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Application of a double bootstrap to investigation of determinants of technical efficiency of farms in Central Europe

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Abstract

The paper provides one of the first applications of the double bootstrap procedure (Simar and Wilson, 2003) in a two-stage estimation of the effect of environmental variables on non-parametric estimates of technical efficiency. This procedure enables consistent inference within models explaining efficiency scores, while simultaneously producing standard errors and confidence intervals for these efficiency scores.

The application is to 88 livestock and 256 crop farms in the Czech Republic, split into individual and corporate. Results suggest that the corporate farms have more homogenous management practices than de novo individual farmers, as their average pure technical efficiency score is greater than individual farms' average. The comparison of estimations using the double bootstrap with the standard estimations in the second stage regression shows only slight differences. Individual farms' efficiency seems to be more affected by size (positive influence on efficiency) and financial stress (negative influence on efficiency) than corporate farms' efficiency.

Keywords: double bootstrap, DEA, truncated maximum likelihood, individual farms, corporate farms, Czech Republic

JEL Classification: D24, Q12

Application de la procédure de double bootstrap à l'analyse des déterminants de l'efficacité technique des exploitations en Europe Centrale

Résumé

L'article présente l'une des premières applications empiriques de la procédure de double bootstrap (Simar and Wilson, 2003) dans une estimation en deux étapes de l'influence de variables environnementales sur des scores non-paramétriques d'efficacité technique. Cette procédure permet d'obtenir des estimations efficaces dans les régressions expliquant les scores d'efficacité, tout en produisant des écarts-type et des intervalles de confiance pour ces scores d'efficacité.

La procédure est appliquée à des exploitations tchèques, séparées selon leur spécialisation de production (animale ou cultures) et selon leur forme légale (individuelle ou collective). Pour les deux spécialisations de production, les exploitations collectives présentent un score d'efficacité technique pure moyen supérieur à celui des exploitations individuelles, suggérant que les exploitations collectives ont des pratiques de gestion plus homogènes que les exploitations individuelles. Les résultats de la régression employant le double bootstrap diffèrent peu de ceux provenant d'une régression standard. Les exploitations individuelles semblent plus affectées par la taille (influence positive sur l'efficacité) et le stress financier (influence négative) que les exploitations collectives.

Mots-clés : double bootstrap, DEA, maximum de vraisemblance tronquée, exploitation individuelles, exploitations collectives, République Tchèque

Classification JEL : D24, Q12

Application of a double bootstrap to investigation of determinants of technical efficiency of farms in Central Europe

1. Introduction

This paper provides one of the first applications of the double bootstrap (Simar and Wilson, 2003) that enables consistent inference within models explaining efficiency scores, while simultaneously producing standard errors and confidence intervals for these efficiency scores. The study analyses the impact of a range of variables on the technical efficiency of Czech farms emerging from the transition from collectivised and state-owned farming to market oriented private agriculture.

The main area of the method application is to the efficiency variations between individual and corporate farms in the Czech Republic. After more than a decade of transition, questions about whether or not one organisational farm type, namely individual farms, is more efficient than other types, such as corporate structures, are still topical (for a summary of the debate see Gorton and Davidova, 2004). At the beginning of the transition process, the most common view was that once the centrally planned system had been dismantled, farm structures would go back to their 'normal' trajectory, namely smaller individual/family type farms (Csaki and Lerman, 1996). On economic grounds, this assumption was based on the view that family farms are more efficient than co-operatives and other types of corporate farms because they have low transaction costs (Schmitt, 1991). So far, the results from the empirical studies have not consistently supported this proposition (Mathijs *et al*., 1999; Mathijs and Vranken, 2001; Curtiss 2002). Mathijs and Vranken (2001) argue that individual farms appear to be more efficient for crop production but such advantages disappear in the dairy sector. They justify their results with the propositions of Allen and Lueck (1998) that problems of 'factory style' farms are more severe where production is spatially diffused and sequential as in these cases the costs of supervising and monitoring of hired labour are higher, e.g. in crop farming.

