Impact of EU accession on farms' technical efficiency in Hungary

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Abstract

In this study, the stochastic frontier analysis method was used to evaluate the technical efficiency of Hungarian farms before and after accession to the European Union (EU), and to investigate the efficiency determinants. Results show that EU-membership has reversed the pre-accession process of efficiency decrease. But the other side of the coin is that access to higher post-accession subsidies contributes to lower efficiency of Hungarian farmers. The other remarkable finding is a seemingly scarcity of labour on the farms, that constrains their production and efficiency. Hungarian government may therefore have to design specific national policies if its aim is to promote a farming system that uses labour and at the same time that is competitive.

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Introduction

During the transition from centrally-plan regime to market-economy, Hungary has seen a strong economic growth, with its gross domestic product (GDP) per capita reaching 12,900 euros in 2003, the second highest of the other Central and Eastern European Countries (CEECs), and with its 5.8 percent unemployment rate much lower than the European Union (EU)-15 average (EC, 2004). However, the growth of the agricultural sector has not been so strong; the output has experienced drops, and finally stagnated at 5,600 Mio euros between 2000 and 2003 (EC, 2001 and 2004).

In May 2004 Hungary has joined the EU along with nine other CEECs. Hungarian farmers are now beneficiaries of the Common Agricultural Policy (CAP). In this frame, they are entitled to receive direct payments per hectare, the Single Area Payments (SAP). While these payments are still lower than the ones received by farmers in the EU-15 (due to the phasing-in period that will cease in 2013), they are higher than what Hungarian farmers used to receive from national pre-accession budget. Moreover, since EU-enlargement farmers can also receive additional payments from the national budget, in the form of top-ups that are coupled to specific productions. The change in market conditions and in agricultural policies following accession to the EU is expected to enhance agricultural growth, by increasing farms' size and promoting technological growth. Various modelling exercises and surveys to farmers have indeed shown that farms would enlarge and produce more (e.g. Bach et al., 2000; Fuller et al., 2003; Douarin et al., 2007). The modification in farmers' decisions brought by EU-accession may however have a negative impact on their performance, by altering the output and input mix. CAP subsidies in particular may decrease farms' performance, by reducing farmers' effort and thus increasing the waste of inputs. Such effect of public support has already been given evidence in several Western and transition countries (e.g. Giannakas et al., 2001; Rezitis et al., 2003; Zhu et al., 2008).

The objective of the paper is to shed light on this issue by investigating the link between Hungarian farm performance and EU-accession. The period studied, 2001-2005, was a crucial period for the country, as it covers the end of the transition (when farmers started to adjust to broader competition) and the first accession years (when farmers started to receive CAP payments). We consider one aspect of farm performance, namely technical efficiency. This measure refers to whether farmers are capable to use at best the existing technology, by producing the most possible from a given set of production factor quantities.

Research about farm technical efficiency in CEECs has largely developed over the last decade, with the objectives of investigating the evolution of efficiency during the transition from centrally-planned regime to market-economy, and during the preparation of farmers to EU enlargement. The Czech Republic and Poland in particular have been the most focused on, in a view of comparing organisational forms, production specialisations and farm sizes (e.g. van Zyl et al., 1996; Mathijs et al., 1999; Munroe, 2001; Curtiss, 2002; Lerman, 2002). By contrast, technical efficiency of Hungarian farmers has not been much explored. The only post-reform paper is by Mathijs & Vranken (2001), who used data from a survey of farms in 1998. Education was found to play a positive role on individual farms' technical efficiency, while for corporate farms, important factors dealt with specific organisational characteristics. While some studies have investigated other aspects of farm performance in Hungary (Total Factor Productivity in 1997 by Hughes, 2000; profitability and Total Factor Productivity in 2000 by Davidova et al., 2002), there is a clear gap regarding technical efficiency of Hungary's farming sector. Moreover, no study has been concerned with the potential change in farms' technical efficiency following CEECs accession to the EU. This paper will therefore contribute to this research area.

The paper is organised as follows. We first discuss the applied methodology, than present the data and the model specification. This is followed by the discussion of the results, and finally the conclusions.

