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Analysis of the Technical and Scale Efficiency of Farms Operating in LFA

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Anotace

Článek analyzuje technickou efektivnost a efektivnost z rozsahu zemědělců hospodařících v LFA. Analýza se zejména zaměřuje na vztah mezi velikostí farem a technickou efektivností, resp. efektivností z rozsahu. Výsledky odhadnutého stochastického hraničního modelu ukazují na signifikantní rozdíly ve vztahu velikost farmy a efektivnosti pouze u technické efektivnosti a velikostní skupiny farem nad 1 000 hektarů.

Článek vznikl v rámci řešení projektu IGA 20131039.

Klíčová slova

Technická efektivnost, efektivnost z rozsahu, dotace, LFA, SFA.

Abstract

The paper deals with an analysis of the technical and scale efficiency of farms operating in LFA. In particular, we provide an analysis of the relationship between farm size and technical and scale efficiency. The results of the fitted stochastic frontier model show that significant differences in the relationship between efficiency and farm size can only be found for technical efficiency in the group of farms with more than 1000 hectares.

The paper arose within the framework of solution IGA 20131039.

Keywords:

Technical efficiency, scale efficiency, subsidies, LFA, SFA.

Introduction

The analysis of efficiency and productivity has been a prominent topic in agricultural economics research over the last two decades. Since efficiency and productivity are often used as indicators of overall competitiveness, the results of such an analysis are important information sources for policy makers. Along with questions concerning competitiveness, questions related to the efficiency and productivity of different groups of farms are also of special interest for policy targeting. This focus is reinforced in the Czech Republic due to the significant dual structure of Czech agriculture.

This study focuses on farms located in LFA. The aim is to identify differences in technical and scale efficiency between size groups of farms. In particular, the paper addresses the following research question. The question concerns the relationship between farm size and efficiency. Is farm size positively correlated with technical and scale efficiency, or can we consider large farms to be more efficient and thus more competitive from this point of view?

The measurement of technical and scale efficiency cannot determine the extent to which farms are economically efficient, but it does address at least a part of this question. If the farm is not technically and/or scale efficient, then it cannot be economically efficient (Kumbhakar, Lovell, 2000). From a given quantity of input, technically inefficient farms cannot produce as much output as more efficient farms or they consume more inputs for the production of a given output, respectively, and their average costs are higher compared to more efficient farms. An inefficient farm can survive on the market in the short run, but its existence in the long run depends on the competitive environment and policy interventions.

The identified differences in technical efficiency can be due to either objective or subjective reasons. Objective reasons are connected with the environment in which the farm produces (e.g. land quality, higher attitude). Subjective reasons are linked to the quality of management, labour and material inputs.

The technical and/or scale efficiency of Czech agriculture was recently analysed in several studies: Methijs et al. (1999a, 1999b and 2001), Hughes (1999), Curtiss (2002), Juřica et al. (2004), Medonos (2006), Jelínek (2006) and Čechura (2009, 2010). However, a detailed analysis of farms in LFA is missing. Moreover, in the majority of cases the analysed period is not relevant to the needs of policy makers.

The paper is organized as follows: Chapter 2 contains the theoretical framework, presents the estimation strategy and describes the data set; Chapter 3 presents the results of the stochastic frontier function estimate, discusses estimated technology and technological change and compares technical and scale efficiency among a defined group of farms. Chapter 4 contains concluding remarks.

Materials and methods

1. Data

The data set was drawn from the database FADN. The data represents an unbalanced panel data set which contains 926 farms and 3205 observations in the period from 2005 to 2010. The price indices were taken from the Czech Statistical Office (CZSO) database.

2. Econometric model

We assume that the production process can be well approximated by a translog production frontier model. The deterministic part of the model is:

$$\ln f(t, \mathbf{x}_{it}; \boldsymbol{\beta}) = \alpha_0 + \sum_{j=1}^{K} \beta_j \ln x_{ijt} + \frac{1}{2}\sum_{j=1}^{K}\sum_{k=1}^{K} \beta_{jk} \ln x_{ijt} \ln x_{ikt} + \beta_t t + \frac{1}{2}\beta_t t^2 + \sum_{j=1}^{K} \beta_{jt} \ln x_{ijt} t \quad (1)$$

where x_{it} is a vector of inputs containing the production factors – Labour (A_{it}), Land (L_{it}), Capital (K_{it}) and Material (M_{it}). Indices i, where i = 1, 2,…, N, and t, where $t \in \tau(i)$, refer to a certain agricultural company and time, respectively, and $\tau(i)$ represents a subset of years T_i from the whole set of years T (1, 2,…T), for which the observations of the i-th farm are in the data set (see unbalanced panel). α_0 is an intercept (productivity parameter).

The employed variables are defined as follows:

- Output (y) represents the value of total production. The output was deflated by the index of agricultural prices (2005 = 100).
- Labour input (A) is the total amount of AWU.
- Land (L) cultivated by the i-th farm is adjusted (multiplied) by the land quality (the land quality index is expressed as the ratio of the official land price of a given region to the maximum official regional price of land).
- Capital (K) represents the book value of tangible assets and was deflated by the index of processing prices (2005=100).
- Material inputs (M) represent the total costs of material and energy consumption and were deflated by the index of processing prices (2005=100).

