The influence of management accounting use on farm inefficiency

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Abstract

This paper aims to estimate a translog stochastic frontier production function with panel data of 147 mixed Catalan farms in a five-year period. The mean output efficiency in the period analysed was estimated to be 62.3%. We added management variables to the traditional factors explaining farm efficiency, and found that fully integrated management based on reliable accounting information and comprising planning and control phases reveals to be a significant factor positively affecting farm efficiency. Farm efficiency levels were also found to be positively influenced by farm size, while rented and irrigated area influence negatively farm efficiency levels.

Keywords: *Output efficiency; Managerial capacity; Accounting information, Farm management.*

JEL classification: C23, Q12

Introduction

The measurement of inefficiency in the agricultural sector of developing and developed countries has received renewed attention since the late eighties from an increasing number of researchers, as the frontier approaches to efficiency measurement have become more popular. There have been a vast number of applications of frontier methodologies to empirical studies with farm-level data in a large number of countries. For a review of empirical applications in agricultural economics, see Battese (1992), Bravo-Ureta and Pinheiro (1993), Coelli (1995), and Thiam et al. (2001).

Technical inefficiency scores obtained from the production frontier approach have a very limited utility for policy and management purposes if empirical studies do not investigate the sources of inefficiency. As observed in previous literature surveys of agricultural efficiency, a large amount of published papers restrict their attention to efficiency measurement without considering its determinants. Until recently, factors hypothesized as influencing farm efficiency were introduced in a limited number of studies and as ad-hoc socio-economic variables without an underlying theoretical model (Bravo-Ureta and Rieger, 1991; Ferrantino and Ferrier, 1995; Battese and Coelli, 1995;

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The authors wish to express their gratitude to the Xarxa Comptable Agrària de Catalunya for providing the data that made this article possible

Coelli and Battese, 1996; Battesse et al., 1996; Battese and Broca, 1997; Álvarez and González, 1998; Wilson et al., 1998; Brümmer, 2001).

Rougoor et al. (1998) provide a complete theoretical framework for analysing farm management. They point out that management is a necessary factor to be added to the traditional factors explaining farm efficiency. The technical and economic results of the farm are determined at a starting point by management, which seeks to optimize or influence technical and biological processes at the farm, which are controllable to a certain extent, and perform their task in a certain environment and economic conditions. Thus, three groups of factors may be hypothesized as influencing the level of efficiency. The first group indicates farm management capacity, represented by personal aspects of the farmer and by practices and procedures used in the decision-making process. Kay and Edwards (1994) use a well-known division of the decision-making process into planning, implementation and control. The second group of factors are technical and biological processes. The third group represents the influence of the institutional, physical and economic environment of the farm. Evidence of the influence of management practices and procedures on the variation in farm performance may become an important source of information for designing policies to achieve high farm performance. The quality of the decision-making process is an important factor influencing the adoption of logical and organized decisions in the farm production process.

Wilson et al. (2001) provide evidence that wheat farmers in eastern England who seek information, have more years of managerial experience, and have a large farm are associated with higher levels of technical efficiency. To our knowledge, this is the only empirical study in the economic literature that explains the influence of management on technical efficiency by including variables that relate both personal aspects and aspects of the decision-making process of the farmer. These authors constructed an “information seeking” variable by summing the number of information sources the farmer declared to use out of the 16 listed in a questionnaire (personal, written, electronic and other sources). However, the decision-making process and the use of accounting information in the decision-making process were not explicitly considered in this study. The scale, scope and quality of information are a crucial element in the decisions managers make. One important component of a modern information system is accounting information. It plays an important role in planning, implementation and control that may greatly influence farm decisions, practices and performance. This is a generalized assumption applied to agriculture, despite the low use of accounting in this sector (Poppe, 1991). For example, Luening (1989) states that farm accounting provides information on the farm’s financial position and performance, a diagnostic tool for identifying strengths and weaknesses, and a planning tool. However, little empirical research has been done to verify that accounting will improve farm performance. This lack of empirical research is also applicable to small firms (Mitchell et al., 2000). Verstegen et al. (1995, 1998), Lazarus et al. (1990) and Tomaszewski et al. (2000) performed regression analysis to demonstrate that the use of management information systems improves profits and performance in sow-herd and dairy farms. However, to our knowledge no previous production frontier studies has included the use of accounting information by farmers to explain technical farm efficiency. Trip et al. (2002) showed positive associations between the efficiency of commercial greenhouse growers and monitoring and firm evaluation.

The principal aim of this paper is to estimate a translog stochastic frontier production function.

This paper differs from much previous research by estimating the sources of inefficiency with a stochastic production frontier model for a balanced panel data set of farms located in a European Union country. The model is specially designed to obtain evidence regarding the influence of the use of accounting information in the decision-making process, as a planning and control tool, on farm efficiency variation.

The paper continues with the following structure. Section 2 outlines the stochastic frontier approach with the inefficiency effects model. The empirical specification of the model is presented in Section 3. Empirical results derived from this model and discussion are presented in Section 4. The empirical results allow us to present efficiency scores, and factors explaining efficiency. The final section summarizes the findings of this research.

The Stochastic Production Frontier Function

Our method constructs a best-practice frontier from the data in the sample (i.e., we construct a frontier for the sample of observation units and compare individual farms with that frontier). Frontier approaches do not necessarily observe the *true* (unobserved) technological frontier, only the best practice reference technology. An observation is technically inefficient if it does not minimize its input given its output. Efficiency scores of unity imply that the individual farms in a given year (the unit of observation) are on the frontier in the associated year. Efficiency scores lower than unity imply that the farm is below the frontier: in this case, a further proportional increase in output is feasible, given productive factor quantities and technology. We assume that each farm attempts to maximize output from a given set of inputs.