However, none of these studies has employed bootstrapping to determine the variability of Data Envelopment Analysis (DEA) efficiency estimates. Only a few recent analyses of technical efficiency of farms in economies in transition that used DEA employed the smoothed homogenous bootstrap and the procedure proposed by Simar and Wilson (1998 and

2000) (Brümmer, 2001; Latruffe *et al*. 2005). However, the problem of the serial correlation among the estimated efficiencies has not been tackled. It is addressed in this paper.

The paper is structured as follows. The next section explains the methodology employed and the third section describes the database. The fourth section summarises the empirical results. The fifth section concludes.

2. Methodology

2.1. Efficiency measurement

DEA is used in the first stage for estimating technical efficiency. The motivation and details of DEA have appeared elsewhere and will not be reiterated here (for more details see Charnes et al., 1978; Färe *et al*., 1994; Thiele and Brodersen, 1999). In this study, an output-orientated farm level model is used because the efficiency score is unbounded from above, but bounded from below which is more adequate when using truncated model in the second stage, and because the output-orientation is consistent with Simar and Wilson's (2003) algorithm.

In order to ease the interpretation of results presented in this paper, it is useful to recall that in the output-orientated DEA model an efficiency score $\hat{\delta}_i$ is calculated for the *i*-th farm by solving the following program (constant returns to scale case)

$$\max_{\lambda,\hat{\delta}_i} \quad \hat{\delta}_i \tag{1}$$

subject to

$$-\hat{\delta}_i y_i + Y\lambda \geq 0$$

$$x_i - X\lambda \geq 0$$

$$\lambda \geq 0$$

where $1\leq\hat{\delta}_i$ and $\hat{\delta}_i-1$ is the proportional increase in outputs that could be achieved by the *i*-th farm with input quantities held constant (Coelli *et al*., 1998). What is reported as efficiency estimate in this study, is $\hat{\delta}_i$ with $\hat{\delta}_i-1$ representing the potential output expansion, thus inefficiency, used as a dependent variable in the second-stage truncated regression.

One output variable, total output in value, is used and four inputs are included: utilised agricultural area (UAA) in hectares (ha) as a land factor; annual work units (AWU) as a labour factor; depreciation plus interest as a capital factor; and the value of intermediate consumption as a variable input factor. Value units are expressed in Czech Koruna (CZK). Four frontiers are estimated, one for each specialisation, livestock and crop, and each management form, individual and corporate farms. The underlying assumption is that different production and organisational types operate under different technology and with a different factor endowment.

2.2. Second stage regression

In the second stage, truncated maximum likelihood estimation is used to regress the efficiency scores ($\hat{\delta}_i - 1$) against a set of explanatory variables. As the main interest of the study is in investigating management rather than scale inefficiencies, the pure technical inefficiency score is chosen as the dependent variable. Truncated maximum likelihood is estimated for each of the four sub-samples (livestock/crop, individual/corporate).

Based on previous research on farm efficiency in developing and transition countries, a number of variables are considered to be possible in the explanation of the variations in farm efficiency scores. UAA for crop farms and livestock units for livestock farms[1] are used as a size variable. The ratios of capital to labour and land to labour are technology proxies. The integration in the factor markets is represented by the shares of hired labour in total labour input and of rented land in UAA. These shares are not included in the corporate farms' regressions as they are nearly 100 per cent for all observations. A ratio of interest plus rentals to total output is included, as an indicator of the financial stress of the farm caused by repayments of loans and rents which may affect its performance. Prior knowledge of the Czech farms indicates that, in general, corporate farms have more liabilities than individual farms. However, a high proportion of these debts stems from the reform process itself and so far corporate farms pay very little or zero interest on these debts, so they exhibit low financial stress (Davidova *et al*., 2003). This might not be the case of the de novo individual farms as they have to pay their debts to the commercial lenders on tight schedules. In addition to these continuous variables, four regional and two legal form dummies are used. The Czech

[1] European Union FADN conversion coefficients are used to convert the average number of animals to livestock units according to the category of animal.