The heteroscedasticity problem is controlled by: Intensity variable (INTO) (the variable states for intensity of breeding), Number of Livestock units (DJ), Ratio of cultivated area in LFA (LFA) and a Dummy variable for farms operating in protected landscape area (CHK).

We use a "True" Random Effects model (TREM) in the analysis (Green, 2002)[1]:

$$y_{it} = (\alpha + w) + \mathbf{x}_{it}'\boldsymbol{\beta} + v_{it} - u_{it}. \quad (2)$$

Inefficiency in relation (2) is time variant and is assumed to have a half-normal distribution. Time-invariant farm heterogeneity is captured by a time-invariant random intercept. The measurement of farm heterogeneity can be done either by $w_i = \mathbf{f}_i'\boldsymbol{\theta} + \omega_i$ (determining the position of the frontier) or as a part of the distribution of inefficiency term u_i with a mean μ_i or μ_{it} (for further reference see Green, 2003). We use the first possibility in the analysis. Finally, we assume that w_i and other variables are not correlated (Green, 2002).

We address the question raised in the introduction through a detailed analysis of technical and scale efficiency in the year 2010. The results for previous

[1] The parameter estimate were found robust under different model specifications. Since the more flexible models forms did not have higher explanatory power according to the LR test we use TREM in the analysis.

years are provided in the appendix. Moreover, the development of technical and scale efficiency is analyzed, and implications with respect to the studied problems are also discussed.

REM is estimated using the maximum simulated likelihood method in the econometric software LIMDEP 9.0.

Results and discussion

Table 1 provides a parameter estimate of the stochastic production frontier model. Since all variables are divided by their geometric mean, the fitted parameters represent production elasticities.

	"True" Random effects model with heteroscedasticity		
Variable	Coefficient	Std. Error	P[│Z│>z]
T	-0.01104	0.00158	0.0000
TT	0.04005	0.00222	0.0000
A	0.17869	0.00661	0.0000
L	0.06688	0.00460	0.0000
K	0.04758	0.00529	0.0000
M	0.67858	0.00725	0.0000
AT	-0.00057	0.00344	0.8681
LT	-0.00465	0.00226	0.0398
KT	-0.00011	0.00305	0.9702
MT	0.00966	0.00384	0.0120
AA	0.10045	0.01620	0.0000
LL	0.03615	0.00285	0.0000
KK	-0.00633	0.00814	0.4371
MM	0.05700	0.01951	0.0035
AL	-0.10078	0.00804	0.0000
AK	-0.00188	0.01231	0.8783
AM	-0.02107	0.01527	0.1677
LK	0.04457	0.00670	0.0000
LM	0.00451	0.00705	0.5222
KM	-0.02127	0.01119	0.0573
suONE	1.12012	0.14435	0.0000
suINTO	-0.41479	0.02834	0.0000
suDJ	-0.00188	0.00009	0.0000
suLFA	0.47753	0.14241	0.0008
suCHK	0.27548	0.02951	0.0000
-	Means for random parameters		
Constant	0.013053	0.00660	0.0000
-	Scale parameters for dist. of random parameters		
Constant	0.28491	0.00292	0.0000
Lambda	2.804		
Log likelihood function	245.2742		
Sigma(u)		0.2552	
Sigma(v)	0.09103	0.00194	0.0000
No. of parameters		28	

Source: own calculations

Table 1: Parameter estimate.

The parameter estimates are consistent with economic theory. The production elasticities comply with both monotonicity and quasi-concavity requirements (evaluated on the sample mean). Moreover, the estimated elasticities are consistent with information in the data set. One exception is that capital elasticity is lower than expected. Material inputs have the highest impact on production, with elasticity of 0.679. On the other hand, capital has the lowest impact, 0.048. The labour elasticity is 0.1787. The lower-than-expected capital elasticity could be influenced by the accounting records of fixed assets. These records do not account for capital inputs financed via leasing, which can lead to the underestimation of capital elasticity. Other reasons could be capital market imperfections and the fact that farmers have poorer access to financial resources. The land elasticity is estimated at 0.067. Land quality is found to be a highly significant factor in the determination of land elasticity. The sum of production elasticities is 0.972, which suggests a slightly decreasing returns to scale.

Technical change has a negative impact on production, but it decelerates over time. The hypothesis about Hicks-neutral technological change was rejected with a 5 % level of significance. Technological change was Material-using and Land-saving. This suggests that added value in Czech agriculture is going down. These results suggest that subsidies, which increase the income of agricultural companies, may not motivate farmers to invest in new technology. This conclusion may have several reasons that differ with respect to the performance and competitiveness of the particular farm.