We consider a panel data model for inefficiency effects in stochastic production frontiers based on the Battese and Coelli (1995) model. Our stochastic production frontier model allows: (i) technical inefficiency and input elasticities to vary over time in order to detect changes in the production structure; and (ii) inefficiency effects to be a function of a set of explanatory variables the parameters of which are estimated simultaneously with the stochastic frontier. Time-invariant efficiency would be an unrealistic assumption given that elimination of slack compresses the efficiency distribution, while generation of slack works the opposite way (Kumbhakar et al., 1997). The approach is stochastic, and farms can be off the frontier because they are inefficient or because of random shocks or measurement errors. Efficiency is measured by separating the efficiency component from the overall error term.

Having data for i farm in year t for input and output data (X_{it},Y_{it}), the stochastic frontier production function model with panel data is written as:

$$Y_{it} = f(X_{it};\ \beta_t) \cdot e^{(V_i - U_{it})} \tag{1}$$

where Y_{it} is the farm output at the t-th observation (t=1,2,...,T) for the i-th farm (i=1,2,...,n);

f(·) represents the production technology;

X_{it} is a vector of input quantities of the i-th farm in the t-th time period;

β_t is a vector of unknown parameters in the t-th time period;

V_{it} are assumed to be independent and identically distributed random errors, which have normal distribution with zero mean and unknown variance σ^2_V);

U_{it} are non-negative unobservable random variables associated with the technical inefficiency in production, such that, for the given technology and level of input, the observed output falls short of its potential output.

In the technical inefficiency effects model the error term (ε_{it}) is composed of the following two components: technical inefficiency effect and statistical noise. That is, $\varepsilon_{it} = V_{it} + U_{it}$. A farm-specific effect is not explicitly considered in the estimated production function model because it would be considered as *persistent* technical inefficiency, which implies that we do not consider the existence of unobserved systematic effects which vary across farms in the production function (Heshmati et al., 1995).

The technical inefficiency effect, U_{it}, could be specified as:

$$U_{it} = z_{it}\delta + W_{it} \tag{2}$$

where U_{it} are non-negative random variables which are assumed to be independently distributed as truncations at zero of the $N(m_{it}, \sigma^2_U)$ distribution;

m_{it} is a vector of farm-specific effects, with $m_{it}=z_{it}\delta$;

z_{it} is a vector of variables which may influence the efficiency of the farm;

δ is a vector of parameters to be estimated;

W_{it}, the random variable, is defined by the truncation of the normal distribution with mean zero and variance σ^2, such that the point of truncation is $-z_{it}\delta$.

An estimated measure of technical efficiency for the i-th farm in the t-th time period may be obtained as:

$$TE_{it} = \exp(U_{it}) \sum [0,1] \tag{3}$$

TE_{it} gives the ratio of the observed output to the maximum level of output evaluated at the frontier. The unobservable quantity U_{it} may be obtained from its conditional expectation given the observable value of $(V_{it}+U_{it})$ (Jondrow et al., 1982; Battese and Coelli, 1988).

From the policy perspective, we are interested in point estimates of farm efficiency scores but also, and even more importantly, in interval confidence in order to know the empirical magnitude of the uncertainty and precision associated with the estimates of efficiency levels. In fact, it is very important to determine with precision whether a farm is significantly inefficient, that is, its efficiency score is significantly different from one. Horrace and Schmidt (1996) proposed a method to calculate confidence intervals for efficiency estimates from stochastic frontier models by imposing distributional assumptions. These authors obtained a wide confidence interval for three panel data sets, which indicates that the efficiency estimates were rather imprecise. They observed that confidence intervals are narrower when the number of periods (T) is large and when σ^2_U is large relative to σ^2_V. Bera and Sharma (1999) showed how once we have the conditional mean and variance of the inefficiency terms, we can report standard errors and construct confidence intervals for farm-level technical inefficiency. This method gives the same confidence intervals as those calculated using Horrace and Schmidt's (1996) formulae (Bera and Sharma, 1999). In a comparison of different methods to construct confidence interval estimates for technical efficiency levels, Kim and Schmidt (2000) could not find much difference between Bayesian and classical procedures, in the sense that the classical MLE based on a distributional assumption for efficiencies gives results that are rather similar to a Bayesian analysis with the corresponding prior.

Notwithstanding, estimation of uncertainty magnitude has been neglected in most of the preceding literature on farm efficiency. The approach proposed by Horrace and Schmidt

(1996) to construct confidence interval estimates was first applied to estimate confidence intervals for technical inefficiency of private farms in Slovenia in 1995 and 1996 by Brümmer (2001).

In this paper we follow the formulation initially proposed by Horrace and Schmidt (1996), whose results are identical to those of Bera and Sharma (1999), for the construction of confidence interval estimates for efficiency scores. For the model in equation (1), given the following distributional assumptions for the error components $U_{it} \cup N(\mu, \sigma^2_U)$ and $V_{it} \cup N(0, \sigma^2_V)$, the conditional distribution of U_{it} given ε_{it} is truncated with normal mean μ_{it*} and variance σ_*, where

$$\mu_{it*} = (\sigma^2_U \cdot \varepsilon_{it}) / (\sigma^2_V + \sigma^2_U), \quad \text{and where} \quad \sigma^2_* = (\sigma^2_U \cdot \sigma^2_V) / (\sigma^2_V + \sigma^2_U).$$

With the conditional mean and variances, confidence intervals for U_{it} given ε_{it} can be estimated. The (1-α)100% lower confidence bound (LCB) and the upper confidence bound (UCB) for TE_{it} are:

$$LCB_{it} = \exp\left[-\mu_{it*} - \Phi^{-1}\{1-(\alpha/2)\cdot(1-\Phi(-\mu_{it*}/\sigma_*))\}\,\sigma_*\right] \quad (4)$$

$$UCB = \exp\left[-\mu_{it*} - \Phi^{-1}\{1-(1-\alpha/2)\cdot\{1-\Phi(-\mu_{it*}/\sigma_*)\}\,\sigma_*\right] \quad (5)$$

$\Phi(\cdot)$ in the preceding equations is the distribution function of the standard normal distribution.