Republic is divided into five large agri-environmental regions. Hughes (2000) labels these as maize, sugar beet, cereal, potato, and mountainous-forage with the maize region being the most favourable for farming and the mountainous-forage region the least. Regional dummies are employed as proxies for environment characteristics (DREG1, DREG2, DREG3 and DREG4) with region 5, mountainous-forage, used as a reference. For the corporate farms' regression, the two dummies are DLTD for limited companies and DJSTOCK for joint stock companies, with co-operatives used as a reference group.

2.3. Bootstrap

Simar and Wilson (2003) noted that the DEA efficiency estimates are biased and serially correlated, which invalidates conventional inferences from the two-stage approaches. The authors proposed a procedure, based on a double bootstrap, that enables consistent inference within models explaining efficiency scores while simultaneously producing standard errors and confidence intervals for these efficiency scores.

The rationale behind bootstrapping is to simulate a true sampling distribution by mimicking the data generating process. The procedure applied in this study follows Simar and Wilson's (2003) Algorithm 2. It consists of the following steps. Firstly, standard DEA efficiency point estimates are calculated (step (i) in Appendix). Secondly, truncated maximum likelihood estimation is used to regress the efficiency scores against a set of explanatory variables (ii). These estimates are then integrated into a bootstrap procedure, that is similar to the smoothed bootstrap procedure of Simar and Wilson (2000) (iii). This bootstrap procedure allows to correct for bias (iv). Finally, the bias corrected scores produced by the preceding bootstrap are used in a parametric bootstrap on the truncated maximum likelihood (v-vi), thus creating standard errors for the parameters of the regression. Confidence intervals are then constructed, for the regression parameters as well as for the efficiency scores (vii). In detail the procedure is described in Appendix (drawn from Simar and Wilson, 2003, Algorithm 2).

The results throughout this paper were obtained from 2,500 bootstrap iterations, in both parts of the double bootstrap, and in total required slightly less than 24 hours of computer time, running on Gauss for Windows on a modern desktop PC.

3. Description of data

The study draws data from the 1999 Czech Farm Accountancy Data Network (FADN) dataset. The initial set included 1,087 farms. After checking for missing or inconsistent data the useable sample was reduced to 753 farms. From these 753 farms, two sub-samples were constructed depending on whether farms specialise in crop or livestock, defined here as farms for which at least 65 per cent of the value of total agricultural output comes from crop or livestock. The extracted livestock sub-sample contains 88 farms and the crop sub-sample, 256 farms. The farms were also split according to their management form into individual and corporate sub-samples. The individual farms are the most numerous group, 274 in all. They account for 86 per cent of the crop farms and 60 per cent of the livestock farms. The summary statistics of the variables of interest for the sample farms are presented in Table 1.

The sample farms are located in different agri-environmental regions. Within the sub-samples, no individual livestock farm is located in the maize region and no corporate crop farm in the mountainous-forage region. For this reason, in the truncated maximum likelihood estimation region 4, potato, is used as a reference for the corporate crop farms instead of region 5, mountainous-forage.

4. Empirical results

4.1. Technical efficiency: comparison of point and interval estimates

Estimates of total technical, pure technical and scale efficiency are presented in Table 2. The percentage of efficient farms represents the share of farms with an efficiency score of unity. DEA estimates, presented in Table 2, reveal that, contrary to some theoretical expectations related to transaction costs, overall, corporate farms appear to be more totally technically efficient than individual farms in a sense that the observations lie, on average, closer to the efficiency frontier within the corporate sample. This is consistent with Hughes' (2000) Total Factor Productivity (TFP) findings for the Czech Republic. The main total technical efficiency differences between the individual and corporate farms appear in livestock production. The differences in average total efficiency estimates between the two management types in crop production are small. However, when the pure technical efficiency is compared, the corporate farms observations lie closer to the efficiency frontier for both crop and livestock specialisations.

