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Technical Efficiency of Italian Beef Cattle Production Under a Heteroscedastic Non-Neutral Production Frontier Approach

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Abstract

A stochastic production frontier has been estimated to measure the technical efficiency of an unbalanced panel of beef cattle farms extracted from the Farm Accountancy Data Network (FADN) databank of Veneto region in Italy. The technical efficiency is measured based on the estimation of a non-neutral and heteroscedastic production frontier. The model explains the average value of technical inefficiency as a linear function of the farm-specific variables (Battese and Coelli, 1995) and the input interaction variables (Huang and Liu, 1994). The inefficiency term is assumed to be distributed as a truncated normal with a heteroscedastic variance explained as a function of the farm-specific variables (Reifschneider and Stevenson, 1991).

The average value of the farm technical efficiency is 78.6% ranging from a minimum of 30.6% to a maximum of 97.6%. The technical efficiency is positively related with the herd extension expressed as number of LSU (Livestock Unit), the value of beef production per LSU, the rate of purchased concentrated feed, and the percentage of concentrated feed used over the overall feed expenditure. Conversely the technical efficiency is negatively correlated with the intensification of the use of buildings investment and labour per LSU.

Keywords: technical efficiency, stochastic frontier, beef cattle.

1 Introduction

Beef cattle production plays an important role in the Italian agriculture in relation with his economic dimension and with its involvement in the Common Agricultural Policy (CAP). The budget allocated to the beef sector from the CAP for the whole European Union on 2005 is 7.9 billion Euro, corresponding to 14.7% of whole agricultural budget (European Parliament, 2005). Despite the large amount of resources allocated, the orientation of CAP does not encourage Italian rearing system, being comparatively better tailored for extensive systems based on grazing cattle practiced in mainland Europe.

Specialized Italian beef cattle production, is particularly different from mainland Europe's beef rearing system, especially for farms located in the northern lowland that account for the most part of production. Indeed beef cattle production is specialised on fattening light young bulls imported mainly from France, reared in indoor feedlots and fed with locally produced feed (mainly fodder maize and partly cereals) until finished weight. The indoor rearing system give the possibility to cultivate the farm field with maize (corn and fodder) that gives in this region one of the highest yield in the world. The availability of local feed for beef cattle production allows to: i) increase the value added achievable with field crops production and ii) improve the quality of beef and the speed of daily weight gain thanks to the high quality and energetic content of diet.

In the contest of Italian beef sector Veneto Region, located in the North-Eastern Italy, has been taken as case of study. Beef in Veneto is one of the most important agricultural products, with dairy one, representing the 11.2% of the value of regional agricultural production and as much as 15% of national beef production in 2004 (ISTAT - Italian Institute of Statistic).

Since the beginning of CAP, Italian beef market has been mostly based on national appreciation of beef quality that assured to producers, in the context of European/Italian market, a premium in price. This premium in price is further enhanced by the structural deficit of the Italian beef market. The recent progressive liberalisation of agricultural markets and the orientation of CAP toward extensive system have increased the competitive pressures in the Italian beef market. In particular the globalisation and the structural deficit of Italian beef market encourage beef imports. The current European international policy for beef is based on negotiation of European import quota. This quota can take advantage of a reduced tariff, while importations exceeding the negotiated quota pay a full tariff. The expansion of beef production in South America, accompanied by improvements in quality and organization allow, in some conditions, to export beef to Europe at competitive price also under full tariff regime. The increased price competition to local producers brought about by imported beef threatens the profitability of Italian beef cattle production. The beef cattle sector is responding to this pressure through a reorganisation in terms of quantity and size of cattle farms (Boatto, Rossetto and Trestini, 2004). Specialised cattle farms are estimated to have undergone a reduction of about 30% in quantity, between 1990 and 2000, with a parallel increase in average size from 180 to 222 head per farm (Ferrazzi and Pretolani, 2005).

The paper aims to analyse the factors that affect the competitiveness of beef cattle farms through the analysis of technical efficiency. In particular, the study wants to identify the main determinant affecting the level of technical efficiency and their role in order to define strategies that farmers and policy makers could adopt to improve the sector competitiveness.