Data and Model Specification

Data.- Our data consists of a balanced panel of observations on 147 mixed farms in Catalonia (Spain) from 1989 to 1993. The source of information is the Farm Accountancy Data Network (FADN)[1].

Variables in the production function model.- The specification of a production function requires the definition of only two types of variables: the output of farm production and the inputs employed in the production process. Empirical measurement of output in agricultural production is not as controversial as it could be in services production, but the agriculture literature on production functions offers a range from physical quantities of output to the monetary value of the output. As has been previously argued in this paper, given multi-output production we reject physical quantities of output as a measurement tool. Instead, we use gross farm income (GFI) as the output measure of farm production. As the European Commission (1991a, p. 34) states, gross farm income is a concept close to value added (GVA), according to national accounts criteria of value added in a nation or industry. Total farm revenue is an inappropriate measure to compare low levels of output of extensive farms with intensive farms presenting high outputs and intermediate consumptions. In contrast with farm revenue, GFI allows comparisons between extensive and intensive farms. In our case, we consider that gross farm income has the advantage of including in the output measure subsidies arising from current productive activity, given that the EU agricultural policy relies heavily on subsidies. This indicator corresponds to the payment for fixed factors of production supplied by the agricultural sector, whether they are external or family factors. As a result, holdings can be compared irrespective of the family/non-family nature of the factors of production employed. The output measure has been deflated using the agricultural GDP deflator and it has been expressed in 1989 euros.

Inputs employed in farm production are represented in this study by five variables:

fixed capital (FIXEDK), current assets (CURRASSETS), annual work units (AWU), specific costs (SPECIFCOSTS) and overhead costs (OVERHEAD)[2]. Four of these variables are measured in monetary terms in order to avoid quality differences in input measures (input heterogeneity), as observed in other studies, and to allow inclusion of all inputs employed in the production process. All monetary values have been expressed in 1989 euros and are deflated by the most suitable category in the series of input prices paid by the agricultural sector published by the Spanish Agricultural Ministry.

The advantage of using monetary values as input measures is that we obtain a measure that is closer to productive or output efficiency than to technical efficiency, given that input paid prices may affect the inefficiency measures. Then, in the rest of the paper we refer to estimated efficiency scores as output efficiency.

Table 1 identifies the output and input variables in the analysis, and also shows summary statistics. The average temporal evolution of inputs and outputs of the 147 Catalan farms is depicted in Table 2. These variables do not show a clearly defined trend, mainly due to agricultural price fluctuations.

Table 1. Summary Statistics for Variables in the Stochastic Frontier Models (n=735)

Variable	Sample mean	Standard deviation	Minimum	Maximum
Output variable:				
Gross farm income (GFI)	17336.03	18119.50	357.22	169439.95
Input variables:				
Fixed capital (FIXEDK)	127351.47	144235.64	5020.43	1214219.40
Current assets (CURRASSETS)	33101.41	41342.26	132	253245.00
Annual work units (AWU)	1.53	0.73	0.36	5.06
Specific costs (SPECIFCOSTS)	33216.93	60675.45	40	358619.00
Overhead costs (OVERHEAD)	5094.46	6039.22	47	45875.00
Variables hypothesized as influencing efficiency:				
Age of the farmer (AGE)	47.18	11.21	19	70
Accounting use (ACCOUNTI)	0.35	0.48	0	1
Herfindhal concentration index (CONCHERF)	0.59	0.23	0.1	1
Control (CONTROL)	0.05	0.23	0	1
% Family work units (FWU)	89.48	19.20	0	100.00
Extensive farming (EXTENSCR)	0.17	0.37	0	1
Permanent crops (PERMCROP)	0.49	0.50	0	1
Dairy and drystock (DAIRYDRY)	0.03	0.18	0	1
Pigs and poultry (PIGPOULT)	0.13	0.33	0	1
Location in mountain zone (MOUNTZO)	0.05	0.21	0	1
Location in less favoured zone (LESSFAZO)	0.42	0.49	0	1
% of irrigated utilized agricultural area (IRRUAA)	33.07	41.09	0	100.00
Economic size units (ESU)	22.47	20.25	1	140.00
% of rented utilized agricultural area (RENTEDUA)	7.35	20.27	0	100.00
% of current subsidies on total output (CURRSUBS)	9.17	15.62	0	163.71
Ratio of debt to assets (%) (LIABILTO)	5.72	10.62	0	64.82

Variables in the inefficiency effects model.- In our model, unexplained systematic production differences are attributed to inefficiency. Several types of factors are hypothesized to influence inefficiency variation.

As mentioned earlier, previous frontier production models attempt to explain inefficiency through a set of available variables on technical and economic characteristics of farms, but with the exception of Wilson et al. (2001) they did not consider management as a crucial factor. Using the theoretical framework of Rougoor et al. (1998) as a basis, we sought to build a complete model, which included farm, environmental and management characteristics. The main focus of interest of this study is the role played by accounting information in the management process.

Variables hypothesized as influencing farm efficiency are grouped into management capacity and environment variables. Management capacity variables include:

- Personal aspects: age of the farmer (AGE).
- Three phases of the decision-making process:
- Planning: accounting use (ACCOUNTI).
- Implementation: Herfindahl concentration index (CONCHERZ), percent of family work units to annual work units (FWU).
- Control: carrying out sophisticated control of farm activity making use of various data from other farms as a benchmark (CONTROL).