Methodology

Technical efficiency can be measured using parametric or non-parametric approaches. The latter (e.g. Data Envelopment Analysis, DEA) have however severe shortcomings such as the sensitivity of the results to outliers, and the potential bias in the results due to the exclusion of potentially more efficient firms. To circumvent this problem, researchers have resorted to various methods such as the bootstrapping technique (e.g. Brümmer, 2001). Another drawback of the non-parametric methods is that they do not account for random noise. For these reasons, the Stochastic Frontier Analysis (SFA) is used here. Aigner at al. (1977) and Meeusen and & den Broeck (1977) have simultaneously, yet independently, developed the use of SFA in efficiency analysis. The main idea is to decompose the error term of the production function into two components, one pure random term (v_i) accounting for measurement errors and effects that cannot be influenced by the firm (such as weather, trade issues, access to materials), and a non-negative random term (u_i), measuring the firm's technical inefficiency, i.e. the systematic departures from the frontier (equation (1)):

$$y_i = f(x_i)\exp(v_i - u_i) \tag{1}$$

where y_i is the output of the i^{th} firm; x_i is the vector of inputs used in the production; $f(\cdot)$ is the production function; u_i and v_i are error terms as explained above.

Given this specification, a firm's technical efficiency (TE) score, defined as the ratio between the firm's observed output to the production possibility frontier, is given as follows (equation (2)):

$$TE_i = \exp(-u_i) \quad \text{with} \quad 0 \le TE_i \le 1 . \tag{2}$$

A technical efficiency score of 1 indicates a perfectly efficient firm, that is to say whose actual output is equal to the maximum attainable output. Lower scores indicate lower efficiency.

Several hypothesis tests must be carried out in order to ensure that results are not biased. The first test is whether the stochastic frontier production function (with double error term) is more appropriate than the standard OLS estimation (with single error term) (Hypothesis 1). For this, we use the parameterisation of Battese & Corra (1977), defining γ the share of deviation from the frontier that is due to inefficiency as (equation (3)):

$$\gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2} \tag{3}$$

where σ_u is the standard deviation of the non-negative term u; σ_v is the standard deviation of the other error term v. This parameter is tested to be different from zero using a likelihood ratio (LR) test. It should be noted however, that the test statistic has a 'mixed' chi square distribution, with critical values tabulated in Kodde & Palm (1986). The second test relates to the fact that applying SFA requires distributional and functional form assumptions. First, because only the error term $w_i = v_i - u_i$ can be observed, we need to have specific assumptions about the distribution of the composing error terms. The random term v_i, is usually assumed to be identically and independently distributed drawn from the normal distribution, $N(0, \sigma_v^2)$. There are various assumptions that can be made regarding the distribution of the non-negative error term. However most often it is considered to be identically distributed as a half normal random variable, $N^{+}(0,\sigma_u^2)$ or a normal variable truncated from below zero, $N^{+}(\mu,\sigma_u^2)$.

Second, being a parametric approach, we need to specify the underlying functional form of the Data Generating Process (DGP). There are a number of possible functional form specifications available, however most studies employ either the Cobb-Douglas, or translog specifications. Since the two models are nested, it is possible to test the correct functional form by a LR test, which is done in this paper (Hypothesis 2). Another aspect that needs attention when using frontier models is that the consequences of heteroscedasticity are severe, as the frontier changes when the dispersion increases. We test here for heteroscedasticity (Hypothesis 3) and we follow Caudill et al. (1995), who introduced a model which incorporates heteroscedasticity into the estimation. The method relies on modelling the relationship between the variables responsible for heteroscedasticity and the distribution parameter σ_u (equation (4)):

$$\sigma_{ui} = \exp(\sum_j x_{ij}\rho_j) \tag{4}$$

where σ_u is the standard deviation of the non-negative term u; x_{ij} are the i^{th} firm production factors that may cause heteroscedasticity; ρ_j are parameters to be estimated.

