FACEPA

Farm Accountancy Cost Estimation and Policy Analysis of European Agriculture

Application and extensions of the Cost of Production Model

- Use and applicability of SFA -

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Executive Summary

Two main approaches have been developed to estimate the unknown production frontier. The nonparametric approach (within this category the most commonly used method is Data Envelopment Analysis, DEA) essentially requires the solving of a mathematical programming problem. Within the parametric approaches, the Stochastic Frontier Analysis, (SFA) is commonly used. *Aigner at al.* (1977) and *Meeusen and Van den Broeck* (1977) have simultaneously yet independently developed the use of SFA in efficiency analysis. In this deliverable we first present the econometrics underpinning the application of SFA, the various models possible to estimate, their caveats and extensions. In the second chapter some efficiency and farm productivity papers applying SFA and relevant for the aims of FACEPA project are discussed.

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Abbreviations and Acronyms

CD	Cobb-Douglas
CEE	Central and Eastern European Countries
COLS	Corrected Ordinary Least Squares
DEA	Data Envelopment Analysis
DGP	Data Generation Process
EU	European Union
FACEPA	Farm Accountancy Cost Estimation and Policy Analysis of European Agriculture
FADN	Farm Accountancy Data Network
LR	Likelihood Ratio
ML	Maximum Likelihood
SFA	Stochastic Frontier Analysis
TE	Technical Efficiency

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Introduction

Of the three possible farm efficiency approaches, parametric, non-parametric and semi-parametric, in this paper we discuss the methodology and applicability of parametric methods, more precisely the SFA. The deliverable is organized as follows: in the first chapter we discuss the econometrics of the approach, highlighting the extensions of the basic model. Chapter two presents empirical applications using SFA, relevant for the aims of the FACEPA project. This chapter is divided into two sections, the first presents papers focusing of farm type and size issue, whilst the second section summarizes the results of studies analyzing the effect of subsidies upon farm performance. The final part of the paper concludes.

Parametric farm performance and efficiency methodology: Stochastic Frontier Analysis

Within the parametric approaches, the Stochastic Frontier Analysis, (SFA) is commonly used. *Aigner at al. (1977)* and *Meeusen and Van 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 can not be influenced by the firm such as weather, trade issues, access to materials, and a non-negative one, measuring the technical inefficiency, i.e. the systematic departures from the frontier (u_i):

$Y_i = f(x_i)\exp(v_i - u_i)$ or, equivalently:

$\ln(Y)_i = \beta x_i + v_i - u_i)$

where Y_i is the output of the i^{th} firm, x_i a (k+1) vector of inputs used in the production, $f(\cdot)$ the production function, u_i and v_i the error terms explained above, and finally, β a (k+1) column vector of parameters to be estimated. The output orientated technical efficiency, (TE) is actually the ratio between the observed output of firm i to the frontier, i.e. the maximum possible output using the same input mix x_i (*Battese, 1992*), figure 1:

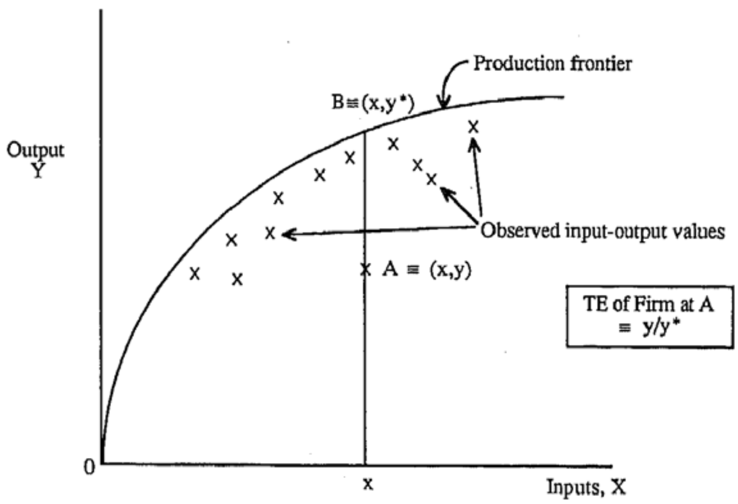

Figure 1. *Technical efficiency of farms.* Source: *Battese (1992)*, pp. 187

Arithmetically, technical efficiency is equivalent with:

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{\exp(x_i\beta + v_i - u_i)}{\exp(x_i\beta + v_i)} = \exp(-u_i)\,,\ 0 \le TE_i \le 1\,.$$

As illustrated on figure 2, contrary to the non-parametric DEA approach, where all production technical efficiency score are located on, or below the frontier, in SFA they are allowed to be above the frontier, if the random error *v* is larger that the non-negative *u*.