The following types of farming represent variables of technical and biological processes: extensive farming (EXTENSCR), permanent crops (PERMCROPS), dairy and drystock (DAIRYDRY), and pigs and poultry (PIGPOULT).

Environment and economic variables include:

- Institutional aspects: year (YEAR).
- Physical aspects: location in mountain zone (MOUNTZO), location in less favoured zone (LESSFAZO), percent of irrigated utilized agricultural area (IRRUAA).

Economic aspects: economic size units (ESU), percent of rented utilized agricultural area (RENTEDUA), percent of current subsidies on total outputs (CURRSUBS), ratio of debt to assets (LIABILTO).

AGE is expressed in years and it is an indicator of experience. It is expected that more experienced and professional farmers will have better skills enabling more effective decision making and assuring the efficiency of their farms.

Table 2. Development of Production in Catalan Farms (Average Values)

	1989	1990	1991	1992	1993
Gross farm income (GFI)	17020.59	17030.63	17396.96	18078.44	17153.50
Fixed capital (FIXEDK)	148768.12	141479.95	118228.33	112779.92	115501.01
Current assets (CURRASSETS)	28576.50	27804.52	32137.30	37152.94	39475.79
Total employment (AWU)	1.55	1.49	1.52	1.56	1.55
Specific costs (SPECIFCOSTS)	32821.71	32129.30	32076.79	33916.87	35139.96
Overhead costs (OVERHEAD)	4083.54	4554.86	5128.47	5581.69	6123.72
GFI per employed person	10427.24	11501.19	11510.36	11420.68	11198.39
Fixed capital per person	100626.56	100704.24	80371.20	73149.61	79304.63
Variable capital per person	20862.27	21006.35	24147.92	25148.71	26884.97

Two variables were included to reflect the quality of information used in farm management. Usually farmers base their decisions on intuitive and poorly elaborated information. In this respect, we assume that accounting provides significant incremental information that usually represents an improvement on the information available to farmers. ACCOUNTI is a dummy variable equal to 1 if the farm currently uses elaborated accounting information in its management process and 0 otherwise. This variable reflects a prior elementary use of high-quality information provided by accounting. Farms were asked whether or not they usually base their decisions on an analysis of the economic and financial situation of the farm provided by the FADN. It is assumed that farms using accounting information make a better evaluation of the effects of their decisions than those that base them on intuitive information. This is the kind of planning that can reasonably be expected in small firms such as farms. It would be unrealistic to expect a formal budgeting procedure taking the form of balance sheet, cash or profit and loss statements. The control phase of the management process was assessed with the variable CONTROL. As in the planning procedure, farmers usually control their activity with intuitive perceived information. In meetings with the accounting agencies, we found data on those farms that performed a more sophisticated control procedure consisting in discussing, analysing and comparing their FADN data with those of other farms as a benchmark. We consider that this is a reasonable proxy variable for the existence of a control procedure in farms. Thus, CONTROL is a dummy variable equal to 1 if the farm carries out control and 0 otherwise.

Confidentiality is an important commitment of the FADN. It was therefore impossible for us to get in direct contact with farms. Questionnaires about ACCOUNTI and CONTROL were sent to the XCAC, who distributed them to the accounting agencies, who then answered and submitted them.

The implementation phase of the decision-making process is represented by output diversification and the use of hired labour. Farms are small organizations in which, apart from operational tasks, there is a limited array of decisions, which can be summarized as the number of products to be produced on the farm and the amount of hired labour. The type of farming is a consequence of several factors, mainly climatic conditions and the geographical determinants of the area in which the farm is located. However, given a type of farming, the farmer can decide whether to diversify risk with different products, or to specialize and seek efficiency.

CONCHERZ indicates the output concentration of a farm, calculated by means of the Herfindahl index with the values of 22 different items of farm output. Allen and Lueck (1998) argue that product diversification in farms mitigates the reduction in income produced by random effects

FWU indicates the family orientation of the farm. The farmer may decide whether to limit the size of his business to the available family work, or to enlarge it and take the responsibility of organizing a team of workers. The European Commission (1991a) found this variable interesting and valuable.

Technological conditions are represented by four dummy variables indicating the type of farming. The type of farming determines the technical and biological processes the farmer has to cope with. Farms where the predominant type of farming is extensive crops are indicated with EXTENSCR, permanent crops and horticulture with PERMCROP, dairy and drystock farming with DAIRYDRY, pigs and poultry farming with PIGPOULT, and mixed farming with the dummy variable omitted. These are dummy variables equal to 1 if the farm is identified as corresponding to each of the four groups and 0 otherwise.

The whole sample used in this study belongs to the same region, which means the same institutional environment. Thus, the only modifications in the institutional framework are introduced by yearly changing conditions represented by the variable YEAR.

Physical aspects are represented by farm location and irrigation. We use the dummy variables LESSFAZO and MOUNTZO to refer to farm location in less favoured and mountain zones respectively, while the omission of the dummy variable indicates farms located in normal zones. Farms situated in less favoured and mountain zones are expected to be less efficient, because they are handicapped by low potential for crop diversification, and poorly endowed in terms of infrastructure and services, etc. The European Commission (1994) found better performance on farms located in normal zones than those located in these areas.

IRRUAA indicates the percentage of irrigated utilized agricultural area of the holding. A dry climate and water shortages handicap farming in Mediterranean countries, because they limit farms to a few types of farming and reduce farm productivity. Higher inefficiency is expected for lower values of this variable.

Economic aspects include economic size, tenancy and financial status. ESU is a standard measure of size used in the FADN methodology. The ESU defines the economic size of an agricultural holding on the basis of its potential gross added value in total standard gross margin (European Commission, 1990 and 1998).