Heteroscedasticity was found being highly significant. All the variables capturing heteroscedasticity are significant even with 1 % significance level. As was expected the intensity variable and variable representing number of livestock have a positive impact on the technical efficiency. On the other hand the higher is the ratio of cultivated area in LFA (LFA) the lower is the technical efficiency. Moreover, if the farm operates in protected landscape area (CHK), it has in general lower technical efficiency.

The value of λ shows that the variability in inefficiency is more pronounced than the variability in statistical noise. 2.8 suggests that efficiency differences among farms are important reasons for variations in production.

Table 2 provides descriptive statistics of the technical efficiency for the whole sample. The average of the technical efficiency is 85.65 %. With respect to the distribution of technical efficiency, two-thirds of the farms have technical efficiency higher than 80 %. Thus, the variability in technical efficiency around the average is a significant characteristic of the analyzed sample.

Table 3 provides figures about technical efficiency according to farm size for the year 2010 (results for the years 2005 to 2009 are provided in the appendix). The farms were divided into size groups based on the amount of cultivated area. The size interval was defined in the length of 100-1000 ha and 500-2000 ha. The results show that the technical efficiency of farms with a cultivated area up to 800 ha is between 81 and 85 %. The estimates of technical efficiency for these farms do not show any significant relationship between technical efficiency and the amount of cultivated area (correlation coefficient is 0.26). Standard deviation fluctuates in the interval from 0.092 to 0.155. That is, more than 60 % of farms with a cultivated area up to 800 ha have a technical efficiency in the interval 70 to 95 %. The relative variability is around 15 %, which is quite high. Farms with a cultivated area of more than 800 ha have a higher average technical efficiency. However, the groups of farms with a cultivated area between 800 and 1000 ha still have high variability in technical efficiency. The standard deviations or variation coefficients in these groups are 0.10 and 0.12 or 0.12 and 0.14, respectively. For the group of farms with more than 1000 hectares, technical efficiency significantly increases and variability decreases with land size. Whereas technical efficiency is about 90 %, the relative variability is 7 % for the group of farms with a cultivated area between 1000 and 2000 hectares, and 3.5 % for the group of farms with a cultivated area larger than 2000 hectares.

	Average	Std. Dev.	Minimum	Maximum
"True" Random effects model	0.8565	0.09893	0.28396	0.99166

Source: own calculations

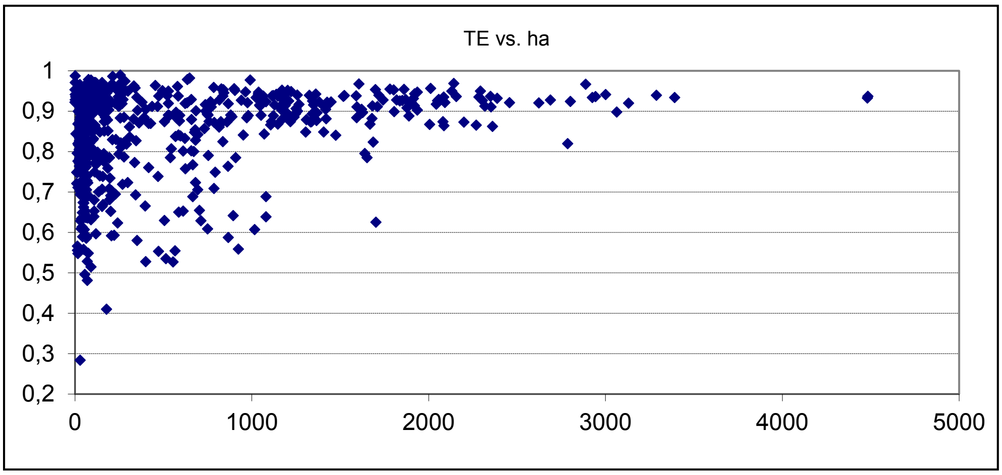
Table 2: Descriptive statistics of technical efficiency.

	No. of ha	0 - 100	101 - 200	201 - 300	301 - 400	401 - 500	501 - 600	601 - 700
TE	Average	0.8210	0.8433	0.8401	0.8476	0.8181	0.8145	0.8295
	Std.Dev.	0.1207	0.1136	0.1234	0.1097	0.1550	0.1396	0.0920
	Var.Coef.	0.1471	0.1347	0.1469	0.1295	0.1894	0.1714	0.1109
	Median	0.8496	0.8764	0.8568	0.8808	0.8700	0.8752	0.8328
	Min.	0.2844	0.4102	0.5918	0.5807	0.5279	0.5277	0.6533
	Max.	0.9876	0.9712	0.9897	0.9628	0.9640	0.9617	0.9820
	No. of farms	214	70	34	17	11	22	21

	No. of ha	701 - 800	801 - 900	901 - 1000	1001 - 1500	1501 - 2000	>2000
TE	Average	0.8271	0.8629	0.8685	0.8953	0.9038	0.9192
	Std.Dev.	0.1138	0.1068	0.1227	0.0632	0.0638	0.0325
	Var.Coef.	0.1376	0.1237	0.1413	0.0706	0.0706	0.0353
	Median	0.8751	0.8866	0.9052	0.9096	0.9223	0.9277
	Min.	0.6089	0.5881	0.5590	0.6073	0.6256	0.8203
	Max.	0.9590	0.9561	0.9774	0.9520	0.9673	0.9690
	No. of farms	17	17	10	64	35	37

