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Determinants of technical efficiency of crop and livestock farms in Poland

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Abstract

Poland is one of the candidate countries for European Union membership that is currently experiencing acute structural problems within agriculture. This study analyses technical efficiency in 2000 for a panel of individual farms in Poland specialised in crop and livestock production. Technical efficiency is estimated with stochastic frontier analysis (SFA) and confidence intervals are constructed. Determinants of inefficiency are also evaluated. The SFA results are compared with results using Data Envelopment Analysis (DEA).

On average, livestock farms are more technically efficient than crop farms. For both specialisations, the size-efficiency relationship is positive *i.e.* large farms are more efficient. The SFA findings are generally supported by the DEA results. Soil quality and the degree of integration with downstream markets are highly important determinants of efficiency. Also education is a constraint to efficiency particularly for crop farms. The use of factor markets (land and labour) is important for crop farms, while livestock farms can rely on family labour and own land.

Keywords: Poland, farms, technical efficiency, specialisation, DEA, stochastic frontier, determinants

JEL classification: D24, Q12

Résumé

La Pologne est l'un des pays d'Europe de l'Est candidats à une accession à l'Union Européenne, qui rencontre de graves problèmes de restructuration agricole. Ce papier étudie l'efficacité technique en 2000 d'exploitations agricoles individuelles polonaises spécialisées en élevage et en grandes cultures. L'efficacité est estimée par la méthode de frontière stochastique, et sa variabilité statistique évaluée par la construction d'intervalles de confiance. Le papier examine également les déterminants de l'efficacité. Les résultats obtenus pas la méthode de frontière stochastique sont comparés avec ceux obtenus par la méthode de Data Envelopment Analysis (DEA).

En moyenne, l'efficacité technique des exploitations d'élevage est supérieure à celle des exploitations de grandes cultures. Pour les deux spécialisations, la relation entre l'efficacité et la taille des exploitations est positive : les grandes exploitations sont les plus efficaces. Les résultats obtenus par la méthode de frontière stochastique sont généralement confirmés par la méthode DEA. La qualité de la terre et le degré d'intégration dans les marchés d'aval sont d'importants déterminants de l'efficacité. La faible éducation est un obstacle majeur à l'efficacité, en particulier pour les exploitations de grandes cultures. De plus, celles-ci utilisent beaucoup les marchés de facteurs (terre et travail), alors que les exploitations d'élevage utilisent plutôt leurs propres terres et le travail familial.

Mots clé: Pologne, exploitations agricoles, efficacité technique, spécialisation, DEA, frontière stochastique, déterminants

Classification JEL: D24, Q12

Determinants of technical efficiency of crop and livestock farms in Poland

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1. Introduction

Poland is one of the candidate countries for European Union membership that is currently experiencing acute structural problems within agriculture. The prevalence of small-scale farming coupled with a high average density of agricultural employment per hectare, 3.2 times the European Union level (Pouliquen, 2001), creates doubts about the future viability of Polish agriculture in an enlarged Union. The public view of the Polish Ministry of Agriculture is that in the medium term only 400 to 500 thousand market farms are sustainable (European Commission, 1998). This figure has to be viewed relative to the total number of farm holdings in Poland which produce for the market. According to the last agricultural survey there were 1.5 million of such farms in 2000 (GUS, 2001). For this reason shedding light on the efficiency of Polish farms and its determinants is of substantial policy relevance.

The objective of the paper is to analyse differences in technical efficiency between Polish livestock and crop farms and to evaluate various determinants of inefficiency for both specialisations. The determinants include various farm characteristics, including size, soil conditions, use of hired or rented factors and human capital characteristics. The stochastic frontier approach is used in conjunction with the construction of confidence intervals for the efficiency scores. The results are compared with those of a previous study employing Data Envelopment Analysis in order to assess the consistency and robustness of the results.

The paper is structured as follows. The next section reviews previous studies on determinants of technical efficiency in Central and Eastern European Countries (CEECs). Section 3 presents the theory behind the stochastic frontier approach, whilst section 4 explains the methodology and describes the data set. Section 5 discusses the results and section 6 compares them with results from Data Envelopment Analysis. Section 7 concludes.

2. Previous studies about determinants of technical efficiency in CEECs

Three groups of variables are generally investigated in studies concerning the determinants of technical efficiency at the farm level. These are characteristics of the farm and technology employed, locational and environmental variables characterising the conditions for farming, and human capital variables. Farm characteristics always include farm size although there is little agreement how to measure the economic farm size. Lund and Price (1998) underline that there is no generally accepted measure in economics literature. Various measures have been used in various contexts: output, sales, inputs and incomes. Standard man-days and standard gross margin have also been applied. Utilised agricultural area can be a good proxy for size in a crop farm but is deficient in characterising the size of intensive livestock farming. Curtiss (2000) for Czech crop farms and Morrison (2000) for Slovakian crop farms measure the size in terms of hectares and find a positive relationship with the technical efficiency. For livestock farms, Morrison uses the number of feeding days in Slovakia, while Mathijs and Vranken (2000) employ the value of total output for crop and dairy farms in Hungary and Bulgaria. These authors also found a positive relationship, except for Bulgarian crop farms. Generally, the findings about size-efficiency relationship seem to confirm an L-shaped average cost curve. Larger farms attain economies of size by spreading fixed costs over more land and output, by getting volume discounts for purchased inputs, or by achieving a better market access and higher prices for large volumes delivered (Hall and LeVeen, 1978).