RENTEDUA indicates the percentage of rented agricultural area of the farm. Farmers will be unlikely to invest in land improvements of rented land, thus contributing to inefficiency.

The percentage of current subsidies on total output (CURRSUBS) indicates the relative importance of current subsidies in a farm. This variable is included in the model because gross farm income includes current subsidies received by farms, they are an important share of income in some European farms (European Commission, 1994), and they have an increasing importance in Catalonia, as can be seen in Table 3.

The ratio of debt to assets (LIABILTO) is a classical indicator of debt burdens. The financial structure of farms is not related to their economic efficiency, but heavily indebted farms with financial burdens are highly vulnerable to the frequent random effects that lead to shortfalls in income. When a farm faces a reduction in its revenues because prices fall or climatological phenomena affect production, income and cash flow subsequently fall. The farm is unable to service its debts. Consequently, the farm needs to increase its debts or obtain liquidity through land sales, by depleting inventories or effecting disadvantageous sales. This was noted by Foster and Rauser (1991), who found that financially stressed farmers make inefficient decisions. We hypothesize that indebtedness will contribute to farm inefficiency.

Table 3 presents the temporal evolution of factors hypothesized as influencing efficiency. These data show trends that are characteristic of the agricultural sector, and specifically that of Catalonia. The average age of farmers is constantly increasing because most of farmers' offspring refuse to continue farming. The low values for the variables ACCOUNTI and CONTROL reflect that farmers usually apply purely intuitive management. Possible explanations for the low percentage of farmers using FADN information is that usually farmers have no appropriate economic and management skills, and that they do not likely find FADN a suitable instrument to be used for efficient management. The values of the variables CONCHERF and ESU fluctuate according to climate and price fluctuations. The high proportion of family work reflects the predominance of small family farms, which is characteristic of Western agriculture (Schmitt, 1991). The persistent increase in subsidies received by farms is a consequence of the period immediately following the admission of Spain to the EU and the Common Agricultural Policy (CAP). The low but increasing trend in the rate of indebtedness is characteristic of Catalan and Spanish farms. Variables indicating farm location, percentage of irrigated land and type of farming do not show variation during this period because they reflect structural characteristics of farms. The sample scarcely represents the proportion of Catalan farms with pigs and poultry as the predominant type of farming, but this is a recognized and generalized drawback of the FADN for the whole EU (Commission of the EU, 1988; Vard, 1993).

Specification of the production function model.- To render the model operational and to limit the restrictive properties imposed on the production process, the following translog production function is chosen and tested against the restricted Cobb-Douglas functional form:

$$y_{it} = \beta_0 + \sum_{j=1}^{5} \beta_j x_{jit} + \beta_t t + \sum_{j=1}^{5}\sum_{h=1}^{5} \beta_{jh} x_{jit} x_{hit} + \beta_{tt} t^2 + \sum_{j=1}^{5} \beta_{jt} x_{jit} t + V_{it} + U_{it}, \quad (4)$$

where y is the log of gross value added, and x is a vector of the logarithms of the 5 inputs considered; and where the technological change can be specified as an additional input (time trend, t) representing the rate of technical change or the shift in the production function over time. This specification makes it possible to consider time varying coefficients and non-neutral technical change.

Table 3. Evolution of Factors Hypothesized as Influencing Efficiency

Factors	1989	1990	1991	1992	1993
Age of the farmer (AGE)	46.03	46.66	47.46	47.36	48.39
Accounting use (ACCOUNTI)	0.35	0.35	0.35	0.35	0.35
Herfindhal concentration index (CONCHERF)	0.58	0.64	0.57	0.58	0.55
Control (CONTROL)	0.05	0.05	0.05	0.05	0.05
% family work units (FWU)	89.20	89.96	89.80	88.75	89.69
Extensive farming (EXTENSCR)	0.17	0.17	0.15	0.16	0.17
Permanent crops (PERMCROP)	0.50	0.49	0.50	0.47	0.47
Dairy and drystock (DAIRYDRY)	0.03	0.04	0.03	0.03	0.03
Pigs and poultry (PIGPOULT)	0.13	0.12	0.12	0.13	0.14
Location in mountain zone (MOUNTZO)	0.05	0.05	0.05	0.05	0.05
Location in less favoured zone (LESSFAZO)	0.42	0.42	0.42	0.42	0.42
% of irrigated utilized agricultural area (IRRUAA)	31.90	33.18	33.48	32.82	33.98
Economic size units (ESU)	22.77	23.10	24.59	20.50	21.38
% of rented utilized agricultural area (RENTEDUA)	7.18	7.14	7.09	7.63	7.73
% of current subsidies on total output (CURRSUBS)	3.33	8.50	8.38	9.42	16.24
Ratio of debt to assets (%) (LIABILTO)	4.81	5.27	5.76	6.49	6.26

Results

Estimates of the Production Function

Following Battese and Coelli (1995), maximum likelihood estimation (performed using FRONTIER 4.1; Coelli, 1996) was employed to simultaneously estimate the parameters of the stochastic production frontier and the inefficiency effects model. The program automatically checks the OLS residuals for correct skewness before proceeding to a maximum likelihood estimate of the frontier. The results of this procedure corresponding to the translog production function are presented in Table 4. The variance parameters are expressed in terms of $\gamma \equiv \sigma^2_U / (\sigma^2_U + \sigma^2_V)$. The estimates of the first-order coefficients of the variables in the translog function cannot be directly interpreted as output elasticities.