Source: own calculations

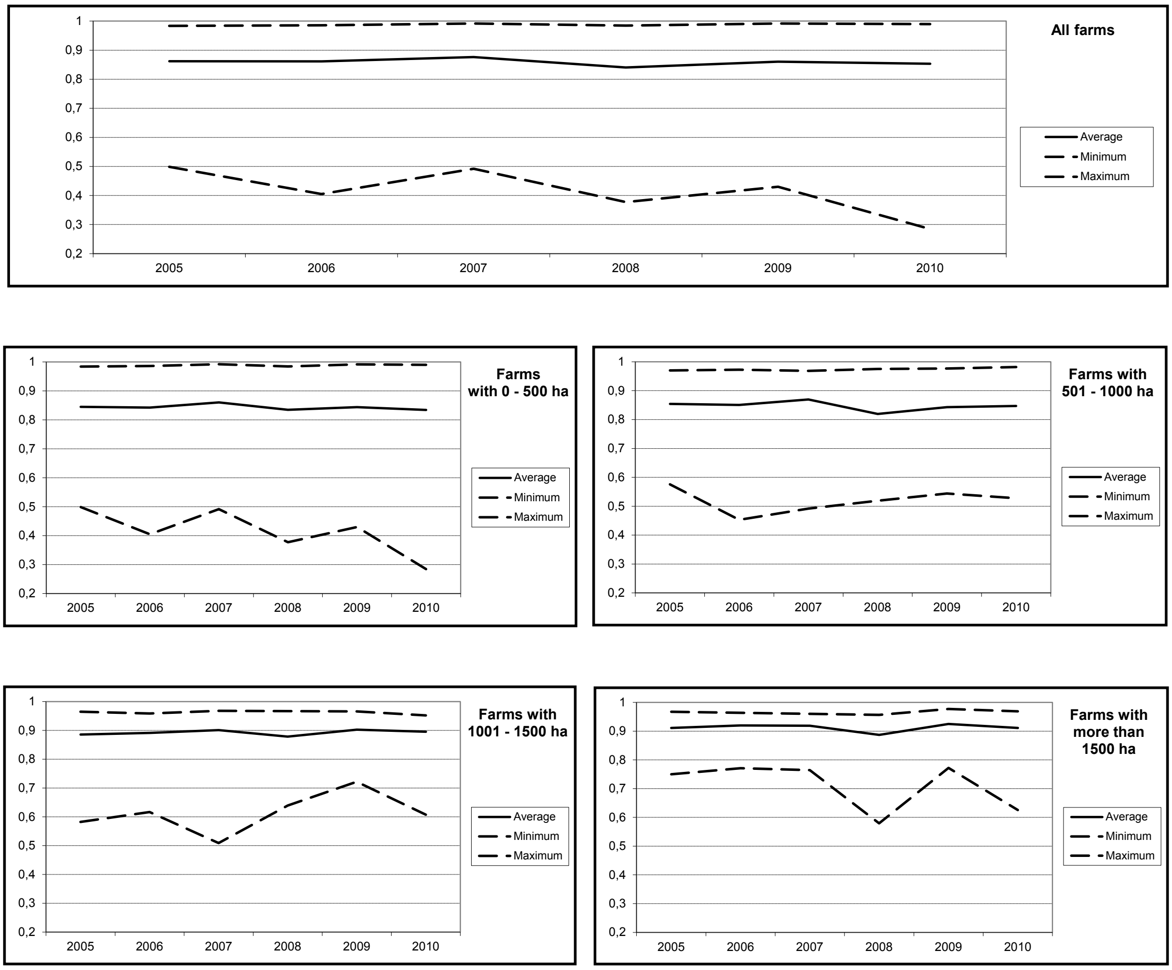
Table 3: Technical efficiency in selected size categories (ha) in 2010.



Source: own calculations

Figure 1: Technical efficiency with respect to cultivated area (ha) in 2010.

The results show that farms with a cultivated area of more than 1000 hectares have significantly higher technical efficiency than farms with less than 1000 hectares. Figure 1 graphically illustrates this conclusion. The same conclusion can be obtained from the technical efficiency estimate in other analysed years, i.e. 2005 to 2009. Detailed figures are provided in the appendix. Here we restrict our attention to the development of technical efficiency between 2005 and 2010. We focus on the total development of technical efficiency and the development in four size groups: 0-500 ha, 501-1000 ha, 1001-1500 and 1501 or more hectares. Figure 2 shows that the development of mean technical efficiency in the whole sample has a nearly constant trend. The same holds true for maximum technical efficiency. We cannot observe any significant change



Source: own calculations

Figure 2: Development of technical efficiency.