The organisational type of the farm is also commonly included as a farm characteristic in studies on transition economies (Curtiss, 2000; Mathijs and Swinnen, 2001). Debate about the efficiency of different post-reform farm structures will not be reviewed here since this study focuses only on those individual farms that are the prevailing organisational form in Poland. However, the results here do not reveal any clear efficiency superiority of family farming over corporate type of structures, such as producer co-operatives or various types of farming companies, which are prevailing in some transition economies.

Several authors also investigate the effect of specialisation on technical efficiency. Mathijs and Vranken (2000) for Hungary and Bulgaria, Curtiss (2000) for the Czech Republic and Brümmer (2001) for Slovenia all find that highly specialised farms are more technically efficient. The effect of technology is studied through factor intensity. Mathijs and Vranken (2000) report that Bulgarian crop farms that are more capital intensive are more efficient.

Efficiency variations between farms can also be explained by the farm locational and environmental characteristics. Farm location is important since farms may operate under different climate or altitude conditions, and different soil quality. Brümmer (2001) reports that Slovenian farms are less efficient in altitudes above 600 metres. Morrison (2000) also finds that agro-climatic region has a significant impact on technical efficiency of Slovakian farms. As noted by Bhalla and Roy (1988), land quality is also an important factor. Unfortunately, existing efficiency studies for CEECs usually do not employ this variable, although van Zyl *et al*. (1996) adjust farm size for differences in land quality within regions in Poland. The physical infrastructure can also differ regionally. Munroe (2001) finds that Polish farmers with higher modernisation, in terms of use of electricity and gas heating, are more technically efficient.

Finally, much emphasis has been placed on the characteristics of on-farm human capital. The effect of the principal farmer's age on efficiency has been extensively studied, but the conclusions are not consistent. Mathijs and Vranken (2000) and Munroe (2001) consider age as a proxy for farming experience and find a positive relation with technical efficiency in samples of Hungarian and Polish crop farms, but a negative effect in Bulgarian crop farms and Hungarian dairy farms. Mathijs and Vranken (2000) also include education and the share of women in the household. Both variables have a positive impact on efficiency in Hungary and Bulgaria. Finally the concentration on farming has also been explored. Brümmer (2001) notes that full-time farmers in Slovenia are more technically efficient than people involved in part-time farming.

Some of the aforementioned variables will be explored in the present study of the Polish farms. However, some additional variables will be included in order to characterise soil quality and integration to the market, up- and down-stream.

3. Stochastic Frontier theory

Broadly, three quantitative approaches are developed for measurement of production efficiency: parametric (deterministic and stochastic), non-parametric based on Data Envelopment Analysis (DEA), and productivity indices based on growth accounting and index theory principles (Coelli *et al*., 1998). Stochastic Frontier Analysis (SFA) and DEA are the most commonly used methods. Both methods estimate the efficient frontier and calculate the firm's technical efficiency relative to it. The SFA approach requires that a functional form be specified for the frontier production function. The DEA approach uses linear programming to construct a piece-wise frontier that envelops the observations of all firms. The frontier shows the best performance observed among the firms and it is considered as the efficient frontier. An advantage of the DEA method is that multiple inputs and outputs can be considered simultaneously, and inputs and outputs can be quantified using different units of measurement. Moreover, DEA allows calculating scale efficiency. However, a strong point of SFA in comparison to DEA is that it takes into account measurement errors and other noise in the data [1]. This point is very important for studies of transition economies as data generally include measurement errors (Morrison, 2000). For this reason the present study employs SFA.

The stochastic frontier model was simultaneously proposed by Aigner *et al*. (1977) and by Meeusen and van den Broeck (1977). In contrast to a deterministic model it includes a random term representing the noise.

The model for the i-th farm is written as follows:

$$\ln(y_i) = f(x_i, \beta) + v_i - u_i \quad (1)$$

where

y_i is the observed output quantity of the i-th farm;

f is the production function;

x_i is a vector of the input quantities used by the farm;

β is a vector of parameters to be estimated;

v_i is an error term, independent and identically distributed (iid) with $N(0, \sigma_v^2)$;

[1] A more detailed comparison between SFA and DEA can be found in Coelli *et al.*(1998).

u_i is a non-negative random term, accounting for inefficiency, iid, with $N(\mu_i,\sigma_u^2)$, truncated to zero to ensure non-negativeness.