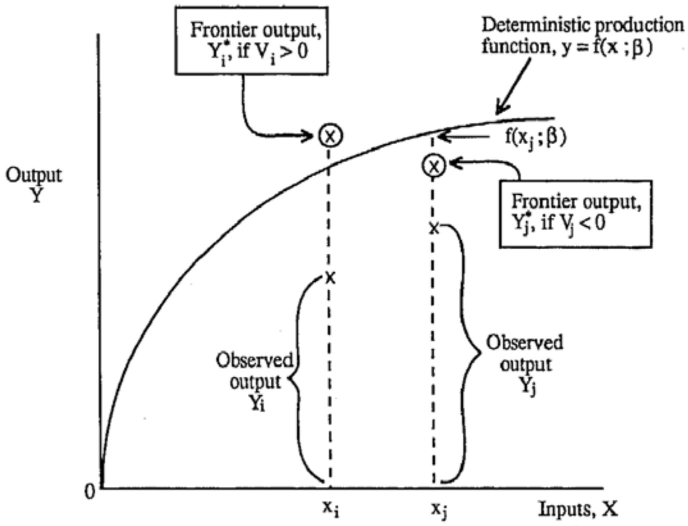

Figure 2. *Stochastic frontier model.* Source: *Battese (1992)*, pp. 191.

Applying SFA methods requires distributional and functional form assumptions. First, because only the $w_i = v_i - u_i$ error term can be observed, one needs 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, $N(0, \sigma_v^2)$, independent of u_i. There are a number of possible assumptions regarding the distribution of the non-negative error term u_i associated with technical inefficiency. 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 Cobb-Douglas:

$$f(x_i) = e^{\beta_0} \prod_{k=1}^{K} x_{ik}^{\beta_k}$$

or TRANSLOG specification:

$$\ln f(x_i) = \sum_{k=1}^{K} \beta_k \ln x_{ik} + \frac{1}{2} \sum_{k=1}^{K} \sum_{j=1}^{K} \beta_{kj} \ln x_{ik} \ln x_{jk} \ .$$

Because the two models are nested, it is possible to test the correct functional form by a Likelihood Ratio, LR test. The TL is the more flexible functional form, whilst the CD restricts the elasticities of substitution to 1. The model could be estimated either with Corrected Ordinary Least Squares, COLS or Maximum Likelihood, ML. With the availability of computer software, the estimation by ML became less computationally demanding, and the ML estimator was found to be significantly better than COLS (*Coelli et al.,1997*).

With panel data, TE can be chosen to be time invariant, or to vary systematically with time. To incorporate time effects, *Battese and Coelli (1992)* define the non-negative error term as exponential function of time:

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

where t is the actual period, T the final period, and η a parameter to be estimated. TE either increases (η>0), decreases (η<0) or it is constant over time, i.e. invariant (η=0). LR tests can be applied to test the inclusion of time in the model. Since TE is allowed to vary, the question arise what determines the changes of TE scores? Early studies applied a two-stage estimation procedure, first determining the inefficiency scores, and then, in a second stage regressing TE scores upon a number of firm specific variables assumed to explain changes in inefficiency scores. Some authors however showed, that conflicting assumptions are needed for the two different estimation stages. In the first stage, the error term representing inefficiency effects, are assumed to be independently and identically distributed, whilst in the second stage they are assumed to be function of firm specific variables explaining inefficiency, i.e. they are not independently distributed (*Curtiss, 2002*). *Battese and Coelli (1995)* proposed a one stage procedure where firm specific variables are used to explain the predicted inefficiencies within the SFA model. The explanatory variables are related to the firm specific mean μ of the non-negative error term u_i:

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

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.

Using cross-section or panel data may often lead to heteroscedasticity in the residuals. With heteroscedastic residuals, OLS estimates remain unbiased but no longer efficient. In frontier models however, the consequences of heteroscedasticity are much more severe, as the frontier changes when the dispersion increases. *Caudill et al. (1995)* introduced a model which incorporates heteroscedasticity into the estimation. That is done by modelling the relationship between the variables responsible for heteroscedasticity and the distribution parameter σ_u:

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

where x_{ij} are the j^{th} input of the i^{th} farm, assumed to be responsible for heteroscedasticity, and ρ_j a parameter to be estimated.

Within SFA approach it is possible to test whether any form of stochastic frontier production function is required or the OLS estimation is appropriate using a LR test. Using the parameterisation of *Battese and Cora (1977)*, define γ, the share of deviation from the frontier that is due to inefficiency:

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

where $\sigma^2{}_v$ is the variance of the v and $\sigma^2{}_u$ the variance of the u error term.