in the mean and maximum technical efficiency in the defined size groups. The only change can be observed in the minimum of technical efficiency, and especially in the group of farms with less than 500 hectares of cultivated area. The less technically efficient farms in this group were falling more and more behind. The situation of less efficient farms did not significantly change in the group with 501 to 1000 hectares, and mild improvement could be observed in the group with 1001-1500 hectares. The less efficient farms with more than 1500 hectares experienced a rather stochastic development, which is connected with the entry and exit of the farms in the database (see unbalanced panel data set). To sum up, the development of technical efficiency is in favour of the above-stated conclusion, derived for the year 2010. In other words, it holds true for the analysed period of 2005 to 2010 that farms with a cultivated area larger than 1000 hectares have significantly higher technical efficiency than farms with less than 1000 hectares.

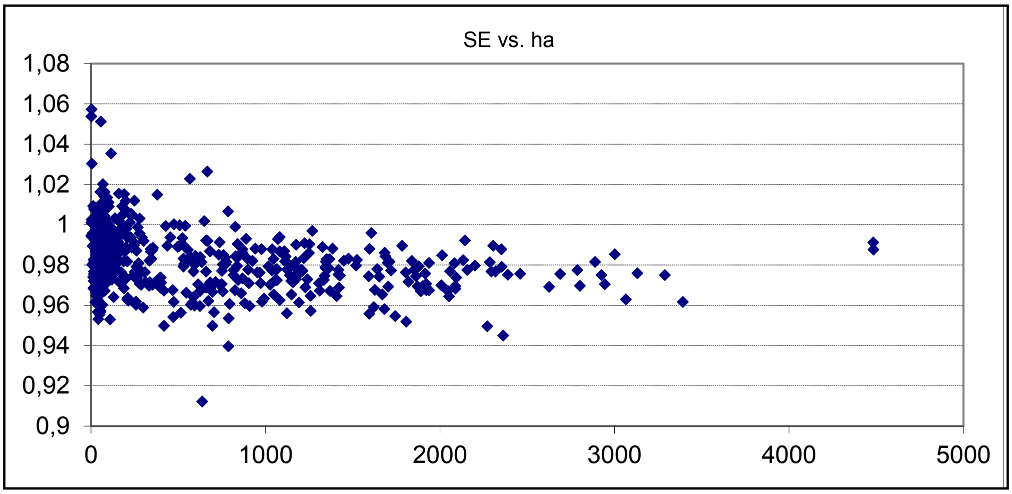
Table 4 provides figures on the scale efficiency estimate for groups with a defined size according to the cultivated area. We can observe small differences both between and within groups. Since the estimated scale efficiency is close to one, we cannot observe any significant exploitation of economies of scale (see also Figure 3). That is, from the static point of view, farms operate at an almost ideal size. The same also holds true for other analysed years (see figures in the appendix).

	No. of ha	0 - 100	101 - 200	201 - 300	301 - 400	401 - 500	501 - 600	601 - 700
TE	Average	0.9887	0.9881	0.9842	0.9805	0.9767	0.9810	0.9751
	Std.Dev.	0.0152	0.0139	0.0154	0.0119	0.0183	0.0158	0.0220
	Var.Coef.	0.0154	0.0140	0.0156	0.0121	0.0187	0.0161	0.0225
	Median	0.9883	0.9865	0.9844	0.9764	0.9714	0.9820	0.9714
	Min.	0.9531	0.9529	0.9589	0.9685	0.9498	0.9563	0.9122
	Max.	1.0574	1.0354	1.0120	1.0149	1.0003	1.0229	1.0264
	No. of farms	214	70	34	17	11	22	21

	No. of ha	701- 800	801 - 900	901 - 1000	1001 - 1500	1501 - 2000	>2000
TE	Average	0.9741	0.9798	0.9737	0.9773	0.9738	0.9752
	Std.Dev.	0.0158	0.0101	0.0103	0.0088	0.0103	0.0102
	Var.Coef.	0.0163	0.0103	0.0106	0.0090	0.0105	0.0105
	Median	0.9771	0.9795	0.9736	0.9776	0.9745	0.9759
	Min.	0.9396	0.9610	0.9596	0.9560	0.9519	0.9450
	Max.	1.0066	0.9990	0.9882	0.9970	0.9959	0.9923
	No. of farms	17	17	10	64	35	37

Source: own calculations

Table 4: Scale efficiency in selected size categories in 2010.



Source: own calculations

Figure 3: Scale efficiency with respect to cultivated area in 2010.

Conclusion

In the conclusion we focus on the research question raised in the introduction. That is, we deal with the relationship between farm size and technical and scale efficiency. In particular, is farm size positively correlated with technical and scale efficiency, or can we consider large farms to be more efficient and thus more competitive from this point of view?

The results show that significant differences in the relationship between efficiency and farm size can only be found for technical efficiency in the group of farms with more than 1000 hectares. In other words, farms with more than 1000 hectares are more efficient compared to farms which operate with less than 1000 hectares. The same conclusion can be drawn from the results of the technical efficiency estimate between the years 2005 and 2009 – see appendix.