The technical efficiency of the i-th farm is given by $TE_i = \exp(-u_i)$ and has a value between 0 and 1, with 1 defining a technically efficient farm. Since only the difference between both random terms $w_i = v_i-u_i$ can be observed, u_i is predicted by its conditional expectation given the estimated value of w_i: $E[u_i|w_i]$ (Coelli *et al.*, 1998). The conditional distribution of $u_i|w_i$ is that of a truncated $N(\mu_i^*,\sigma^{*2})$, where $\mu_i^*=(w_i\sigma_u^2-\mu_i\sigma_v^2)/(\sigma_u^2+\sigma_v^2)$ and $\sigma^{*2}=\sigma_u^2\sigma_v^2/(\sigma_u^2+\sigma_v^2)$ (Jondrow *et al.*, 1982).

The technical inefficiency effects u_i are frequently estimated in a first step and the determinants of inefficiency are obtained in a second-stage regression. However, this can induce both bias and inefficiency in the estimates. Therefore, inefficiency effects are simultaneously conditioned on several specific factors and estimated using the parameterisation (Battese and Coelli, 1995):

$$\mu_i = \delta_0 + z_i\delta \tag{2}$$

where

z_i is a vector of observable explanatory variables;

δ_0 and δ are respectively a parameter and a vector of parameters to be estimated.

The construction of confidence intervals is straightforward given distributional assumptions about the random terms. TE_i is a monotonic transformation of u_i, therefore, the lower and upper bounds L_i and U_i of the $(1-\alpha)$-percent confidence interval for $u_i|w_i$ are translated directly into upper and lower bounds on $TE_i|w_i = \exp(-u_i)|w_i$. They are given by (Horrace and Schmidt, 1996):

$$L_i = \exp(-\mu_i * - z_L\sigma *) \tag{3}$$

$$U_i = \exp(-\mu_i * - z_U\sigma *)$$

where the quantiles z_L and z_U are calculated as

$$Pr(Z>z_L) = (\alpha/2)[1-\Phi(-\mu_i^*/\sigma^*)] \tag{4}$$

$$Pr(Z>z_U) = (1-\alpha/2)[1-\Phi(-\mu_i^*/\sigma^*)].$$

Z follows a standard normal distribution, therefore the quantiles are:

$$z_L = \Phi^{-1}\{1-(\alpha/2)[1-\Phi(-\mu_i*/\sigma^*)]\} \quad (5)$$

$$z_U = \Phi^{-1}\{1-(1-\alpha/2)[1-\Phi(-\mu_i*/\sigma^*)]\}$$

with Φ the standard normal cumulative density function.

4. Methodology and data employed

The production function for SFA was specified here as a Cobb-Douglas. Specifications such as the translog provide the opportunity to characterise the data in a more flexible way. However, with limited data it also tends to be overparameterised. Attempts to use a translog induced convergence failures possibly for this reason, hence the more restrictive Cobb-Douglas form was used. Using data from transitional economies, other researchers, *e.g.* Mathijs and Swinnen (2001), also opted for the Cobb-Douglas for similar reason. A single output variable, total output in value, has been used. Four inputs have been included: utilised agricultural area (UAA) in hectares as land factor, annual work units (AWU) as labour factor, depreciation plus interests as capital factor, and intermediate consumption as variable factor. The 95 per cent confidence intervals of the SFA efficiency scores were constructed.

As discussed in section 2, explanatory variables for inefficiency have been included in the model. The choice of variables in the final model has been subject to data availability and the requirement that the model is statistically significant. This significance can be evaluated through the significance of the parameter γ, defined as $\gamma = \sigma_u^2/(\sigma_u^2+\sigma_v^2)$ (Singh *et al.*, 2000). This parameter represents the share of the deviation from the frontier that can be attributed to inefficiency (the rest being attributed to noise) (Coelli *et al.*, 1998). However, most authors use hypothesis testing to evaluate the model (Curtiss, 2000; Morrison, 2000; Abdulai and Eberlin, 2001). This involves testing whether the coefficients δ in (2) are significantly different from zero. The hypothesis H_0 $\{\delta_k=0\ \forall k\}$ is tested (Battese and Coelli, 1995). A third constraint specific to this study is the comparison between livestock and crop specialisations. The same determinants for livestock and crop farms have to be chosen in order to compare their effects according to specialisation. Several models were tested in the light of this.

The need to specify a functional form, using SFA, is problematic because the paper attempts to analyse efficiency variations within the sector, according to size and specialisation. As pointed out by Mathijs and Swinnen (2001), small and large farms might operate with different production functions. Moreover, here livestock and crop farms are analysed separately, and it may not be valid to use the same production function for both sectors (this has been also noted by Abdulai and Eberlin, 2001, estimating efficiency of maize and beans producers in Nicaragua). Thus, as in Mathijs and Swinnen (2001), a comparison with results from DEA was carried out in order to evaluate the consistency and robustness of the results.