The study proposed in this paper evaluates technical efficiency of an unbalanced panel data sample of beef cattle farms, collected in Veneto Region by National Institute of Agricultural Economics (INEA) within the Farm Accountancy Data Network (FADN) framework. It applies the stochastic frontier approach, proposed for the first time by Aigner, Lovell and Schmidt (1977), Meeusen and van den Broeck (1977) and Battese and Corra (1977), and following developments.

Although the analysis of technical efficiency is widely spread and discussed in literature, with several application to livestock sector (Battese, 1992), published studies involve mainly dairy farms and very few researches deal with the beef cattle sector. Also the Italian literature pays little attention to analyse the efficiency beef farms, orienting the research effort mainly on productivity analysis (e.g. Boatto, 1987) and production costs evaluation. From this point of view this paper could contribute to improve knowledge in this research field.

Section 2 of the paper presents and discusses the methodology, while Section 3 describes and analyses the empirical model whose results are discussed in Section 4. Finally, conclusions are presented in Section 5.

2 Methodology

According to Farrell's (1957) approach, Technical Efficiency (TE) is defined as the capability of a producer to obtain the maximum level of production given the set of inputs (*output-increasing oriented*) or as the capability to use the minimum amount of inputs given a level of outputs (*input-saving oriented*) (Koopmans, 1951).

Farrell (1957), in his seminal work, assuming constant returns to scale, proposed a measure of TE based on an *input-saving orientation*. Defined a unit isoquant, describing the minimum combinations of inputs needed to produce a unit of output, every combinations of inputs along the isoquant are considered technically efficient and any points above are technically inefficient. TE is measured as the distance from the observed input combination and the best combination point (technically efficient). With an *output-increasing orientation* TE is obtained comparing the observed output with that which could be produced by a fully efficient firm, given the same bundle of inputs.

Based on Farrell (1957) model, several procedures have been developed in literature to estimate TE, see e.g. Battese (1992) and Murillo-Zamorano (2004) for a more comprehensive review of the most important methods and applications proposed in literature in the context of this study.

This section is dedicated to the Stochastic Frontier Production (SFP) Function Models, independently and simultaneously proposed by Aigner, Lovell and Schmidt (1977), Meeusen and van den Broeck (1977) and Battese and Corra (1977). In the SFP models the production frontier is specified defining the output as a stochastic function of a given set of inputs that incorporates the inefficiency term. The presence of a stochastic element makes the model less vulnerable to the influence of outliers than deterministic frontier models. In the latter, the production frontier function is not subject to statistical noise and deviations from frontiers are explained only by means of the inefficiency term. Examples of deterministic frontier models are given by Aigner and Chu (1968) and Timmer (1971). The error term of a stochastic frontier may be separated in two terms: a random error (statistical noise) and a random variable that explains the technical inefficiency effect. In general a stochastic production frontier can be represented as:

$$\begin{aligned} & y_i = f(x_i, \beta)\exp\varepsilon && (1) \\ & \varepsilon = (v_i - u_i) \qquad i = 1,2,\ldots\ldots N & \end{aligned}$$

where y_i denotes the level of output for the i-th observation; x_i the row vector of inputs; β is the vector of parameters to be estimated; $f(.)$ is a suitable functional form for the frontier production function; v_i is a symmetric random error assumed to account for factors that are not under the control of the firm, factors not included in the production function and error measurements; and u_i is an asymmetric non negative error term assumed to account for technical inefficiency in production. The v_i random term is assumed to be independent and identically distributed as a normal random variable with zero mean and variance σ_v^2:

$$v_i \sim N(0,\ \sigma_v^2) \qquad i = 1,2,\ldots\ldots N$$

On concerning the u_i distribution, several proposals have been formulated; half normal (Aigner, Lovell and Schmidt, 1977), exponential and gamma (Greene, 1980). The most diffused and generally accepted assumption is the hypothesis of independent and identically distribution as a truncation at zero of a normal distribution with mean μ and variance σ_u^2 is (Kumbhakar, 1987; Battese and Coelli, 1988).

$$u_i \sim N\,|0,\ \sigma_v^2\,| \qquad\qquad i = 1,2,......N\,.$$

Truncated normal distribution overcomes some shortcomings of other distributional forms. Half-normal and Exponential distributions both have a mode at zero. This causes conditional technical efficiency score, especially in the neighbourhood of zero, which can involve artificially high technical efficiency level. Additionally Gamma distribution does not imply a shape on distribution overcoming the shortcoming of truncated normal, but the complexity associated with the estimation procedures seems likely to overweight their benefits (Murillo-Zamorano, 2004).