The results suggest that large farms (especially farms with more than 1000 hectares) seem to be more competitive, at least from a technical efficiency point of view, and thus less sensitive to changes in subsidies. On the other hand, farms with less than 1000 hectares can be sensitive to LFA subsidy degressivity, which is an important message for policy makers with respect to the setting of CAP subsidies for the next programme period.

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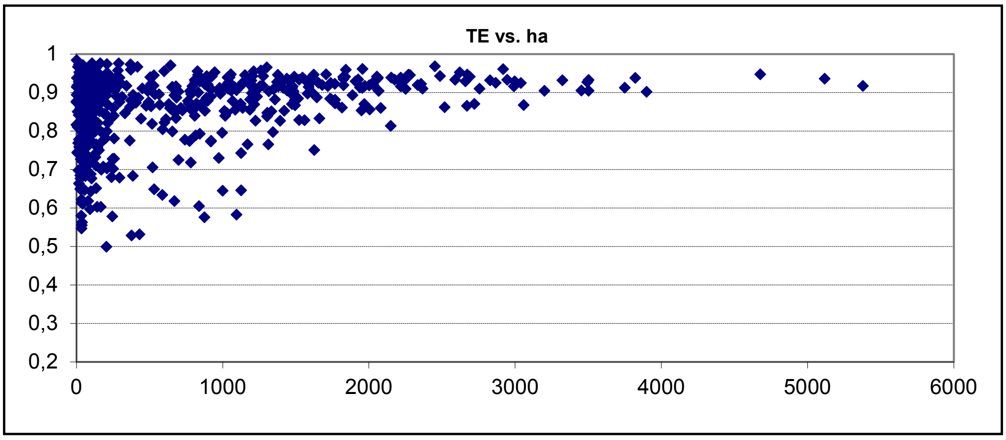
Appendix

Results for technical efficiency in the years 2005 to 2009



Source: own calculations

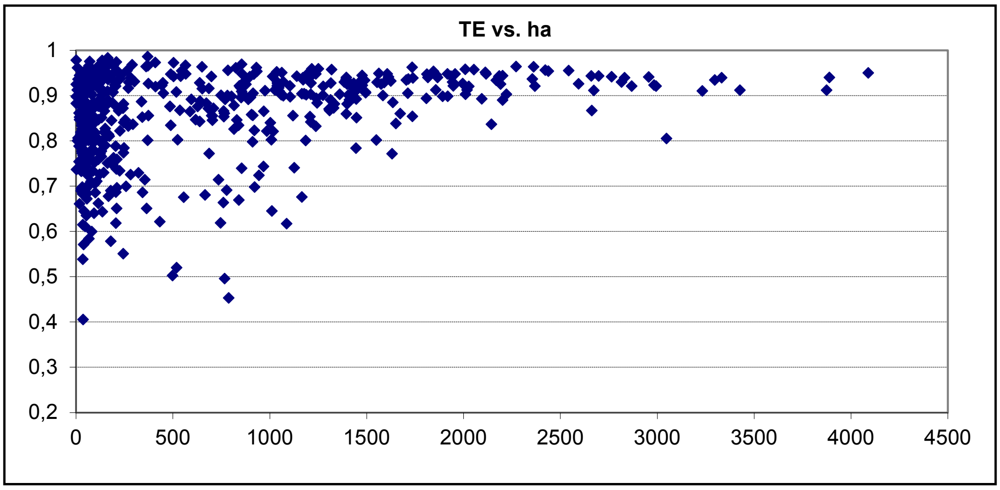
Figure A1: Technical efficiency with respect to cultivated area (ha) in 2005.

	No. of ha	0 - 100	101 - 200	201 - 300	301 - 400	401 - 500	501 - 600	601 - 700
TE	Average	0.8290	0.8519	0.8444	0.8440	0.8551	0.8437	0.8502
	Std.Dev.	0.0962	0.0932	0.1156	0.1272	0.1194	0.1087	0.0818
	Min.	0.5465	0.6021	0.4988	0.5282	0.5308	0.6337	0.6179
	Max.	0.9834	0.9757	0.9756	0.9733	0.9666	0.9550	0.9702
	No. of farms	184	68	39	12	10	14	17

	No. of ha	701 - 800	801 - 900	901 - 1000	1001 - 1500	1501 - 2000	>2000
TE	Average	0.8458	0.8660	0.8655	0.8855	0.9036	0.9192
	Std.Dev.	0.0627	0.0964	0.0756	0.0695	0.0428	0.0292
	Min.	0.7176	0.5756	0.7298	0.5825	0.7501	0.8131
	Max.	0.9161	0.9550	0.9524	0.9650	0.9609	0.9676
	No. of farms	11	24	12	78	40	54

Source: own calculations

Table A1:Technical efficiency in selected size categories (ha) in 2005.