This study uses data from the annual survey of individual farms carried out by the Polish Institute of Agricultural and Food Economy (IERiGZ). Two sub-samples were selected according to farm specialisation, crop and livestock. The specialisation criterion was set at 65 per cent of the total output coming from crop or livestock production respectively. This threshold is not as high as in some other efficiency studies for transitional economies (*e.g.* Mathijs *et al*., 1999 applied 75 per cent for a Czech farm sample) but it is justified by the fact that the Polish farms are generally not highly specialised. According to this criterion, there were 222 crop and 250 livestock farms. However, similarly to the overall IERiGZ sample, both sub-samples are not representative for the Polish farm population since they are biased towards larger farms. For example, the 2000 agricultural yearbook of the Central Statistical Office (GUS, 2001) indicates that 23.8 per cent of Polish farms have an average land area between 1-2 ha and only 9.9 per cent have more than 15 ha. In the IERiGZ sample these shares are 1.3 and 48 per cent respectively. In both samples used in this analysis, although the smallest farms are included, the proportion of farms above 15 ha is even higher than in the overall IERiGZ sample (Table 1).

(Table 1)

Some basic characteristics of the sample farms are presented in Table 2. Crop farms have a larger mean land. Crop farms are also larger than livestock when size is measured by total assets in Polish zloty (PLZ). The more labour intensive character of livestock production is reflected in the fact that, when comparing the size according to labour input measured in AWU, the difference between crop and livestock disappears. Standard deviations show that the livestock farms are more clustered around the mean than crop farms according to the three size measures.

(Table 2)

5. Results

5.1. Technical efficiency estimates

Summary statistics for technical efficiency are presented in Table 3 and suggest that specialised livestock farms are, on average, more technically efficient than crop farms. Although the maximum score found within each sample is quite similar and close to the unity, the crop sample presents a minimum score that is much lower than for livestock farms and has a greater standard deviation. The results from previous empirical studies of production efficiency of crop and livestock farms in transition economies vary. Mathijs and Swinnen (2001) for East Germany and Hughes (2000) for Hungary report a higher average technical efficiency for livestock farms that is consistent with the estimates in this study, while Mathijs *et al.* (1999) and Mathijs and Vranken (2000) conclude that crop farms in the Czech Republic, Hungary and Slovakia are more efficient.

(Table 3)

Graphs 1 and 2 depict average technical efficiency scores with respect to 7 size intervals for both samples. Among livestock farms, large farms (over 15 ha) are the most efficient, and substantially more than the middle-sized farms. The curve for crop farms is Γ-shaped, clearly showing that the smallest farms (under 2 ha) have a very low efficiency. An ANOVA analysis for the efficiency estimates showed that farm size has a highly significant impact on efficiency (Table 7 in Appendix).

(Graph 1) (Graph 2)

5.2. Statistical robustness

The confidence intervals calculated as in (3) are very wide and overlap. The average width is 0.51 for the livestock sample and 0.53 for the crop sample. It shows that it is difficult to identify farms that are significantly less, or more, efficient than the average.

5.3. Determinants of inefficiency

Table 4 reports the results provided by the SFA model. The first part of the table presents the estimated parameters of the production function. Expected positive signs are found for land input for livestock farms, and for labour input and variable inputs (intermediate consumption) for both samples. The negative sign of the land input coefficient for crop farms is surprising. However, the parameter is not significantly different from zero. Mathijs and Swinnen (2001) also found an unexpected negative sign for labour input for East German farms, and attributed it to misspecification. However, such an argument is not compelling for the capital input (depreciation plus interest) for both samples since there is a highly significant negative sign. This may be due to the characteristics of the equipment in Polish farms. A large part of the machinery owned by the farms is very old and perhaps less productive. For example, the European Commission reports that only 5.9 per cent of the total number of tractors were made in the period 1991-1996, all the others were older (European Commission, 1998).

(Table 4)

The second part of Table 4 presents the results for inefficiency effects model. Several models have been estimated and models that fitted well to one specialisation appeared poorly suited for the other specialisation. Although the coefficients of the final model presented in Table 4 are not significant for some determinants, for both samples the parameter γ is highly significant and the hypothesis H_0 is rejected.

Most of the signs related to the inefficiency determinants are as expected and are similar for livestock and crop farms. Although the size of the farms, represented by the total output, has little impact (the coefficient is close to zero), it positively affects efficiency. This confirms the relationship depicted on Graphs 1 and 2. The degree of market integration with down-stream markets, defined as the ratio of total revenue over total output, gives an idea about how much of its output the farm sells on the market. As expected, more commercially oriented farms are more efficient. Moreover the large absolute value of the coefficient suggests that this variable is an important determinant of efficiency particularly for crop farms. The negative sign linked to the soil quality index is also expected. The greater the soil quality, the higher the efficiency. It may appear strange that soil quality is a determinant for livestock farms, but this might be due to the fact that feed is mostly produced on-farm. It is logical, however, that the parameter for livestock sample is much lower than the one for crop farms, meaning that soil quality matters less for the livestock sector. For both specialisations older farmers are less efficient, but the small value of the coefficients suggests that the age is not a major constraint to efficiency. An interesting result is the different sign attached to the share of hired labour for livestock and crop farms. The more hired labour they employ, the more efficient crop farms are. The opposite is true for livestock farms. This suggests that crop farms need some external labour to perform specialised tasks while livestock production that requires closer and permanent attention is more efficient with family labour input. The latter, as the residual claimant, might be better motivated for good husbandry.