The TE efficiency measure is obtained calculating the ratio of y_i to the maximum achievable level of output:

$$TE = \frac{y_i}{y^*} = \exp(-u_i) \qquad (2)$$

where y^* is the frontier level of output.

The MLE (Maximum Likelihood Estimation) of (1) estimates the value of β and the individual value of u_i through the separation of the composed error ε (Jondrow, Lovell, Materov and Schmidt, 1982).

This model has been applied firstly to cross-sectional data under the hypothesis of half-normal distribution of u_i (Aigner, Lovell and Schmidt, 1977). Than, consequently to inconsistency of cross-sectional estimation of u_i, panel data models have been formulated (Pitt and Lee, 1981; Kumbhakar, 1987; Battese and Coelli, 1988). Finally Battese, Coelli and Colby (1989) proposed a MLE estimation based on unbalanced panel data with a truncated normal distribution of u_i.

Most of SFP models proposed in literature give a consistent measure of technical efficiency but are not appropriated to evaluate factors that affect efficiency. In fact the previous model is able to associate a level of efficiency to each observation but it could be also interesting to evaluate how different variables affect the level of efficiency. In order do estimate these effects, some authors proposed a so called *two stage* approach; the first stage involves the specification and estimation of the SFP function and the prediction of the technical efficiency of firms involved; the second stage of analysis involves the specification of a regression model for the levels of technical efficiency of the firms in terms of various explanatory variables and an additive random error (Pitt and Lee, 1981; Kalirajan, 1982). An alternative approach regards the *one stage* procedure, using methods that involve an efficiency effect model inside the stochastic frontier model specification. Efficiency effects are modelled in terms of different explanatory variables through a simultaneous estimation of frontier production and inefficiency effect model (Kumbhakar *et al.*, 1991; Reifschneider and Stevenson, 1991; Huang and Liu, 1994).

According to Battese and Coelli (1995), the *two stages procedures* are inconsistent with the assumption that u_i is independently and identically distributed. Because of that It should be preferred the *one stage* approach that overtakes this shortcoming.

In addition Battese and Coelli (1995) proposed a *one stage* model applied to panel data where the efficiency effect model is specified by means of a set of firm-specific variables directly incorporated in the MLE.

In Battese and Coelli (1995), the inefficiency term u_{it} has a truncated (at zero) normal distribution with mean δz_{it} :

$$u_{it} = \delta z_{it} + w_{it} \tag{3}$$

where w_{it} is a random error term which is assumed to be independently distributed as a truncated normal with mean zero and variance σ_w^2 such that u_{it} is non negative ($w_{it} \geq \delta z_{it}$).

The z_{it} is the set of firm-specific variables used to explain inefficiency term and δ is the set of unknown parameters to estimate.

Previous models by Reifschneider and Stevenson and (1991) Huang and Liu (1994), even if were not applied to panel data, they introduced some interesting specifications.

The first accounted the effect of firm-specific variables to inefficiency term variance introducing the hypothesis of a heteroscedastic relation:

$$\sigma_{ui}^2 = \sigma_{u_0}^2 + g(z_i, \delta) \tag{4}$$

Huang and Liu (1994) assumed that the explanatory variables in the inefficiency model could be explained, besides firm-specific variables, also by interaction variables of the stochastic frontier with firm-specific ones. This makes the model a non-neutral shift of the traditional average response function.

3 Empirical model

Frontier production model specification

According to the theoretical framework proposed in the previous section, there follows the description of empirical model applied in this work.