Source: own calculations

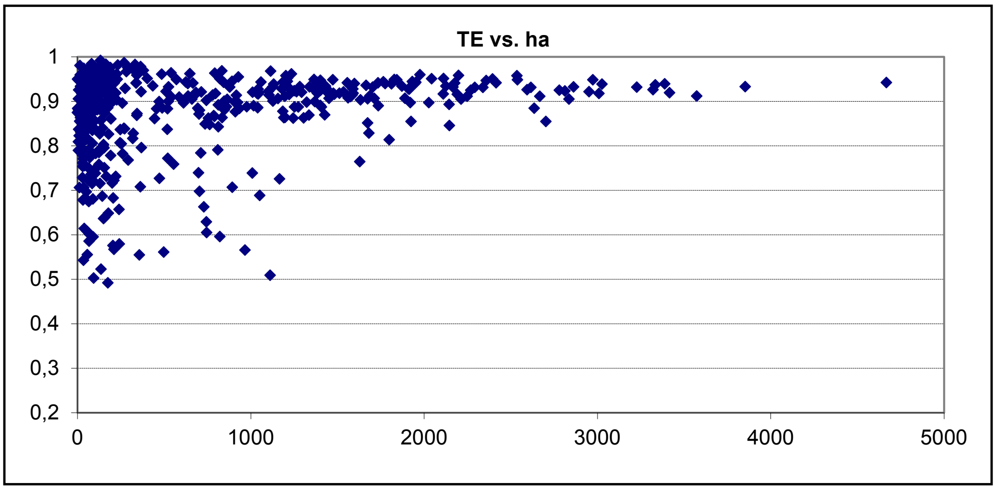
Figure A2: Technical efficiency with respect to cultivated area (ha) in 2006.

	No. of ha	0 - 100	101 - 200	201 - 300	301 - 400	401 - 500	501 - 600	601 - 700
TE	Average	0.8347	0.8636	0.8258	0.8420	0.8457	0.8656	0.8709
	Std.Dev.	0.0986	0.0930	0.1125	0.1154	0.1476	0.1324	0.0757
	Min.	0.4051	0.5781	0.5508	0.6503	0.5024	0.5195	0.6805
	Max.	0.9776	0.9829	0.9739	0.9858	0.9726	0.9724	0.9634
	No. of farms	180	73	33	13	11	13	13

	No. of ha	701 - 800	801 - 900	901 - 1000	1001 - 1500	1501 - 2000	>2000
TE	Average	0.7818	0.8844	0.8505	0.8913	0.9140	0.9258
	Std.Dev.	0.1490	0.0756	0.0830	0.0668	0.0439	0.0318
	Min.	0.4531	0.6689	0.6977	0.6170	0.7710	0.8050
	Max.	0.9552	0.9689	0.9616	0.9588	0.9621	0.9639
	No. of farms	17	19	15	74	34	43

Source: own calculations

Table A2: Technical efficiency in selected size category (ha) in 2006.



Source: own calculations

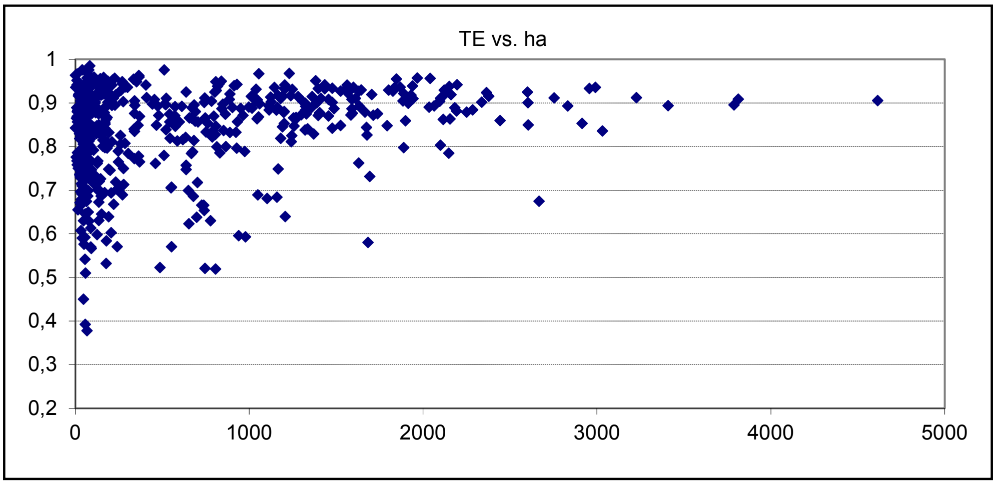
Figure A3: Technical efficiency with respect to cultivated area (ha) in 2007.