With panel data, the production coefficients and the TE can be chosen to be time invariant, or to vary systematically with time. Both hypotheses are tested here (Hypothesis 4 and Hypothesis 5, respectively). To account for time effects in the production frontier, the validity of cross-terms between the four inputs and a time trend variable is tested. To incorporate time effects in the TE, Battese & Coelli (1992) define the non-negative error term as exponential function of time (equation (5)):

$$u_{it} = \exp[(-\eta(t-T)]u_i \tag{5}$$

where t is the time; T is the final period and η is a parameter to be estimated .

With this specification, TE either increases (η>0), decreases (η<0) or is constant over time, i.e. invariant (η=0). LR tests can be applied to test the inclusion of time in the model.

Given that TE is allowed to vary, the question arises what determines the changes of TE scores. In order to investigate the determinants of efficiency, Battese & Coelli (1995) proposed a one stage procedure where firm-specific variables are used to explain the predicted inefficiencies. The explanatory variables are related to the firm-specific mean (μ) of the non-negative error term u_i (equation (6)):

$$\mu_i = \sum_j \delta_j z_{ij} \tag{6}$$

where μ_i is the i^{th} firm-specific mean of the non-negative error term; δ_j are parameters to be estimated; z_{ij} are i^{th} firm-specific explanatory variables.

The last two tests carried out are thus whether there are inefficiency effects (Hypothesis 6) and if yes, whether an intercept term must be included within the specification given by equation (4) (Hypothesis 7).

Data and model specification

Farm-level data are employed in the econometric estimations. Hungarian Farm Accountancy Data Network (FADN) data between 2001 and 2005, provided by the Hungarian Agricultural Research Institute, are used to build a balanced panel of 3,210 observations.

The output variable (y) used in the stochastic frontier consists of total net farm revenue from sales. The four input variables included in the production function are: utilised agricultural area (x_1) measured in hectares; total intermediate consumption in value (x_2) including seeds, fertiliser, pesticides, fodder, purchase of animals and other direct material costs; capital (x_3) defined as the total depreciated value of the machinery; and labour (x_4), measured in total annual working hours (AWH). Time variables were added to the stochastic production function in order to capture the short and long-run evolution of the production frontier, that is to say the possible technology change.

There exists a large set of farm-specific variables (z) that could potentially explain the differences in technical efficiency between the farms in the sample (see for example Brümmer, 2001; Mathijs & Vranken, 2001; Bozoglu & Ceyhan, 2007). After performing significance tests, the following variables were kept as determinants of technical efficiency, representing farm characteristics and management/production system characteristics.

A trend variable is introduced, to capture the evolution of technical efficiency over time. In addition, two year dummies are used, taking the value of 1 for the years 2004 and 2005 respectively, and 0 otherwise, thus collecting the effects of the first two years of EU-membership. It is expected that EU-accession contributes to efficiency improvement, due to increased competition and more market opportunities.

Two region dummies are employed, Region 1 collecting the farms from counties in Dunántúl (west), and Region 2 representing farms from counties in Alföld (south, south-east), the control region being Region 3 Északmagyarország (north). In the latter, the economical, natural and geographic conditions for agriculture are worse than in the other two regions. We therefore expect lower farm efficiency in this region. The region dummies may not capture sufficiently the soil conditions where the farms operate, and for this reason an index of soil quality is also introduced, with larger values representing better quality. Greater soil index is thus expected to have a positive effect on technical efficiency.

In order to assess the efficiency discrepancy between legal statuses, we introduce a legal form dummy, taking the value 1 if the farm is a company and 0 otherwise (family farm). No clear-cut conclusion from the literature can be found on which form (corporate of individual) is superior in terms of technical efficiency (see for example Gorton & Davidova, 2004): corporate farms may benefit from positive size effects but may be constrained by supervision costs.

The land to labour ratio enables to investigate the efficiency differences between more and less labour extensive technologies. We do not have a priori expectations on the sign of the effect.

Introducing the ratio of output from livestock activities to the total output along its square value can shed light on the efficiency superiority of various farms' specialisations (crop specialised, livestock specialised, or mixed farms). As in the case of legal status, the literature does not agree on which type of farm is the most technically efficient. We therefore do not have a priori expectations.