The stochastic production frontier applied to unbalanced panel data, $y_{it} = f(x_{it}, \beta)\exp(v_{it} - u_{it})$, has been approximated by a Cobb-Douglas function i.e.:

$$\ln(y_{it}) = \beta_0 + \sum_{n=1}^{N} \beta_n \ln x_{nit} + \varsigma_1 T + v_{it} - u_{ti} \tag{5}$$

the term v_{it} is a symmetric and normally distributed random error, which represent those factors that can not be controlled by farmers, measurement errors in the dependent variable and explanatory variables omitted. The term v_{it} and u_{it} are assumed to be independently distributed.

The term u_{it} accounts for the inefficiency effect. In the model is assumed that the mean of the pre-truncated distribution depends on both farm-specific variables and input-interaction variables. In addition variance of pre-truncated distribution depends only on farm-specific variables.

These assumptions lead to the estimation of a heteroscedastic, non-neutral production frontier model. Particularly this model joins the Huang and Liu’s (1994) specification for the mean and the Reifschneider and Stevenson’s (1991) formulation for the variance as proposed by Karagiannis and Tzouvelekas (2005).

The whole specification obtained is the following:

$$\mu_{it} = \delta_0 + \sum_{n=1}^{N} \delta_n x_{nit} + \sum_{m=1}^{M} \delta_m z_{mit} + \sum_{t=1}^{T} \delta_t D_t \tag{6}$$

$$\sigma^2_{u_{it}} = \exp\left(\theta_0 + \sum_{m=1}^{M} \theta_m z_{mit} \right) \tag{7}$$

where the unknowns parameter to be estimated are:

- δ_n, related to non-neutral effect variables;
- δ_m, related to farm-specific variables;
- δ_t, related to time dummies variables;
- θ_m, related to farm-specific variables in the variance model.

According to Karagiannis and Tzouvelekas (2005) the above specification is fairly general and includes several models proposed in literature as special cases: i) if $\theta_m = 0$ the model becomes a Huang and Liu (1994) non-neutral production frontier model; ii) if $\delta_n = \delta_m = \delta_t = 0$ assuming no mean inefficiency effects and accounting only for heteroscedasticity effect; iii) if $\theta_m = \delta_n = 0$ than the model is reduced at the first technical efficiency effect model applied to panel data proposed by Battese and Coelli (1995); iv) if $\theta_m = \delta_n = \delta_m = \delta_t = 0$ it results in a Stevenson (1980) model; v) finally if $\theta_m = \delta_n = \delta_m = \delta_t = \delta_0 = 0$ the model is reduced to Aigner, Lovell and Schmidt (1977) proposal.

The frontier model is estimated by the Maximum Likelihood method using Limdep program (Version 8.0).

Data and variables

The dataset used in this study was derived from the official Farm Accountancy Data Network (FADN) with reference to the period between 1980 and 2000. The final sample is an unbalanced panel with 487 observations. 221 farms were analysed with a number of observations per farms ranging from 1 to 8. Depending on availability, data from 2001 to 2003 were excluded because of large difference of farms characteristics occurring after a complete turnover in the regional farm sample. Indeed, the latter period consist of larger beef cattle farms in place of family farms included in the previous period.

Although in the sample there are a large number of farms rearing beef cattle, we selected only observations specialised on this production system. In addition, also mixed farms have been excluded. This ensures that the underlying assumption of the best practice frontier approach (i.e. that the sample farms operate under a common technology) is met as fully as possible.

In the stochastic frontier production, the output has been measured as gross production value expressed as a difference between final and initial value of cattle stock, respectively at the end and at the beginning of one year, adding the value of sales and deducting the value of purchases. This value describes the increase in beef cattle value obtained during a defined period of time.

Among variables used to explain frontier production function (Table 1), capitals have been introduced as user cost in place of stock value. User cost has been calculating, following Christensen and Jorgenson (1969), through the sum of the opportunity cost of capital and the annual depreciation of capital. In case of leased capital the price paid is considered as user cost.

The user cost of fixed asset includes land and farm building value. The user cost of no-fixed asset account for machinery and input/output stocks. The calculation of user costs of the latter is done with reference to the depreciation, for machinery, and the opportunity cost of both the investment in machinery and the net anticipation in value for inputs.

