, as already stated, the samples were biased towards large farms. However an ANOVA analysis for each size-efficiency result was conducted and suggested that farm size had a statistically significant impact on efficiency at 1 per cent level, except for the pure technical efficiency of livestock farms in 1996.

(Graph 1)

(Graph 2)

Statistical variability

The point estimates' confidence intervals constructed with bootstrapping are generally wide. The samples' average width ranges from 0.07 to 0.19. This suggests that the farms might be less efficient than revealed by the point estimates alone. For instance, the mean pure technical efficiency of the 2000 livestock sample showed that the farms could on average attain the same level of output by reducing their inputs by 26 per cent. However, the confidence intervals suggest that on average inputs could be reduced by between 28 and 41 per cent. Farms originally identified as being on the frontier, may in fact lie well below it. For example in 2000, livestock farms with a pure technical efficiency score of 1 have an average lower confidence bound of 0.55. The ranking of farms might be also different than originally estimated, as shown in Table 5. Bootstrapping reveals that with an average lower bound of 0.25, the smallest group (1-2 ha) might not be the most efficient, although these farms were originally estimated to be fully efficient. Moreover, there might not be any difference in mean efficiency between the five middle groups (from 2-5 ha to 15-50 ha), since the confidence intervals are fairly similar for these groups.

(Table 5)

In order to provide a summary statistic of the degree of overlap between confidence intervals, a useful measure is introduced in this study, which we call 'the coefficient of separation'. This statistic is calculated by taking each farm in turn and then identifying the farms in the sample that are significantly more efficient than it, that is to say the farms with a lower bound strictly greater than the upper bound for the farm in question. More precisely, the number N_1 of farms with lower bound strictly greater than the upper bound for the considered farm is counted. By repeating this process, it can be found that M_1 farms in the sample have N_1 farms significantly more efficient than them; M_2 farms have N_2 farms significantly more efficient etc. Graph 3 shows the relationship between the numbers N_1, $N_2 \ldots N_n$ and the numbers M_1, $M_2 \ldots M_n$, expressed as percentages of the sample for total technical efficiency of livestock farms in 2000. The coefficient of separation for the estimated sample is given by the area under the curve in comparison with the area under the bold line that would have applied in the case of perfect separation. For example, here 5 per cent of the farms on X-axis are significantly less efficient than 70 per cent of the farms on Y-axis. If the farms were perfectly separated, the curve would be the bold straight line and 5 per cent of the farms would be significantly less efficient than 95 per cent of the farms. In this example the coefficient of separation is 61 per cent. The coefficients for all other efficiency estimates were also low, between 41 per cent and 61 per cent, which is not a surprising result as wide intervals imply low separation. These measures show that it is difficult to identify farms that are significantly less or more efficient than the average.[4]

(Graph 3)

Despite the weakness of the findings about farm ranking, confidence intervals supported the results about the efficiency variation between specialisations. Except for pure technical efficiency in 2000, the livestock and crop farms' average confidence intervals do not overlap, with livestock farms being more efficient than crop farms in average. The intervals also confirmed that between 1996 and 2000 the efficiency of the livestock farms had decreased, but this could not be asserted with certainty for the crop farms.

Discussion and conclusions

From the methodological point of view this paper employed bootstrapping to determine the variability of DEA efficiency estimates and to produce estimates that were bias

[4] One cause of the high statistical variability might be the "curse of dimensionality" present in many non parametric methods (Simar and Wilson, 2000, pp. 55-56). The rate of convergence in this single-output multi-input model is $N^{-2/6}$, which is smaller than the typical rate in parametric estimation, $N^{-1/2}$. A large number of observations (N) would therefore be necessary to avoid very wide confidence intervals.

corrected. The usefulness of providing efficiency estimates that contain less bias is self-evident. However, knowing the variability of efficiency estimates is enormously helpful when conducting and evaluating subsequent analyses. In this study the variability of the estimates was found to be quite large, with confidence intervals sometimes in excess of 0.1 on average. The paper introduced a measure called the 'coefficient of separation' using the bootstrapped efficiency variability estimates. It provided a summary of the degree with which efficiency estimates could be said to distinguish between different farms in a statistically significant sense. It indicated that many farms could not be considered statistically significantly different from many others, even when the point estimates of their efficiencies indicated otherwise. The methodological implications are that any subsequent analysis using DEA scores may induce 'errors in variables bias' should they be used as explanatory variables. It may also explain the difficulty in assessing the importance of potential explanatory factors for efficiency. For example, knowing the variability of the DEA estimates produced in other studies, such as van Zyl et al (1996), might help explaining the failure to detect any impact of size on efficiency. Therefore, it suggests that any DEA study should employ bootstrapping as standard practice providing the sample sizes are not so large as to make it impractical.