Finally, the effect of public subsidies on farms' technical efficiency is investigated by introducing the ratio of total subsidies received by the farms to their total output. Using a ratio enables to control for size effects. The sample's average value over the period is 0.218, indicating that farms received 218 HUF of subsidies for each 1000 HUF[1] of output that they produced. The average value is much higher post-accession (0.30) than pre-accession (0.16). For this reason, we also introduced cross-terms of year 2004 and 2005 dummies with the subsidy to output ratio, in order to check the specific impact of the larger post-accession payments (SAPS plus top-ups) on farms' technical efficiency. Our expectation is that technical efficiency is reduced by subsidies, as it was so far found in other countries (see section 1).

All variables expressed in national currency were deflated to the base year 2000 using the appropriate deflators (agricultural output index, intermediate agricultural input price index, machinery investment price index, consumer price index).

[1] The average exchange rate over the sample period was 250.58 HUF/EUR.

Estimation results

Production function results

The initial unrestricted model was used to test various hypotheses on parameters (Table 1), then to formulate the final restricted model. The null hypothesis that OLS would suffice to estimate the production function is rejected (Hypothesis 1), indicating that the use of SFA is appropriate. The null hypothesis that the estimated model can de reduced to the simpler however more restrictive Cobb-Douglas specification was strongly rejected (Hypothesis 2), and therefore a translog form is used. The null hypothesis that the coefficients of the heteroscedastic part are jointly zero is rejected, indicating heteroscedasticity in the model (Hypothesis 3). Three input variables proved to be significantly explaining the heteroscedasticity in the model: intermediate consumption, capital and labour. Despite the significant differences between the amounts of land farms are using, the total used land input was not significant in the heteroscedastic part. Production coefficients were found to be time varying (Hypothesis 4), and therefore cross-terms between the trend variable and the production factors are maintained in the model.

- insert Table 1 here -

The estimates of the final restricted production function are presented in Table 2. The model appears to fit the data well, since all the coefficients are statistically significant at 5 percent, except for the time trend variable and the four input-time cross-terms. The latter finding suggests that Hungarian farmers did not increase their factor use over the period studied 2001-2005. Regarding their production level, despite the positive coefficient of the square of the variable suggesting an upward move of frontier, the time trend is not significant.

This suggests that production has only slightly increased, in opposite to what could be expected for this period (adjustment and then accession to the EU).

The production factor elasticities, computed from the estimated model, are respectively 0.181, 0.411, 0.118 and 0.319 for land, intermediate consumption, capital, and labour inputs. The highest elasticities correspond to intermediate consumption and labour, suggesting that output could be increased by using more variable inputs and more labour.

Finally, in the translog function, returns to scale are determined by the sum of output elasticities. For the sample used, the return to scale coefficient is 1.032. The coefficient is close to 1, indicating that Hungarian farmers apply constant returns to scale (CRS) technology and have thus an optimal scale of production.

- insert Table 2 here -

Technical efficiency scores and determinants

Table 1 indicates that the null hypothesis of time invariant efficiency scores (Hypothesis 5) is rejected. The explanatory variables are found to be jointly significant, suggesting the presence of inefficiency effects, however excluding a constant term (Hypotheses 6 and 7).

Table 3 shows the coefficients of the explanatory variables included in the final model, but attention should be given when reading the results: with the SFA approach, the estimated coefficients explain the cause of inefficiency in the model. Thus, determinants with a positive sign suggest an obstacle to efficiency, while a negative sign indicates variables that enhance efficiency.

The sample's average efficiency score over the whole period is 0.73, suggesting that, on average, Hungarian farmers could increase their output by 27% without increasing their input use. The positive and significant coefficient for the trend variable given in Table 3 indicates that efficiency scores are deteriorating over time. By contrast, the negative sign for the two year dummies 2004 and 2005 indicates a reverse in this decreasing trend. Hence, taken together, the parameters of the trend variable and of the two year dummies jointly indicate that that pre-accession efficiency was decreasing while it started to increase again post-accession.