By specialisation, among individual farms crop farms are on average more totally technically efficient than livestock farms. Among corporate farms, the opposite is true. In terms of pure technical and scale efficiency the relations between the two specialisations are the same as in the case of the total technical efficiency.

The confidence intervals of the efficiency scores, constructed with bootstrapping, are wide (Table 3). This is particularly the case for the individual livestock farms, for both total and pure technical efficiency. This finding proves a high statistical variability of DEA efficiency estimates. Similarly wide intervals were found for a sample of farms in Poland (Latruffe *et al*., 2005). Both Brümmer (2001) and Latruffe *et al*., found that the interval width varies considerably over the samples.

Table 4 reports the bias, and the lower and upper bounds of the total technical efficiency scores' confidence intervals as an average for each sub-sample. The biases are substantial for all sub-samples except the corporate livestock farms. The interval results appear to confirm only some of the rankings indicated by the point estimates. Within the corporate farms, livestock specialisation appears more total technically efficient as the mean upper bound for the livestock farms is strictly less than the mean lower bound for the crop farms. However, within the group of individual farms the results are inconclusive as the intervals overlap. The comparison between the corporate and individual farms shows that corporate farms are relatively more total technically efficient than individual farms in livestock production, but it is difficult to assert a conclusion for crop farms due to overlapping intervals. These results are consistent with some previous studies (Sarris *et al*., 1999; Mathijs *et al*., 1999). However, when the interval bounds for pure technical efficiency are compared, there is clear-cut evidence about the relative efficiency superiority of corporate over individual farms in both specialisations.

4.2. Factors accounting for technical efficiency variations

The truncated bias corrected maximum likelihood results are presented in Table 5 and the non bias corrected ones in Table 6. As mentioned, the dependent variable represents inefficiency, therefore the parameters with negative signs indicate sources of efficiency and vice versa.

Within the livestock farms, size, measured in livestock units, is an important source of efficiency for individual farms. The dispersion around the mean size is much greater for individual than for corporate livestock farms. This may suggest that some individual farms, which are de novo post-reform farm structures, have not yet had time, management skills and capital to reach the minimum efficient size. This corroborates the conclusions made by Hughes (2000).

The ratio of capital to labour negatively affects the efficiency of individual livestock farms but has no impact on corporate farms. Again, as above, the coefficient of variation is greater for individual than for corporate farms, which indicates a greater dispersion. It appears that some individual farms are overcapitalised. It is necessary to recall that capital is measured by depreciation plus interest. Therefore, the result may indicate weaknesses in management decisions to purchase machinery and equipment, and construct new buildings irrespective of the farm size and the potential efficiency with which it could be used. On the other hand, some individual farmers have old and obsolete capital stock. The maintenance costs for such stock are usually high and often require loans and payment of interest. Similar situation has been described for Poland (Latruffe *et al*., 2005).

Financial stress lowers the efficiency of both individual and corporate livestock farms; the relationship is stronger for individual farms.

The comparison between individual and corporate crop farms indicates that most of the variables impact significantly on the individual farm technical efficiency. The land to labour ratio has a positive significant influence. Some individual farms appear overmanned for the land area cultivated, which is the case in many of the Central European countries as agriculture has been used as a shelter from industrial unemployment during the process of transition. Individual farms that rely mainly on family labour, will achieve efficiency gains through the higher use of hired labour. The latter normally brings some specialised skills. The share of rented land (the largest proportion of land in the Czech Republic is rented) has a negative impact on the individual crop farms' efficiency. The same relationship has been identified for the financial stress which takes into account the burden of the repayment of rentals and interest.

The results regarding the regional dummies suggest that the performance of individual farms is more dependent on the agri-environmental characteristics. This may indicate a lower input (more extensive) technology than the corporate farms.