From the policy point of view several of the findings need more extensive discussion. The first is that farms with prevailing livestock production in their output-mix were more efficient than farms with prevailing specialisation in arable farming. Livestock farms relied mostly on family labour while crop farms had a higher share of hired labour in their labour input, they were more capital intensive and had more land per unit of labour. The fact that livestock farms relied mainly on family labour might help explaining why they were found to be on average more technically efficient. The family labour is in full control of the resources and technology and, as the only residual claimant, has incentives for the most efficient resource use. Moving to hired labour involves gains from task specialisation, but may also result in shirking that can bring about a wasteful resource use. However, simple family farms face high capital costs and, therefore, use little capital (Allen and Lueck, 1998). Data in Table 1 support these arguments, as livestock farms used much less capital and land per unit of labour.

However, Allen and Lueck's model predicts that family labour and family controlled production narrow to stages strongly influenced by the biological processes, thus, they are more suited to crops and particularly to highly seasonal crops. The modern, more intensive, livestock technologies largely eliminate the influence of nature, and therefore farm organisations extensively using hired labour and benefiting from task specialisation are more often engaged in livestock farming. Despite this, empirical research on productivity and efficiency in economies in transition has often found that individual private farms engaged in livestock production are more efficient (productive) in comparison to their larger, often corporate, counterparts in crop production (Hughes, 2000; Mathijs and Swinnen, 2001). This might be due to the less intensive livestock technologies applied in these countries during transition. However, controversy still reigns and Mathijs et al. (1999) and Mathijs and Vranken (2000) argue that individual farms in the Czech Republic, Hungary and Slovakia are more efficient in crop production but not in dairy. Therefore, further research is necessary in order to confirm or reject the efficiency superiority of family type farming in livestock production during transition. What has been revealed in the current study might be a temporary situation. Once the transitional constraints, particularly those concerning the functioning of the land market, are removed crop farms would be able to increase to an efficient size and the efficiency relations between individual livestock and crop farms might change. Moving to a more intensive livestock technology might also undermine the positive effect of the reliance on family labour and might bring about a need for a higher task specialisation.

Another important result relates to the low pure technical efficiency in comparison to scale efficiency which suggests that inefficiencies are mostly due to inefficient management practices. The large decrease in the mean pure technical efficiency of livestock farms between 1996 and 2000 might have resulted from the lack of adaptation of their management practices to the market requirements. However, the increase in the standard deviation for pure technical efficiency in livestock farms during the same period suggests that with the development of transition process some managers started adapting better to the market pressures. In the crop farms' sample there were not substantial changes in the mean pure technical efficiency and in the standard deviation during this period.

The fact that inefficiencies in Polish farming are mainly due to management practices is a substantive issue that may undermine the competitiveness of Polish farms post-accession. The low level of education of farmers might be a substantial constraint to increase in efficiency. The degree of utilisation of production factors increases with the increase in education. Several studies testing the effect of education on farm efficiency found a positive relationship (Wu, 1977; Stefanou and Saxena, 1988). In Poland, 43 per cent of people engaged in agriculture have only elementary education, compared to 13 per cent in industry and 8 per cent in services (European Commission, 2001). People in farming are five times less likely to have a university degree than people engaged in other sectors of the economy. Improvement in human capital might be crucial for the future of Polish farming in the enlarged Union in two ways. First, it may improve the technical efficiency of those staying in farming, and second it may increase the opportunities for non-farm employment. This, in turn, may allow farmers to exit from agriculture, decreasing the overmanning in the sector and facilitating farm consolidation. Improving human capital is a long-term task and requires various policy instruments from setting-up young farmers to focusing extension service advice on improved management practices and better factor use. It is a difficult challenge, but it is central to the future competitiveness of Polish agriculture.

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Table 1: Variables characterising the sample livestock and crop farms

Variables	Livestock farms				Crop farms			
	Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum
				1996				
Total output (000 PLZ)	93.5	122.1	6.7	718.8	96.5	125.8	6.4	1,078.1
Land (ha)	19.8	20.5	1.3	126.6	42.3	75.6	2.3	754.5
Labour (AWU)	2.16	1.11	0.40	6.64	2.29	2.17	0.17	23.35
Capital (000 PLZ) [a]	8.3	9.8	0.3	50.4	11.6	13.7	0.4	107.6
Intermediate consumption (000 PLZ)	68.7	95.0	4.0	554.0	52.9	74.5	3.0	707.0
Capital / Labour (000 PLZ) [a]	3.4	2.5	0.4	13.2	5.2	6.5	0.7	84.3
Land / Labour (ha)	8.6	6.4	1.5	41.6	16.9	19.8	1.5	203.3
Hired labour (%)	4.6	11.1	0	58.4	12.5	19.1	0	93.2
Rented land (%)	16.9	24.0	0	96.3	24.0	30.0	0	100
				2000				
Total output (000 PLZ)	96.1	114.2	6.8	732.3	124.5	213.0	2.1	1,949.8
Land (ha)	21.4	20.1	1.1	161.0	48.3	84.1	1.6	754.5
Labour (AWU)	2.01	0.99	0.33	8.02	1.95	2.33	0.07	27.1
Capital (000 PLZ) [a]	10.4	11.4	0.4	92.1	18.0	26.6	0.6	266.3
Intermediate consumption (000 PLZ)	75.5	99.7	5.1	689.2	86.1	143.6	4.0	1,478.5
Capital / Labour (000 PLZ) [a]	4.8	3.8	0.4	26.0	9.6	7.7	1.2	54.8
Land / Labour (ha)	10.2	6.9	1.8	48.4	23.2	21.9	1.6	117.3
Hired labour (%)	6.9	12.3	0	72.1	13.5	19.3	0	91.9
Rented land (%)	17.7	21.3	0	96.0	23.0	27.4	0	100

[a] Capital is proxied by depreciation plus interest.