Conform to the intuition, farms in Regions 1 and 2 are more efficient than farms in Region 3, and the effect of soil quality on technical efficiency is positive. This indicates that natural conditions on which farmers have no power play an important role on their technical inefficiency. Evidence of such role was also found in other countries (e.g. Hansson, 2007).

The dummy for the legal form (Company dummy) indicates that companies are more efficient than family farms. This suggests that, despite the supervision and transaction costs problems that might arise in large farms, the size effect is prevailing.

The positive sign of the land to labour ratio indicates that farms with a production system that is more intensive in labour are less inefficient. The more labour per amount of land is used, the more efficient farms are. This result it is somehow puzzling as it would suggest the scarcity of labour in the rural areas of the country. The large elasticity of labour (0.319) in the production function, (computed at the mean) supports this finding.

The positive sign of the square of the livestock output to total output ratio indicates that mixed farms are more efficient than specialised farms, while the negative sign of the ratio itself indicates that, within specialised farms, livestock farms are more efficient than crop farms.

Finally, the subsidies to output ratio has a positive influence on inefficiency, suggesting that public subsidies prevent farms from being efficient. This result is in line with previous studies' findings in Western countries and CEECs (see section 1). We investigate this issue further with the help of the cross-terms. The cross-term between the year 2004 dummy and the subsidy to output ratio has no significant coefficient. Such insignificant effect may be due to the delay that Hungarian farmers experienced in receiving the first CAP payments, as payments for 2004 were only made in 2005. By contrast, the cross-term of the 2005 dummy and the subsidy to output ratio has a significant positive coefficient, implying that access to higher subsidies post-accession increased the inefficiency of Hungarian farms.

- insert Table 3 here –

Discussion and conclusions

This study investigated the determinants of Hungarian farms' technical efficiency during the period 2001-2005, a crucial phase of adjustment and first years of membership to the EU. Results revealed that accession to the EU has reversed back the pre-accession trend of decreasing efficiency. Increased competitiveness, opening of new market opportunities or access to better inputs may be reasons behind.

The investigation of the determinants of technical efficiency has allowed characterise the most efficient farms in Hungary over the period studied: these were companies, located in the favourable region of Western Hungary, and with a production system that was not specialised but labour intensive. This, along with the large production elasticity of labour (0.319), suggests labour scarcity in Hungarian agriculture 10-15 years after the transition. Such a claim may seem paradoxical, since rural areas in Hungary have plaid the role of shock absorbers during the transition, as in the other CEECs. The main evidence of such role was the increase of rural unemployment, when industrial workers returned to the land following their redundancy due to the collapse of the state-owned industrial sector. However, agricultural employment in the country dramatically declined during the transition; in 2003, agriculture accounted for only for 5.4 percent of the total employment, almost as little as in the EU-15, compared to more than 15 percent in other CEECs (EC, 2004). Although the number of agricultural holdings has also decreased, the paradox of the transition is that farm labour is getting scarce. As early as in 1998, Pouliquen (2001) reported that the employment per hectare in Hungary was only 90 percent of the EU-15 average, while it was up to 300 percent in other CEECs. One explanation for this scarcity is that the industrial sector has experienced a quicker recovery than the agricultural sector, and the service sector has developed remarkably. The industrial sector employs more than 40 percent and the service sector more than 50 percent of the labour force in rural areas as reported by the Network of Independent Agricultural Experts in the CEE Candidate Countries (2004). These experts recognised that employment in agriculture is dependent on many factors, one of them being agricultural policies, which highly influence farm incomes. In particular, increased farm incomes may attract more labour force in agriculture.

In this regard, the direct effect of agricultural support policies on farm production and efficiency was investigated in this paper. Accession to the EU was found to only enhance slightly technological change and production, contrary to what was expected from accession, but to improve farms' efficiency. However, the other side of the coin about EU-membership is that public subsidies received by farmers in the frame of the CAP have negative influence on their technical efficiency. As it has often been shown in agriculture, public support reduces farmers' effort, implying greater waste of resources and thus further location from the efficient frontier. This effect was found here to be even stronger in periods where subsidies were higher (2005 against 2004), letting us guess what may happen when SAP levels are increased in the next years.