From a methodological point of view, the comparison of truncated maximum likelihood estimations on bias corrected efficiency scores (Table 5) with the standard estimations on non bias corrected scores (Table 6) shows only slight differences in the direction of stronger relationships indicated by the application of Simar and Wilson's (2003) algorithm.

5. Conclusions

The paper provides one of the first applications of the double bootstrap procedure (Simar and Wilson, 2003) in a two-stage estimation of the effect of environmental variables on non-parametric estimates of technical efficiency. Two main conclusions could be drawn from this application. Computationally, the procedure is straightforward, and reasonably efficient when using moderate sample sizes such as those employed here. Therefore, it is recommended for routine use in two-stage estimation of the effect of environmental variables on non-parametric estimates of technical efficiency. However, the results using a simple two-stage truncated regression on standard DEA scores did not differ substantively from those which employed the double bootstrap. Therefore, it is the contention here that the findings of previous studies, employing a simple two-step approach, largely remain valid.

Concerning the key issue addressed in this paper, the relative efficiency of individual and corporate farms emergent post-reform in the Czech Republic, the results indicate that it differs according to farm specialisation. In livestock production, the corporate farms are more total technically efficient than the individual farms as the observations for the corporate farms lie closer to their respective efficient frontier. This result has been confirmed by both point and interval estimates. Within the crop sectors the results are inconclusive. Point estimates suggest a very slight difference in the total efficiency scores, while the intervals overlap. This corroborates some previous research and with the model of Allen and Lueck (1998) pointing out that corporate farming will be more efficient and predominate when the production task makes it less costly for the residual claimant to relate individual effort to commonly produced results, such as capital intensive, less seasonal sectors. However, if the pure technical efficiency is concerned, then there is clear-cut evidence about the relative superiority of corporate over individual farms in both specialisations. This suggests that the corporate farms have more homogenous management practices than de novo individual farmers.

Appendix: Bootstrap procedure

The seven steps of the double bootstrap algorithm are as follows.

i) A DEA output-orientated efficiency score $\hat{\delta}_i$ is calculated for each farm, i.e. the following program is solved for i=1,…,n (constant returns to scale case):

$$\max_{\lambda,\hat{\delta}_i} \quad \hat{\delta}_i \tag{2}$$

subject to
$$-\hat{\delta}_i y_i + Y\lambda \geq 0$$
$$x_i - X\lambda \geq 0$$
$$\lambda \geq 0$$

where y_i and x_i are respectively the original output and input matrices of the *i*-th farm; Y and X are respectively the original output and input matrices of the sample; λ is a nx1 vector of constants; the DEA score $\hat{\delta}_i$ is bounded by one on the left: $\hat{\delta}_i \geq 1$ for i=1, …n.

ii) Maximum likelihood is used in the truncated regression of $\hat{\delta}_i$ on z_i, to provide an estimate $\hat{\beta}$ of β and an estimate $\hat{\sigma}_\varepsilon$ of σ_ε.

iii) For each farm i=1,…n, the next four steps (a-d) are repeated B_1 times to yield a set of B_1 bootstrap estimates $\left\{\hat{\delta}_{i,b}* \quad b=1,...B_1\right\}$.

a) ε_i is drawn from the $N(0,\hat{\sigma}_\varepsilon{}^2)$ distribution with left-truncation at $(1-\hat{\beta}z_i)$.

b) $\delta_i* = \hat{\beta}z_i + \varepsilon_i$ is computed.

c) A pseudo data set (x_i*, y_i*) is constructed, where $x_i* = x_i$ and $y_i* = y_i\hat{\delta}_i / \delta_i*$.

d) A new DEA estimate $\hat{\delta}_i*$ is computed on the set of pseudo data (x_i*, y_i*), i.e. Y and X are respectively replaced by $Y* = \{y_i* \quad i=1,...n\}$ and $X* = \{x_i* \quad i=1,...n\}$ in program (2).