A number of statistical tests were carried out to identify the appropriate functional forms and the presence of inefficiency and its trend. As a misspecification analysis we used the log-likelihood ratio tests (LR) (Kumbhakar et al., 1997). LR tests were performed to test various null hypotheses as listed in Table 5. The first test shows that, given the specification of the inefficiency effects model, the null hypothesis that the Cobb-Douglas functional form is preferred to the translog is rejected. The null hypothesis is rejected by the test at the 5% level and hence all results presented here refer solely to the translog. Also, in test 2, the null hypothesis that there is no technical change in the period 1989-1993 for production in Catalan farms is accepted. Hence, technical change is not present in the preferred model presented in Table 4.

Table 4. Maximum Likelihood Estimates of Parameters of the Translog Stochastic Frontier Production Function (Preferred Model)

Variable	Parameter	Coefficient	Standard error	t-ratio
Stochastic Frontier Model:				
Constant	β_0	4.3585	2.6289	1.658
FIXEDK	β_1	0.1732	0.2286	0.758
CURRASSETS	β_2	1.1619	0.2950	3.938***
AWU	β_3	0.1064	0.7699	0.138
SPECIFCOSTS	β_4	-0.0800	0.2463	-0.325
OVERHEAD	β_5	-0.8235	0.4362	-1.888*
FIXEDK square	β_6	-0.0008	0.0006	-1.358
CURRASSETS square	β_7	0.0253	0.0113	2.242***
AWU square	β_8	0.1695	0.0977	1.735*
SPECIFCOSTS square	β_9	0.0103	0.0994	1.042
OVERHEAD square	β_{10}	0.0427	0.0297	1.436
FIXEDK·CURRASSETS	β_{11}	-0.1090	0.0283	-3.856***
FIXEDK·AWU	β_{12}	0.0805	0.0585	1.375
FIXEDK·SPECIFCOSTS	β_{13}	0.0428	0.0202	2.117**
FIXEDK·OVERHEAD	β_{14}	0.0765	0.0340	2.250***
CURRASSETS·AWU	β_{15}	0.0420	0.0475	0.884
CURRASSETS·SPECIFCOSTS	β_{16}	-0.0164	0.0153	-1.067
CURRASSETS·OVERHEAD	β_{17}	-0.0063	0.0303	-0.211

Variable	Parameter	Coefficient	Standard error	t-ratio
AWU·SPECIFCOSTS	β_{18}	0.0430	0.0437	0.983
AWU·OVERHEAD	β_{19}	-0.1929	0.0861	-2.241***
SPECIFCOSTS·OVERHEAD	β_{20}	-0.0504	0.0270	-1.187
Inefficiency Effects Model:				
AGE	δ_1	-0.0027	0.0052	-0.517
ACCOUNTI	δ_2	-0.1750	0.1666	-1.050
CONCHERF	δ_3	-0.0160	0.2575	-0.062
CONTROL	δ_4	-0.7944	0.3810	-2.085**
FWU	δ_5	0.0034	0.0029	1.172
MOUNTZO	δ_6	-0.6830	0.4286	-1.594
LESSFAZO	δ_7	-0.0930	0.1455	-0.639
IRRUAA	δ_8	0.0046	0.0022	2.074**
ESU	δ_9	-0.0296	0.0114	-2.597***
RENTEDUA	δ_{10}	0.0122	0.0051	2.397***
CURRSUBS	δ_{11}	0.0011	0.0038	0.293
LIABILTO	δ_{12}	-0.0108	0.0079	-1.368
YEAR	δ_{13}	0.0072	0.0408	0.176
Variance Parameters:				
	σ^2_S	0.7990	0.2135	3.743***
	γ	0.9076	0.0240	37.881***
Log-likelihood Function		-533.92		

The t-ratios are asymptotic t-ratios. The coefficients corresponding to the cross-product of the input variables in the translog production function are not presented in this table. *** $p<0.001$; ** $p<0.05$; * $p<0.1$.

Tweeten (1969) observed that technical changes and increasing productivity in agriculture are related to the ability of farmers to expand their farms, which in turn depends on the rate at which farmers can abandon farming and find employment outside agriculture. The fact that our data corresponds to a period of recession partly explains our finding of the absence of technical change. This is in accordance with the results of Ball et al. (1991). Moreover, as Schmitt (1991) argues, since most farm tasks are not susceptible to supervision or monitoring, the enlargement of farms is limited to family governance, a fact that limits increases in farm size and technical change. Finally, the persistence and spread of part-time farming allows the existence of inefficient farms and hinders the introduction of technical change in the agricultural sector.

The null hypothesis explored in test 3 is that each farm is operating on the efficient frontier and that the systematic and random inefficiency effects are zero. The null hypothesis that γ is zero is rejected, suggesting that inefficiency was present in production and that the *average* production function is not an appropriate representation of the data. Inefficiencies in production are the dominant source of random errors.

Finally, tests 4, 5 and 6 consider the null hypothesis that the inefficiency effects are not a function of the explanatory variables. Again, in test 4 the null hypothesis is rejected, confirming that the joint effect of these variables on inefficiency is statistically significant.

However, the null hypothesis that the constant term in the inefficiency effects model is zero is accepted, and therefore it is not included in the preferred model. The null hypothesis explored in test 6 is that the type of farm production does not influence farm inefficiency. In this case the null hypothesis is accepted, therefore the group of variables representing the influence of the type of farm is not included in the preferred model.