It should be noted however, that the test statistic has a ‘mixed’ chi square distribution, with critical values tabulated in *Kodde and Palm (1996)*.

Some applications of SFA

Most efficiency and productivity studies focused on three main groups of issues when explaining the sources of inefficiency: farm owner/manager characteristics, farm type and size, and finally the effect of various subsidies. Here we focus on the literature applying SFA methodology and studying the latter two issues.

Farm type and size research

The optimal farm structure as well as the optimal farm size has long been in the focus of agricultural economics debates. The issues seem to be even more controversial in transitional newly acceded EU economies, where (in most cases) political-social and economical changes in the early 1990s were followed by the dismantling of socialist agricultural farm structures (decollectivisation and the breaking up socialist state agricultural enterprises) and the emergence of various new, mostly family farm based structures. *Gorton and Davidova (2004)*, reviewed the efficiency studies focusing on Central and Easter European Countries (CEE). Of the studies employing SFA methodology *Curtiss (2000)* found that on average, in the Czech Republic, wheat and rapeseed farms larger than 150 ha perform better, *Munroe (2001)* found that in Poland, farms smaller than 15 ha are less efficient, whilst for Slovakia, *Morisson (2000)* analysed 7 commodities, and concluded, that there is a positive relationship between the scale of production and efficiency scores. In addition *Curtiss (2002)* found evidence of higher technical efficiency of individual farming in sugar beet production, but lower in wheat production, compared to corporate farming. *Latruffe et al. (2004)* reinforced Munroe's results for Poland, and found that for both crop and livestock farms the size-efficiency relationship is positive, meaning large farms are more efficient. More recently, *Alvarez and Arias (2004)* using data from a group of 196 dairy farms in Northern Spain found a significant positive relationship between technical efficiency and size.

The effect of subsidies upon farm performance research

As it has often been shown in agriculture, public support reduces farmers' effort, implying greater waste of resources and thus further position from the efficient frontier. This maybe even more appropriate when considering decoupled payments since these government transfers are not linked to output. Thus if income supports are mainly through decoupled transfers higher production does not imply further premiums. This in turn may reduce incentives to produce close to the possible frontier resulting in increased inefficiencies (*Serra et al., 2008*).

Serra et al. (2006) elaborated a theoretical framework that allows for both output and input price uncertainty and incorporates economic agent's risk attitudes. The theoretical framework and empirical analysis revealed that in a non-risk neutral scenario decoupling will cause farms with decreasing absolute risk aversion, DARA (increasing absolute risk aversion, IARA) to increase (decrease) input use if the input is risk increasing. If however, the input is risk decreasing than the impacts of decoupled government transfers are inconclusive. *Bakucs et al., (2008)* investigated the determinants of Hungarian farms' technical efficiency, using Hungarian FADN data for the 2001-2005 period, the 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 not specialised and 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. The direct effect of agricultural support policies on farm production and efficiency was also investigated in the 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. This effect was found here to be even stronger in periods where subsidies were higher (2005 against 2004).

More recently, *Latruffe et al. (2008),* using non-parametric methods investigated the relationship between CAP direct payments and managerial efficiency of French crop and beef farms, and found a significantly negative one for crop farms and a significant positive one for beef farms. They concluded that the type of payments also matter, since Less Favoured Area and area-based payments decrease crop farms' efficiency, whilst agri-environmental and headage payments increase beef farms' efficiency scores.

In a recent paper, *Serra et al. (2008)* revisited the issue of the relationship between technical efficiency and decoupling. Using an additive SFA approach as opposed to Stochastic Frontier Production Function used in Serra et al. (2006), authors have shown that since technical inefficiencies are positively related to output variability and negatively to production mean, a decoupling process affecting the input use will also have an impact upon technical inefficiencies. Using empirical farm level data from Kansas the paper found that an increase in decoupled transfers will induce an increase (decrease) in DARA (IARA) farms technical inefficiency, if the given input is risk decreasing. With risk increasing inputs however, the effect of decoupling upon technical inefficiencies can be either positive or negative, somehow contrasting previous studies mostly concluding that government transfers are farm inefficiency increasing.

Conclusions

In this deliverable we have presented the applicability of SFA methodology in farm efficiency and productivity research. A brief review of papers focusing on farm type and effect of subsidies issues applying this methodology presents the results obtained. We may conclude, that considering the aims and goals of the FACEPA project, SFA is an appropriate and applicable methodology.

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