Table 2: Distribution of the sample farms according to area in hectares (%) [b]

Farm specialisation	Small farms			Medium farms		Large farms	
	1-2	2.01-5	5.01-7	7.01-10	10.01-15	15.01-50	>50
1996							
Livestock	0.9	14.0	5.6	13.1	21.5	37.4	7.5
Crop	0.0	5.6	9.3	13.9	11.6	35.2	24.5
2000							
Livestock	0.4	9.2	9.2	8.8	19.2	44.4	8.8
Crop	0.9	8.1	8.1	14.4	9.5	32.9	26.1

[b] The classification into small, medium-sized and large reflects the farm distribution in Poland. If it is compared with other countries, most of the farms should be categorised as small.

Table 3: Descriptive results of efficiency estimates

Farm specialisation	Mean	Standard deviation	Minimum	Share of full efficient farms (%)
Total technical efficiency				
1996				
Livestock	0.85	0.11	0.57	10
Crop	0.66	0.18	0.21	6
2000				
Livestock	0.71	0.15	0.38	7
Crop	0.57	0.18	0.18	3
Pure technical efficiency				
1996				
Livestock	0.88	0.10	0.58	20
Crop	0.7	0.17	0.28	10
2000				
Livestock	0.74	0.15	0.41	10
Crop	0.67	0.18	0.28	10
Scale efficiency				
1996				
Livestock	0.97	0.05	0.68	13
Crop	0.93	0.10	0.36	6
2000				
Livestock	0.97	0.06	0.68	10
Crop	0.86	0.17	0.18	3

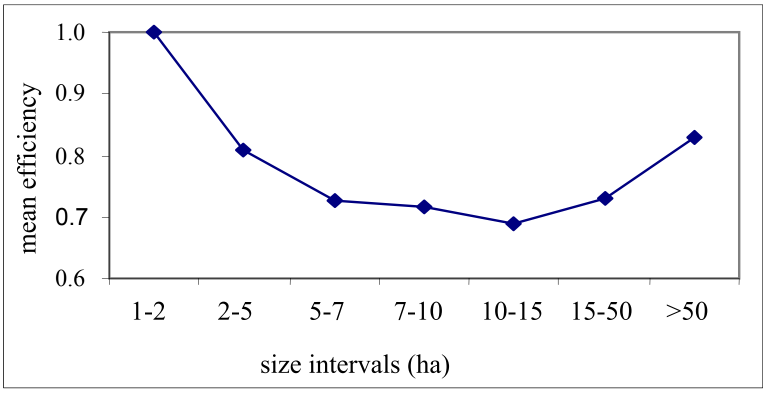
Table 4: Shares of farms with CRS (scale efficient), IRS and DRS (%)

Specialisation	Farms under CRS	Farms under DRS	Farms under IRS
1996			
Livestock	13	50	37
Crop	6	16	78
2000			
Livestock	10	26	64
Crop	3	11	86

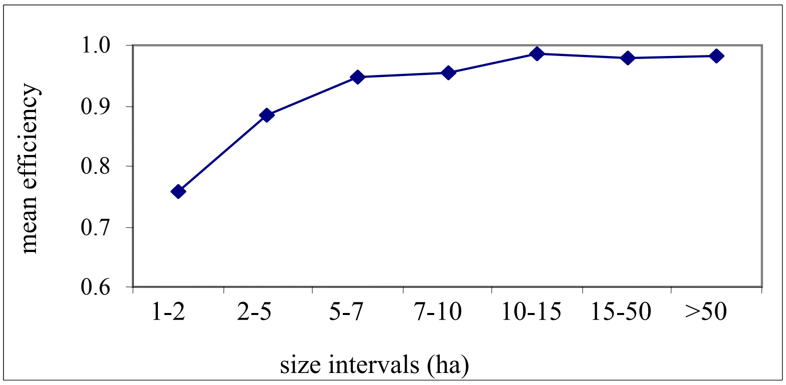
Table 5: Pure technical efficiency estimates and confidence interval bounds of livestock farms according to size, 2000

Size intervals (ha)	1-2	2-5	5-7	7-10	10-15	15-50	>50
Point estimate	1.00	0.81	0.73	0.71	0.69	0.73	0.83
Lower bound	0.25	0.54	0.58	0.60	0.60	0.61	0.51
Upper bound	0.98	0.79	0.71	0.70	0.67	0.71	0.81

Graph 1: Pure technical efficiency for livestock farms according to size (2000)



Graph 2: Scale efficiency for livestock farms according to size (2000)



Graph 3: Separation of farms using confidence bounds: livestock farms, total technical efficiency, 2000 (% of total sample)