6. Comparison with Data Envelopment Analysis (DEA) results

6.1. Efficiency estimation and confidence intervals

The same data set was employed to estimate technical efficiency through DEA employing bootstrapping to construct confidence intervals (Simar and Wilson, 1998 and 2000). The efficiency estimates computed by DEA under constant returns to scale are used for the comparison with SFA estimates (Table 5). As in the case of SFA, livestock farms are on average more technically efficient than crop farms. Not surprisingly, the average technical efficiency estimated by DEA is lower than the one estimated by SFA, as DEA attributes the overall distance from the frontier to inefficiency only. Most of the studies using both DEA and SFA report such conclusions (Fraser and Kim, 2001; Brümmer, 2001). Mathijs and Swinnen (2001) for East German farms present SFA estimates greater than DEA. However they argue that this might be a result of misspecification of the production function. In the current study, the difference between the means of DEA and SFA efficiency estimates is large, 0.17 and 0.16 for livestock and crop farms. This is not a surprising result for data from transitional economies, where substantial measurement errors can be expected (Morrison, 2000). Brümmer (2001) also found large differences when estimating technical efficiency for Slovenian farms with DEA and SFA (0.32 and 0.29 for different years).

The standard deviations given by both methods are quite similar for crop farms, but different for livestock farms, where the standard deviation of SFA estimation is very small. This is due to the high mean of SFA efficiency score.

In contrast to DEA, no farm is found to be totally efficient using SFA estimation. This difference stems from the specifics of the methods applied. In DEA the frontier is determined by the best practice observed. Both methods suggest, however, that the minimum estimated efficiency for crop farms is much lower than for livestock farms, while the maximum for both samples is very similar. This shows that in crop production some of the farms lag far behind and they might reduce the mean efficiency of the sample.

(Table 5)

The shapes of the curves depicting the size-efficiency relationship are consistent between both methods. Livestock farms present a U-shaped curve, less clear-cut with SFA, while the curve for crop farms is Γ-shaped (Graphs 3 and 4) [2]. An ANOVA showing the significance of size for DEA estimates is presented in Appendix (Table 7). Both methods confirm that the largest livestock farms are the most efficient, while the large and medium-size crop farms are almost equally efficient. It is, however, difficult to draw clear conclusions for the smallest farms.

(Graph 3) (Graph 4)

The confidence intervals constructed with bootstrapping are narrower than the intervals obtained with (3) in the SFA case. However, they are also wide. They present a sample's average width of 0.10 and 0.13 for livestock and crop farms respectively. While this result does not undermine the overall findings about average efficiency, it does indicate that researchers should be cautious about making conclusions concerning the relative efficiencies of specific farms on the basis of point estimates of efficiency alone. The results herein may reflect variability that is not representative of other samples. However, it would be the contention here that farm specific efficiency scores should be treated cautiously in any DEA analysis, where standard errors for these efficiencies have not been calculated.

6.2. Determinants of inefficiency

A Tobit regression (Green, 1993) of DEA efficiency estimates on potential determinants was also undertaken and compared with the SFA results. A Tobit regression is required

[2] The difference in the shape of the curves between livestock and crop farms might reflect the different influence of the components of the total technical efficiency. Another DEA conducted under variable returns to scale shows that for both specialisations the relationship between pure technical efficiency and farm size is a U-shaped curve, while the relationship between scale efficiency and farm size is a Γ-curve. Thus, the total technical efficiency for livestock farms depicted on Graphs 1 and 3 represents mostly pure technical efficiency, while the total technical efficiency for crop farms depicted on Graphs 2 and 4 represents mostly scale efficiency.

because the inefficiency estimates are truncated at 0 and 1. The results are presented in Table 6.

(Table 6)

The results are consistent with the SFA inefficiency effects model. The same sign and relative values for livestock and crop farms are found for the size variable, share of hired labour, degree of market integration, soil quality and age. Technology is represented in the determinants by the ratios of capital over labour and land over labour. Although the negative sign related to the land intensity can be expected, the positive sign related to the capital intensity ratio is surprising. It shows that more capital-intensive farms are less efficient, which is contradictory to the expectations and is not consistent with results reported for other countries in transition (Mathijs and Vranken, 2000). However, this might be explained by the obsolete equipment used by Polish farms. An additional variable representing a proxy for integration in factor markets has been included, the share of rented land. The result is similar to that for the use of external labour. Unlike crop farms, livestock operations are more efficient if they rely on their own land. This might be due to the fact that they can achieve efficient size with much less land than crop farms and renting land might not contribute to efficiency. The positive relationship between the education dummy and inefficiency is not surprising, bearing in mind that the value of 1 means no agricultural education. Lower educated farmers are less efficient. The relative values of the coefficient suggest that education is particularly a strong determinant for crop farms efficiency.