	No. of ha	0 - 100	101 - 200	201 - 300	301 - 400	401 - 500	501 - 600	601 - 700
TE	Average	0.8652	0.8755	0.8230	0.8853	0.8516	0.8853	0.9052
	Std.Dev.	0.0958	0.1044	0.1319	0.1165	0.1291	0.0681	0.0595
	Min.	0.5029	0.4917	0.5674	0.5549	0.5612	0.7591	0.7396
	Max.	0.9846	0.9918	0.9871	0.9829	0.9609	0.9641	0.9621
	No. of farms	173	81	27	17	9	11	11

	No. of ha	701 - 800	801 - 900	901 - 1000	1001 - 1500	1501 - 2000	>2000
TE	Average	0.8260	0.8670	0.8644	0.9013	0.9130	0.9252
	Std.Dev.	0.1099	0.1010	0.1143	0.0699	0.0410	0.0238
	Min.	0.6049	0.5960	0.5655	0.5091	0.7647	0.8456
	Max.	0.9634	0.9684	0.9547	0.9679	0.9602	0.9583
	No. of farms	17	15	9	65	38	43

Source: own calculations

Table A3: Technical efficiency in selected size categories (ha) in 2007.



Source: own calculations

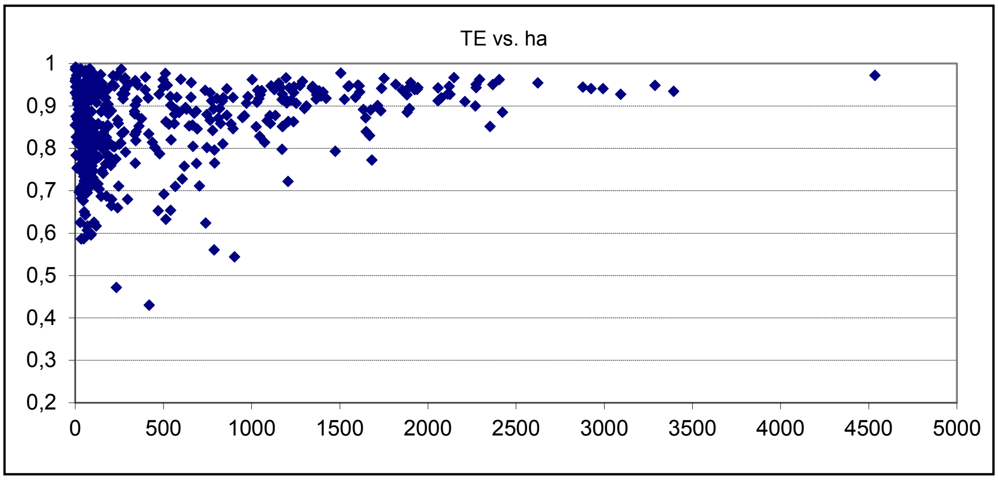
Figure A4: Technical efficiency with respect to cultivated area (ha) in 2008.

	No. of ha	0 - 100	101 - 200	201 - 300	301 - 400	401 - 500	501 - 600	601 - 700
TE	Average	0.8142	0.8323	0.8169	0.8702	0.8392	0.8295	0.8019
	Std.Dev.	0.1121	0.1017	0.1143	0.0708	0.1295	0.0958	0.0901
	Min.	0.3772	0.5315	0.5702	0.7644	0.5222	0.5699	0.6224
	Max.	0.9844	0.9585	0.9562	0.9629	0.9410	0.9751	0.9248
	No. of farms	185	78	31	16	9	17	19

	No. of ha	701 - 800	801 - 900	901 - 1000	1001 - 1500	1501 - 2000	>2000
TE	Average	0.7812	0.8611	0.8234	0.8786	0.8862	0.8881
	Std.Dev.	0.1205	0.0993	0.1171	0.0634	0.0694	0.0514
	Min.	0.5202	0.5190	0.5923	0.6393	0.5795	0.6743
	Max.	0.9109	0.9494	0.9419	0.9671	0.9569	0.9558
	No. of farms	16	19	12	71	41	37

Source: own calculations

Table A4: Technical efficiency in selected size categories (ha) in 2008.



Source: own calculations

Figure A5: Technical efficiency with respect to cultivated area (ha) in 2009.

	No. of ha	0 - 100	101 - 200	201 - 300	301 - 400	401 - 500	501 - 600	601 - 700
TE	Average	0.8458	0.8423	0.8337	0.8883	0.8073	0.8454	0.8493
	Std.Dev.	0.0977	0.0874	0.1237	0.0595	0.1624	0.1078	0.0679
	Min.	0.5861	0.6170	0.4720	0.7650	0.4300	0.6326	0.7278
	Max.	0.9916	0.9740	0.9869	0.9680	0.9621	0.9766	0.9549
	No. of farms	189	65	29	15	10	17	13

	No. of ha	701 - 800	801 - 900	901 - 1000	1001 - 1500	1501 - 2000	>2000
TE	Average	0.8092	0.8853	0.8243	0.9028	0.9158	0.9345
	Std.Dev.	0.1176	0.0382	0.1581	0.0514	0.0458	0.0271
	Min.	0.5601	0.8102	0.5438	0.7219	0.7724	0.8517
	Max.	0.9368	0.9402	0.9221	0.9660	0.9771	0.9722
	No. of farms	13	12	5	47	28	25

Source: own calculations

Table A5: Technical efficiency in selected size categories (ha) in 2009.