Table 5. Generalized Likelihood-Ratio Tests of Hypothesis for Parameters of the Stochastic Frontier Production Function

Test	Null hypothesis (H_0)	Log-likelihood	Value of λ	Critical value	Decision (at 5% level)
1	$H_0 : \beta_{jh} = 0$	-557.4	59.8	32.08	Reject H_0
2	$H_0 : \beta_t = \beta_{tt} = \beta_{jt} = 0$	-531.7	8.4	13.40	Accept H_0
3	$H_0 : \gamma = \delta_0 = ... = \delta_{17} = 0$	-594.2	133.4	24.38	Reject H_0
4	$H_0 : \delta_1 = ... = \delta_{17} = 0$	-547.7	40.4	23.07	Reject H_0
5	$H_0 : \delta_0 = 0$	-528.7	2.4	2.71	Accept H_0
6	$H_0 : \delta_{EXTENSCR} = \delta_{PERMCROP} = \delta_{DAIRYDRY} = \delta_{PIGPOULT} = 0$	-529.3	3.6	8.76	Accept H_0

λ: likelihood-ratio test statistic, $\lambda = -2\{\log[\text{Likelihood}(H_0)] - \log[\text{Likelihood}(H_1)]\}$. It has an approximate chi-square distribution with degrees of freedom equal to the number of independent constraints. The asymptotic distribution of hypothesis tests involving a zero restriction on the parameter γ has a mixed chi-squared distribution. The critical value for this test is taken from Kodde and Palm (1986), Table 1, page 1246.

A high degree of multicollinearity was observed in the translog stochastic frontier using the condition index. When the objective is to estimate output elasticities, the parameter estimates of the translog form are too unreliable because of the use of a flexible functional form and the attendant multicollinearity. Notwithstanding, multicollinearity is not necessarily a severe problem given that the aim of this paper is to focus on efficiency estimation (Puig-Junoy, 2001).

The mean output efficiency of the 147 Catalan farms in the period 1989-1993 is estimated to be 62.3%, with a standard deviation of 19.8% . Mean efficiency by year presents an overall decreasing trend from 1990 to 1993. Average efficiency by year decreased from the highest level in 1990 (0.653) to the lowest level in 1993 (0.591). This means that, according to the stochastic production frontier, the contribution of the efficiency change to total factor productivity after 1990 was a reduction in productivity growth.

Other studies observed that uncertainty about the efficiency level of a farm was definitely not small with relation to the within-sample variability of the efficiency measures (Horrace and Schmidt, 1996; Brümmer, 2001). In most of these studies, lack of precision in efficiency results came from the fact that the variation in $\varepsilon_i = V_i + U_i$ was due to V_i rather than U_i. This is not the case in our estimation of efficiency scores for a panel data set of mixed Catalan farms. In our study, the variance of U is over nine times as large as the variance of V. This makes the mean efficiency estimates very reliable.

Ten farms (6.8%) do not show statistically significant inefficiency during all the period analysed; 21 farms (14.3%) do not appear as statistically inefficient in four of the five years included in this study; and 24 farms (16.3%) appear as statistically inefficient in each of the five years analysed. In this case it is not difficult to separate the farms into low, average and high efficiency. These results indicate that uncertainty about a given farm's efficiency level is small relative to the between-firm variation inefficiencies. Therefore, we can state that in the case of mixed Catalan farms differences across farms in efficiency levels are statistically significant for a large proportion of the farms included in the panel data set. However, confidence intervals for inefficient farms are wide.

Estimates of the Inefficiency Function

The inefficiency function provides some explanations for variation in efficiency levels between Catalan farms in the period 1989-1993. It should be noted that since the explained variable in the inefficiency function is the mode of inefficiency, a positive sign on a parameter in Table 4 indicates that the associated variable has a negative effect on efficiency and a negative sign indicates a positive efficiency effect.

Our results suggest that the technical efficiency of farms is a complex matter. It is a function of several interrelated factors. However, two economic characteristics of farms appear to be the most influential: size improves efficiency and increasing percentage of rented land hinders it. The control phase of the decision-making process follows in importance in positively determining technical efficiency. All these factors affect technical efficiency according to expectations, but one factor representative of physical conditions, percentage of irrigated land, significantly violates them. Given the purpose of this article, it is interesting to note that management built on sound accounting information leads to a significant increase in technical efficiency when farmers accurate control their activity.

In the group of management capacity variables, the only factor appearing as significantly and positively influencing efficiency is CONTROL. In spite of the limitations of the FADN methodology for efficient management, the significant sign of the variable CONTROL suggests that accounting provides significant information to control farm performance, that therefore can be traduced in increased efficiency. Management is a multi-phase process that cannot be considered separately. A complete management process starts with planning. However, it is ineffective unless it is followed up with appropriate decisions and monitoring. In fact, the tiny group of farms in our sample that controlled their activity had previously planned it. It cannot be concluded that planning with sound accounting information is not significantly associated with efficiency. On the contrary, the association exists when planning is complemented with control.

The implementation variables employed in this study do not show a significant relationship with efficiency. One possible explanation is that the smallness and simplicity of farms do not offer leeway for strategic and tactical decisions. It could be suggested that really advantageous implementation variables are found in the quality and intensity of minor operational and technical tasks that are hardly perceivable in a statistical study. More research is needed in this area, especially with in-depth observations and interviews.

In addition, with respect to variable CONCHERZ, our hypothesis about output instability is not confirmed. Insurance policies adopted by farmers and product diversification mitigate the effects of output instability.

The non-significance of the variable AGE suggests the complexity of measuring experience and personal characteristics with the variable AGE. Experience provides management skills, but the most experienced and aged farmers usually have a low education and innovative level. Research by Wadsworth and Bravo-Ureta (1992) and Brangeon et al. (1994) found a threshold of farmer age at which the probability of failure is the lowest and beyond which it increases again. As we could not obtain data on the educational level of the farmers in our sample, the results of variable AGE may summarize some hidden information.