7. Conclusions

This study analysed technical efficiency and its determinants for a panel of individual farms in Poland specialised in crop and livestock in 2000. Technical efficiency was estimated with the parametric method, SFA, and confidence intervals were constructed. Determinants of inefficiency were also evaluated. The SFA results were compared with results using DEA.

On average, livestock farms are more technically efficient than crop farms. For both specialisations, the size-efficiency relationship is positive and, thus, large farms are more efficient. The SFA findings are generally supported by the DEA results. The study suggests that soil quality and the degree of integration with downstream markets are important determinants of efficiency. Also, the use of factor markets (land and labour) is found important for crop farms, while livestock farms could rely on family labour and own land.

The results of this study underline that policy measures that can facilitate a farm size increase might have beneficial effects on efficiency due to the positive size-efficiency relationship. In addition, for crop farms the development of land leasing is also a substantial factor, as the share of rented land positively affects the technical efficiency. Therefore, policies stimulating land market and assisting small farmers to move to non-agricultural employment may contribute to increase technical efficiency in a longer-run.

There are two determinants that are probably the most important for technical efficiency, farmers' education and market integration of the farm. The educational level of people engaged in individual farming in Poland is low. According to 1996 agri-census only 16.2 per cent had secondary education and 3.6 per cent education higher than a secondary school (SAEPR/FAPA, 2000). This is a major constraint as this may impede the adoption of new technologies and different ways of transforming inputs to output that can increase technical efficiency. Education appears to be most important in the crop sector.

The Polish agricultural sector consists of subsistence and semi-subsistence farms that consume the largest portion of their output within the households. The agri-census shows that in 1996 50 per cent of farms produced mainly or exclusively for their needs (SAEPR/FAPA, 2000). This present analysis suggests that these farms might stay in the vicious circle of low technical efficiency and technological backwardness if they are not integrated into the market. From this point of view, support that can assist the commercialisation of semi-subsistence farms can be beneficial for efficiency gains and can facilitate the viability of these farms under an enlarged Union.

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Appendix

Table 7: Impact of size on efficiency: ANOVA analysis, F-test statistics

Farm specialisation	DEA estimated technical efficiency	SFA estimated technical efficiency
Livestock	2.39 **	15.70 ***
Crop	4.52 ***	7.11 ***

*, ***, ***: significance at 10%, 5%, 1%

Table 1: Distribution of sample farms according to area in hectares (%) [1]

Farm specialisation	Small farms (ha)			Medium farms (ha)		Large farms (ha)	
	1-2	2.01-5	5.01-7	7.01-10	10.01-15	15.01-50	>50
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

[1] 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 2: Basic characteristics of the sample farms: Descriptive statistics

	Livestock farms	Crop farms
Land (ha)		
Mean	21.4	48.3
Standard deviation	20.1	84.1
Minimum	1.1	1.6
Maximum	161.0	754.5
Labour AWU		
Mean	2.01	1.95
Standard deviation	0.99	2.33
Minimum	0.33	0.07
Maximum	8.02	27.11
Total Assets (000 PLZ)		
Mean	394.2	560.7
Standard deviation	328.2	681.0
Minimum	28.6	34.4
Maximum	1,947.2	6,314.3

Table 3: Descriptive results of SFA efficiency estimates

Farm specialisation (number of farms)	Mean	Standard deviation	Minimum	Maximum
Livestock (250)	0.88	0.06	0.74	0.99
Crop (222)	0.73	0.13	0.38	0.97

Table 4: Results of the stochastic frontier estimation: Production function and inefficiency effects

	Livestock farms		Crop farms	
	Parameter	t-ratio	Parameter	t-ratio
Production function variables				
Constant	0.54	6.97 ***	0.80	5.22 ***
Land	0.18	6.10 ***	-0. 02	-0.39
Labour	0.14	4.19 ***	0.17	4.76 ***
Capital	-0.11	-3.78 ***	-0.17	-3.68***
Intermediate consumption	0.86	27.8 ***	0.10	15.6 ***
Determinants of inefficiency				
Constant	0.28	1.99 **	0.94	5.38 ***
Total output	-0.001	-2.48 **	-0.001	-6.36 ***
Share of hired labour [1]	0.16	0.92	-0.29	-1.49
Degree of market integration [2]	-0.07	-0.63	-0.40	-2.79 ***
Soil quality index [3]	-0.11	-1.80 *	-0.23	-2.14 **
Age	0.001	0.87	0.001	0.44
Significance of the model				
Parameter γ	0.23	3.69 ***	0.56	5.79 ***
H_0 $\{\delta_k = 0\ \forall k\}$	rejected ***		rejected ***	

*, ***, ***: significance at 10%, 5%, 1%

[1] Ratio between 0 (no hired labour) and 1 (no family labour).

[2] The degree of market integration is given by the ratio of total revenue over total output. The greater it is, the more commercially integrated the farm is.

[3] The soil quality index is based on a soil survey. Smaller values represent lower soil quality. The range in the whole sample is between 0.15 and 1.61.