iv) For each farm i=1,…,n, the bias-corrected estimator $\hat{\hat{\delta}}_i$ is computed as follows:

$$\hat{\hat{\delta}}_i = \hat{\delta}_i - \widehat{bias}_i \tag{3}$$

where $\widehat{bias}_i$ is the bootstrap estimator of bias obtained as (Simar and Wilson, 1998):

$$\widehat{bias}_i = \left(\frac{1}{B_1}\sum_{b=1}^{B_1}\hat{\delta}_{i,b}*\right) - \hat{\delta}_i. \tag{4}$$

v) Maximum likelihood is used in the truncated regression of $\hat{\hat{\delta}}_i$ on z_i, to provide an estimate $\hat{\hat{\beta}}$ of β and an estimate $\hat{\hat{\sigma}}$ of σ_ε.

vi) The next three steps (a-c) are repeated B_2 times to yield a set of B_2 bootstrap estimates $\left\{(\hat{\hat{\beta}}_b*, \hat{\hat{\sigma}}_b*) \quad b = 1,...,B_2\right\}$.

a) For each farm i=1,…n, ε_i is drawn from the $N(0, \hat{\hat{\sigma}})$ distribution with left truncation at $(1 - \hat{\hat{\beta}} z_i)$.

b) For each farm i=1,…n, $\delta_i ** = \hat{\hat{\beta}} z_i + \varepsilon_i$ is computed.

c) Maximum likelihood is used in the truncated regression of $\delta_i **$ on z_i, to provide an estimate $\hat{\hat{\beta}}*$ of β and an estimate $\hat{\hat{\sigma}}*$ of σ_ε.

vii) Confidence intervals are constructed. The estimated $(1-\alpha)$ per cent confidence interval of the *j*-th element β_j of the vector β, is as follows:

$$\Pr ob\left(Lower_{\alpha,j} \le \beta_j \le Upper_{\alpha,j}\right) = 1 - \alpha \tag{5}$$

where $Lower_{\alpha,j}$ and $Upper_{\alpha,j}$ are calculated using the empirical intervals:

$$\text{Prob}(-\hat{b}_\alpha \le \hat{\hat{\beta}}_j * - \hat{\hat{\beta}}_j \le -\hat{a}_\alpha) \approx 1 - \alpha \qquad 96)$$

where $Upper_{\alpha,j} = \hat{\hat{\beta}}_j + \hat{b}_\alpha$

$Lower_{\alpha,j} = \hat{\hat{\beta}}_j + \hat{a}_\alpha$.

The same method is applied to construct confidence intervals for the efficiency scores (Simar and Wilson, 2000).

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Table 1: Summary statistics for the sample farms according to specialisation and organisational form

Variables	Mean	Standard deviation	Minimum value	Maximum value	Mean	Standard deviation	Minimum value	Maximum value
Individual farms	Livestock farms (53 farms)				Crop farms (221 farms)			
DEA model								
Total output (000 CZK)	3,750	5,506	226	25,784	2,807	4,438	114	33,076
Land (ha)	142	257	10	1,400	144	195	15	1,562
Labour (AWU)	4.68	7.03	0.92	40.95	3.20	4.47	0.07	35.00
Capital[a] (000 CZK)	570	818	20	4,798	462	855	3	6,190
Intermediate consumption (000 CZK)	2,937	4,829	201	30,427	1,972	2,855	141	22,789
Second stage regression								
Livestock Units	86.3	135.3	6.2	727.2	-	-	-	-
Capital[a] / Labour (000 CZK /AWU)	128	101	9	456	149	206	2	1563
Land / Labour (ha /AWU)	28	17	8	93	60	54	4	486
Share of hired labour (%)	24	34	0	100	21	31	0	97
Share of rented land (%)	65	33	0	100	68	30	0	100
Financial stress ratio	0.032	0.039	0	0.201	0.054	0.071	0	0.490