The overall conclusion of this study is that, while EU-membership along with the high CAP payments have the positive effect that they may contribute to keep or attract new workforce in agriculture, they have the opposite effect that they reduce farms' performance.

This suggests that the Hungarian government may have to design specific national policies if its aim is to promote a farming system that uses labour and at the same time that is competitive.

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Table 1. Results of hypothesis testing for the model specification

Null hypothesis tested	Value of the test statistic	5-percent critical value	Con-clusion
Hypothesis 1: SFA is invalid ($\gamma = 0$)	884	'mixed' χ^2_{30} =43.1	Reject
Hypothesis 2: Cobb-Douglas specification is appropriate (all $\beta_{jk} = 0$, j and k denoting the four inputs)	391.8	$\chi^2_{15} = 24.99$	Reject
Hypothesis 3: No heteroscedasticity ($\rho_i = 0$, i denoting the i^{th} farm)	87.26	$\chi^2_{7} = 5.99$	Reject
Hypothesis 4: Time invariant production coefficients ($\beta_{Trend} = 0.5\beta_{Trend}{}^2 = \beta_{Trend\times x_1} = \beta_{Trend\times x_2} = \beta_{Trend\times x_3} = \beta_{Trend\times x_4} = 0$)	23.26	$\chi^2_{6} = 12.59$	Reject
Hypothesis 5: Time invariant efficiency scores ($\delta_{Trend} = 0$)	11.6	$\chi^2_{7} = 3.84$	Reject
Hypothesis 6: No inefficiency effects (all $\delta_j = 0$, j denoting the explanatory variables)	822	'mixed' $\chi^2_{11} = 9.04$	Reject
Hypothesis 7: No constant term in inefficiency effects ($\delta_0 = 0$)	0.66	$\chi^2_{7} = 3.84$	Do not reject

Source: Authors' calculations.

Table 2. Results of the estimation of the production function

Variable	Coefficient	Robust standard error
Constant	0.097***	0.023
ln x_1	0.170***	0.013
ln x_2	0.399***	0.024
ln x_3	0.143***	0.013
ln x_4	0.369***	0.023
Trend	0.007	0.008
½ln x_1^2	0.096***	0.010
½ln x_2^2	0.163***	0.021
½ln x_3^2	0.058***	0.005
½ln x_4^2	0.222***	0.022
½*Trend*^{2}	-0.030***	0.012
ln x_1 ln x_2	-0.017**	0.008
ln x_1 ln x_3	-0.019***	0.006
ln x_1 ln x_4	-0.061***	0.010
ln x_1 *Trend*	0.002	0.005
ln x_2 ln x_3	-0.046***	0.008
ln x_2 ln x_4	-0.138***	0.019
ln x_2 *Trend*	-0.007	0.008
ln x_3 ln x_4	0.030***	0.008
ln x_3 *Trend*	0.008*	0.004
ln x_4 *Trend*	-0.010	0.007
ln σ_v	-1.151***	0.026

Notes: The dependent variable is ln y. y is total net farm revenue from sales; x_1 is utilised agricultural area; x_2 is total intermediate consumption in value; x_3 is capital; x_4 is labour; Trend is time trend. ***, **, * indicate significant at 1, 5, 10 percent respectively.

Source: Authors' calculations.

Table 3. Results of the estimation of the determinants of technical inefficiency

Variable	Coefficient	Robust standard error
Time trend	0.619**	0.255
Year 2004 dummy	-1.364***	0.428
Year 2005 dummy	-2.197***	0.743
Region 1 dummy	-0.868***	0.297
Region 2 dummy	-0.543**	0.251
Soil quality index	-1.578***	0.303
Company dummy	-1.812**	0.733
Land to labour ratio	4.825***	1.102
Livestock output to total output ratio	-2.912***	0.969
Square of livestock output to total output ratio	2.997***	1.054
Subsidies to output ratio	0.138***	0.013
Subsidies to output ratio × year 2004 dummy	0.006	0.014
Subsidies to output ratio × year 2005 dummy	0.808***	0.257

Note: ***, **, * indicate significant at 1, 5, 10 percent respectively.

Source: Authors' calculations.