Table 5: Descriptive results of DEA efficiency estimates

Farm specialisation (number of farms)	Mean	Standard deviation	Minimum	Maximum	% farms with efficiency score of 1
Livestock (250)	0.71	0.15	0.38	1	7
Crop (222)	0.57	0.18	0.18	1	3

Table 6: Results of the Tobit analysis: Inefficiency determinants

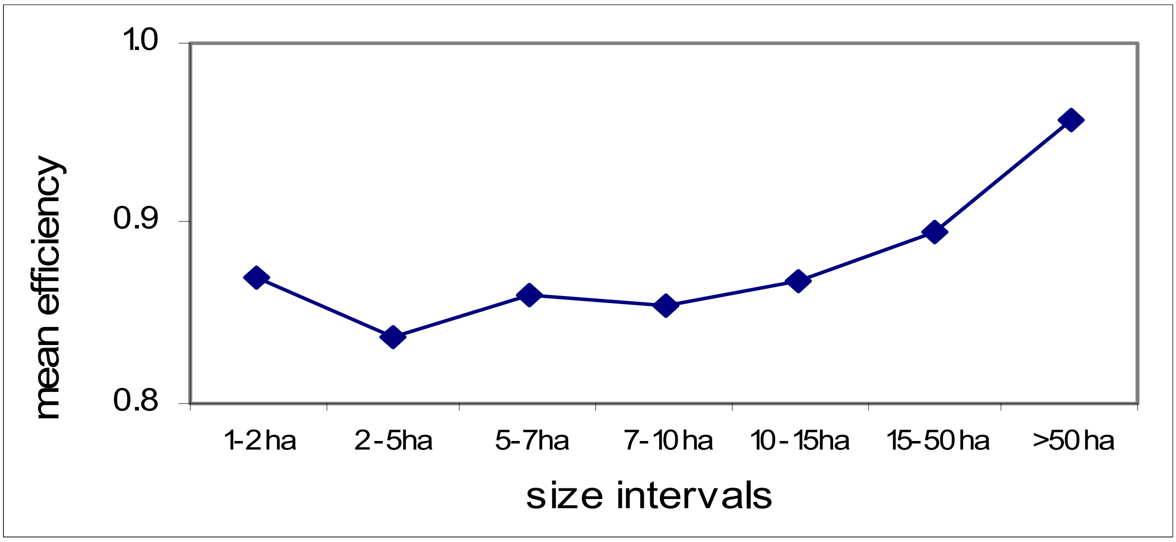
	Livestock farms		Crop farms	
	Parameter	t-ratio [1]	Parameter	t-ratio [1]
Constant	2.02	14.67 ***	3.01	9.09 ***
Total output	-0.002	-8.58 ***	-0.001	-3.33 ***
Ratio of capital/labour	0.05	6.80 ***	0.03	3.43 ***
Ratio of land/labour	-0.007	-1.84 *	-0.002	-0.77
Share of hired labour	0.07	0.36	-0.18	-0.59
Share of rented land [2]	0.03	0.42	-0.22	-1.15
Degree of market integration	-0.54	-4.71 ***	-0.85	-4.52 ***
Soil quality index	-0.24	-3.54 ***	-0.43	-2.33 **
Education dummy [3]	0.05	1.34	0.23	2.10 **
Age	0.0009	0.55	0.0001	0.03
Pseudo-R^2	0.71	145.2 ***	0.12	65.4 ***

[1] For the pseudo-R^2, the significance is evaluated with a Chi^2 test.

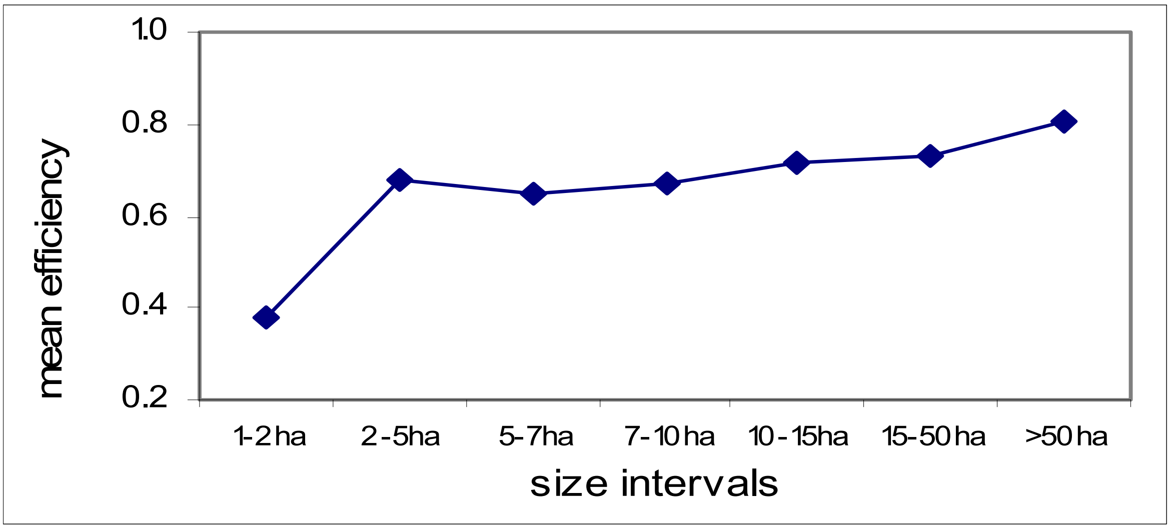
[2] Ratio between 0 (no rented land) and 1 (no own land).