Variables	Mean	Standard Deviation	Minimum value	Maximum value	Mean	Standard Deviation	Minimum value	Maximum value
Corporate farms	Livestock farms (35 farms)				Crop farms (35 farms)			
DEA model								
Total output (000 CZK)	43,727	30,262	6,948	127,951	43,313	34,132	3,652	131,928
Land (ha)	1,480	721	220	3,084	1,498	836	424	3,952
Labour (AWU)	78.87	54.63	12.00	253.00	60.59	38.17	13.00	140.23
Capital[a] (000 CZK)	6,063	4,159	1,336	19,186	5,623	3,742	821	14,953
Intermediate consumption (000 CZK)	31,998	19,296	4,073	73,892	26,088	17,562	4,928	73,454
Second stage regression								
Livestock Units	65.0	33.8	5.6	195.2	-	-	-	-
Capital[a] / Labour (000 CZK /AWU)	85	38	41	197	96	40	42	199
Land / Labour (ha /AWU)	23	13	4	67	29	16	12	70
Share of hired labour (%)	100	0	100	100	100	0	100	100
Share of rented land (%)	99	2	89	100	98	6	70	100
Financial stress ratio	0.040	0.043	0	0.197	0.034	0.028	0	0.117

[a] Interest plus depreciation

Table 2: Descriptive statistics of technical efficiency

Farm specialisation and form		Mean	Standard deviation	Minimum	Share of farms with efficiency score of 1 (%)
	Total technical efficiency				
Individual	Livestock	1.99	0.58	3.47	3.8
	Crop	1.64	0.61	4.94	6.3
Corporate	Livestock	1.24	0.25	1.82	25.7
	Crop	1.62	0.58	2.98	8.6
	Pure technical efficiency				
Individual	Livestock	1.65	0.56	3.07	18.9
	Crop	1.47	0.55	4.47	18.1
Corporate	Livestock	1.16	0.21	1.76	37.1
	Crop	1.29	0.38	2.29	31.4
	Scale efficiency				
Individual	Livestock	1.25	0.37	2.88	3.8
	Crop	1.13	0.20	3.00	6.3
Corporate	Livestock	1.07	0.10	1.44	25.7
	Crop	1.28	0.44	2.86	8.6

Table 3: Width of efficiency estimates' confidence intervals

Farm specialisation and form		Width for total technical efficiency	Width for pure technical efficiency
Individual	Livestock	1.87	2.18
	Crop	1.23	1.41
Corporate	Livestock	0.51	0.59
	Crop	1.00	1.67

Table 4: Total technical efficiency DEA estimate, bias and confidence intervals bounds: means [a]

Farm specialisation and form		DEA estimate	Bias	Lower bound	Upper bound
Individual	Livestock	1.99	-3.54	4.61	6.79
	Crop	1.64	-2.84	3.89	5.30
Corporate	Livestock	1.24	-0.68	1.68	2.26
	Crop	1.62	-2.31	3.23	4.90

[a] The lower bound indicates the highest efficiency and the upper, the lowest.

Table 5: Determinants of pure technical inefficiency: estimation on bias corrected efficiency score