With respect to physical variables, our hypothesis about farm location is not confirmed. A possible explanation for this is that, after years of decrease in the number of farms in mountain and less favoured areas, the remaining farms make use of large amounts of agricultural land and resources; they have reached an efficient size. Variable IRRUAA contradicts expectations. One possible explanation for this surprising result is that farms with plentiful irrigated land continued with their traditional crops. They did not need to search for alternative more profitable crops and livestock as other farms did. Farms with less irrigated land were faced with incentives to reorganize their production or disappeared. It can be seen as an example of misuse of physical endowments when incentives and objectives are not appropriately applied and pursued.

In the group of economic characteristics, one factor positively influences efficiency (ESU), one appears as negatively affecting it (RENTEDUA), both significant at the 1% confidence level, and two variables have no significant effect (CURRSUBS and LIABILTO). These results confirm our expectations that larger size entails better capital and technological endowments, which result in better farm performance and efficiency.

Kalaitzandonakis et al. (1992) built a latent variable model to reconcile the lack of clear evidence between firm size and technical efficiency from previous studies. They supported a positive relationship between the two variables with a study of a sample of 50 Missouri grain farms. They suggested that this relationship does not reflect exploitation of scale economies, but merely suggests that firm size summarizes the effects of factors that are directly related to both technical efficiency and firm growth, for example, entrepreneurial ability, education, farming experience and other personal attributes of the firm manager. We explicitly sought to include other available variables in the model in order to isolate the influence of size, and our findings seem to confirm the exploitation of economies of scale. However, we cannot rule out the possibility that size summarizes other hidden information not included in the inefficiency effects model.

In addition, different measures of size have traditionally been found to be positively correlated with viability (Adelaja and Rose, 1988) and with higher farm income (Brangeon et al., 1994). The studies of the European Commission (1991a, 1991b) also found better performance and viability for larger farms, where the size was measured in ESU.

The significant negative relationship between RENTEDUA and efficiency confirms our expectations that farms with a large proportion of rented land would show low efficiency, because farmers will be unlikely to invest in land improvements of rented land. This result is in accordance to the almost non-existence of rented land in Catalan agriculture. Farmers do not find it advantageous to rent land, and owners who do not work their own land finally decide to sell it.

The non-significant relationship for the variables LIABILTO and CURRSUBS reveal that the financial structure of the farm does not interfere with its efficiency, and suggests that the CAP criteria for subsidies are more closely related to assuring farm income than to efficiency. It confirms, once again, that the CAP did not increase the efficiency of the agricultural sector.

Conclusions

This paper set out to provide estimates of inefficiency in a balanced panel of mixed Catalan farms and to explain variation in inefficiency between farms through decisions concerning a wide range of environmental factors. A translog stochastic frontier production function with inefficiency effects is applied. The results indicate that inefficiency was present in production, and that the traditional *average* response function and the Cobb-Douglas functional form are not an appropriate representation of the data.

Technical change in the mixed Catalan farms over the period analysed is rejected at the 5% level. Thus, our results indicate that farm technology was stagnant over the period. Consequently, output change during the analysed period can only be attributed to input change or efficiency change.

Our results indicate that differences in inefficiency across farms are statistically significant. According to the confidence intervals obtained, it is not difficult to cluster farms into low, average and high efficiency groups.

The most significant factors affecting efficiency are those representing the economic characteristics of size and percentage of rented land. As rented land is almost non-existent in Catalan agriculture, size appears as the truly important factor, thus confirming the continuous trend of reduction in the number of farms and increase in the economic size of the remaining farms in Catalonia, Spain and the EU. Fully integrated management based on reliable accounting information and comprising planning and control phases reveals to be a significant factor positively affecting farm efficiency. Two important conclusions should be stressed with reference to farm management. First, management could be a burden for farms when it is interrupted in the planning process and not carried through with control of farm activity. Second, more research is needed, especially on the implementation phase, with in-depth interviews and observations.

Notes

1 The FADN provides annual statistics on the state of agriculture in the EU based on a sample of almost 60,000 EU farms. Data are collected by surveying a rotating sample of farms. The FADN's field of observation covers professional farms as defined in the farm structure survey of the EU, and excludes smaller farms below FADN thresholds. A full description of FADN procedures and methodology can be found in European Commission (1990a, 1997, 1998). A network of accounting agencies help the farmers to record data and to complete the forms. All data of farms in the FADN are tested and follow the same methodology and accounting standards. The FADN provides the most suitable data for our study that is currently available.

The "Xarxa Comptable Agrària de Catalunya" (XCAC) is the subsidiary of the FADN in Catalonia, Spain, and it follows the methodology of the parent network. The XCAC provided us with data relating to the performance of 180 individual Catalan farms from 1989 to 1993. Omitted variables and unreliable information reduced the panel data set to 147 observations.

2 FIXEDK is the amount of fixed assets employed by the farm. It includes monetary values of agricultural land, forest capital, buildings, machinery and values at closing valuation of breeding livestock. CURRASSETS is the amount of current assets employed by the farm. It includes monetary values at closing valuation of all non-breeding livestock and crop and livestock products, and other circulating capital, such

as amounts receivable in the short term and cash balances.

AWU is the total labour input employed by the farm, family labour included, expressed in annual work units, which means full-time worker equivalents in the region under consideration and on the same type of holding. The amount considered in Catalonia for the annual work unit was 2.200 hours in the period studied. A person who spends his entire annual working time employed on the holding represents one annual unit, even if his actual working time exceeds the mentioned normal annual working time.

SPECIFCOSTS is the amount of supply costs linked to specific lines of production. It includes monetary values of the cost of crop-specific inputs (for example, seeds, fertilizers, crop protection, etc.), feed and other livestock-specific costs, and specific forestry costs.

OVERHEAD is the amount of supply costs linked to productive activity but not linked to specific lines of production. It includes monetary values of current costs of machinery and buildings, energy expenses, costs linked to contractors, water, insurance and other farming overheads.

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