[3] The education dummy is rather a non-education variable as it takes the value 0 if the farmers have some agricultural education, and 1 if they have not.

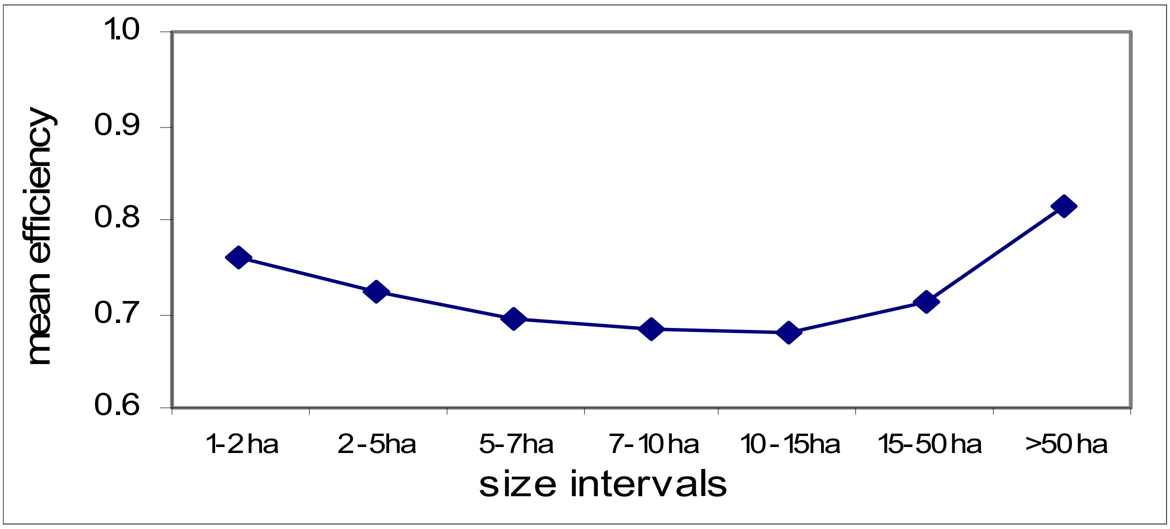
Graph 1: Technical efficiency for livestock according to size (SFA)



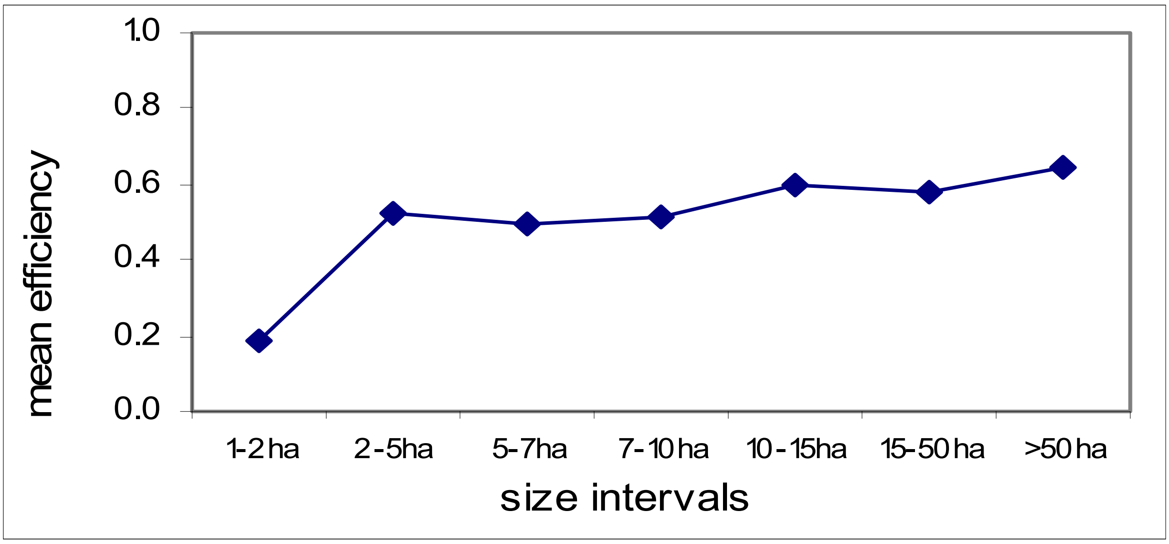
Graph 2: Technical efficiency for crop according to size (SFA)



Graph 3: Technical efficiency for livestock according to size (DEA)



Graph 4: Technical efficiency for crop according to size (DEA)



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