	Individual farms		Corporate farms	
	Livestock	Crop	Livestock	Crop
Constant	3.35 **	7.16 **	0.76 **	0.51
	(2.26, 4.45)	(5.39, 8.88)	(0.44, 1.07)	(-5.55, 1.10)
Size variable [a]	-4.26 E-2 **	-0.11 E-2	-2.27 E-2	0.17 E-2
	(-7.29, -3.31) E-2	(-1.09, 0.85) E-2	(-5.37, 0.05) E-2	(-0.07, 0.51) E-2
Ratio capital/labour	5.38 E-2 **	0.03 E-2	-2.04 E-2	1.78 E-2
	(2.48, 8.89) E-2	(-0.07, 0.08) E-2	(-4.62, 0.02) E-2	(-3.85, 8.27) E-2
Ratio land/labour	-23.84 E-2 **	-6.96 E-2 **	1.55 E-2	-10.48 E-2
	(-47.22, -5.55) E-2	(-11.6, -5.84) E-2	(-7.32, 10.43) E-2	(-32.48, 6.48) E-2
Share of hired labour	4.06 E-2	-10.78 E-2 **	-	-
	(-5.03, 15.29) E-2	(-19.1, -6.74) E-2		
Share of rented land	2.61 E-2	5.58 E-2 **	-	-
	(-7.02, 13.54) E-2	(1.39, 11.98) E-2		
Financial stress ratio	84.06 **	43.04 **	4.91 **	2.44
	(7.49, 171.7)	(24.43, 72.87)	(2.73, 7.77)	(-3.01, 9.90)
DLTD	-	-	-2.66 **	3.83
			(-5.46, -0.28)	(-0.62, 9.50)
DJSTOCK	-	-	-1.33	3.30
			(-3.81, 0.39)	(-2.41, 10.01)
DREG1	-	-53.75 **	-1.46	-2.42
		(-73.49, -37.68)	(-4.93, 1.97)	(-16.74, 9.62)
DREG2	-16.55 **	-50.00 **	27.35 **	55.54
	(-27.96, -8.89)	(-67.94, -33.92)	(5.99, 48.44)	(-19.73, 144.4)
DREG3	-4.92	-45.66 **	-1.79	-2.08
	(-14.80, 3.90)	(-62.95, -28.76)	(-3.94, 0.07)	(-8.68, 3.15)
DREG4	-6.73	-41.03 **	-1.60	-
	(-17.07, 2.82)	(-58.99, -23.13)	(-3.57, 4.40)	

**: 5% significance. E-2: 10 power –2. Lower and upper bounds for 5 percent confidence interval between brackets.

[a] UAA for crop farms, livestock units for livestock farms.

Table 6: Determinants of pure technical inefficiency: standard estimation on efficiency score

	Individual farms		Corporate farms	
	Livestock	Crop	Livestock	Crop
Constant	0.86 **	2.32 **	0.19	-0.02
	(0.25)	(0.35)	(0.11)	(0.26)
Size variable [a]	-1.17 E-2**	-0.03 E-2	-1.11 E-2	0.07 E-2
	(0.56 E-2)	(0.22 E-2)	(1.00 E-2)	(0.08 E-2)
Ratio capital/labour	2.33 E-2 **	-0.14 E-2	-1.35 E-2	0.77 E-2
	(0.69 E-2)	(0.19 E-2)	(0.85 E-2)	(1.79 E-2)
Ratio land/labour	-8.20 E-2	-2.07 E-2 **	3.18 E-2	-3.41 E-2
	(4.63 E-2)	(0.73 E-2)	(2.99 E-2)	(5.91 E-2)
Share of hired labour	1.86 E-2	-3.38 E-2 **	-	-
	(2.24 E-2)	(1.37 E-2)		
Share of rented land	0.57 E-2	0.70 E-2	-	-
	(2.34 E-2)	(1.14 E-2)		
Financial stress ratio	40.63 **	18.35 **	2.82 **	0.56
	(17.63)	(4.93)	(0.87)	(1.97)
DLTD	-	-	-1.57	2.12
			(0.91)	(1.53)
DJSTOCK	-	-	-0.92	1.44
			(0.66)	(1.90)
DREG1	-	-20.00 **	-0.48	-2.23
		(3.74)	(1.24)	(3.88)
DREG2	-6.41 **	-18.59 **	19.92 **	33.21
	(2.09)	(3.41)	(7.07)	(24.01)
DREG3	2.49	-16.86 **	-0.97	-1.33
	(2.04)	(3.44)	(0.69)	(1.84)
DREG4	-3.02	-14.75 **	-0.78	-
	(2.20)	(3.62)	(0.75)	

** : 5% significance. E-2: 10 power –2. Standard errors into brackets.

[a] UAA for crop farms, livestock units for livestock farms.

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