The livestock value has not been considered as a capital but as a product waiting to be sold, since it represents part of the value of the cattle sold at the end of its lifecycle (INEA, 2000b). This value has been considered through the opportunity cost of the no-fixed capital. The labour has been considered as a physical value corresponding to the total number of hours available.

The final specification does not include feed costs because of its high correlation with the gross output. One possible solution was to specify the frontier as value added or to exclude the variables from the model. The latter option has been adopted assuming that there is a technical relationship between feed costs and gross output.

All values expressed in Lire have been converted in Euros and then deflated to 1980 prices based on ISTAT (Italian Institute of Statistic) official prices index. Since these indices vary over time but not over farms, and farm-specific price were not available, differences in quality of outputs or inputs are reflected in differences in quantity (Reinhard, 1999).

Table 1 – Variables and parameters of the stochastic production frontier

Parameters	**Variables**	**Description**
β_n		**Independents variables**
β_{SKFO}	**SKFO**	User cost of fixed capital (€ 1980 base)
β_{SKES}	**SKES**	User cost of no-fixed capital (€ 1980 base)
β_{LAV}	**LAV**	Labour hours
β_T	**T**	Time

An additional set of variables has been considered to explain technical efficiency differences across farms. The variables used are taken from literature depending on dataset availability. A synthetic review of variables used in literature to explain differences in farms technical efficiency with special attention to livestock farms applications is presented in Table 10 of Appendix.

Variables introduced in the empirical model have been classified in two main groups according to Huang and Liu’s (1994) specification that distinguish non-neutrals variables and farm-specific variables (Table 2 and 3). Variables used to explain technical efficiency that have resulted to be significant are:

−FAB: the annual depreciation of farms building per LSU;
−ULAV: the number of total labour hour available per LSU;
−LAVF: the share of family labour over total labour;
−PL: the value of gross production per LSU;
−UBA: the number of LSU;
−Q_MANG: the share of concentrated feed purchased over total concentred feed expenditure;
−Q_FOR: the share of fodder expenditure over total feed expenditure;
−POLICY: a time dummy variable that accounts for Mc Sharry CAP Reform; the variable have a dummy value equal to 1 for years after the reform (1993) and equal to 0 fro years before.

Summary statistics of variables used in the model are given in Table 4.

Table 2 – Explanatory variables and parameters introduced in the mean model of inefficiency term

Parameters	Variables	Description
δ_n		*Non-neutral variables*
δ_{FAB}	**FAB**	Annual depreciation of farms building per LSU (€ 1980 base)
δ_{LAV}	**ULAV**	Number of total labour hour available per LSU
δ_{LAVF}	**LAVF**	Share of family labour over total labour
δ_m		*Farm-specific variables*
δ_{PL}	**PL**	Value of gross production per LSU (€ 1980 base)
δ_{UBA}	**UBA**	Number of LSU
δ_{Q_MANG}	**Q_MANG**	Share of concentrated feed purchased over total concentred feed expenditure
δ_{Q_FOR}	**Q_FOR**	Share of fodder expenditure over total feed expenditure
δ_t		*Time dummy*
δ_{POLICY}	**POLICY**	Time dummy variable that accounts for Mc Sharry CAP Reform – equal to 1 after 1993 and 0 before

Table 3 – Explanatory variables and parameters introduced in the variance model of inefficiency term

Parameters	Variables	Description
θ_m		*Farm-specific variables*
θ_{PL}	**PL**	Value of gross production per LSU (€ 1980 base)
θ_{UBA}	**UBA**	Number of LSU
θ_{Q_MANG}	**Q_MANG**	Share of concentrated feed purchased over total concentred feed expenditure
θ_{Q_FOR}	**Q_FOR**	Share of fodder expenditure over total feed expenditure

The first three variables (FAB, ULAV and LAVF) and POLICY have been used to explain the mean of pre-truncated distribution of the technical inefficiency term. The following four variables (PL, UBA, Q_MANG and Q_FOR) are the firm-specific variables used to explain both the mean and the variance of pre-truncated distribution of the technical inefficiency term.

FAB and ULAV give an evaluation on the intensity in use of inputs per LSU as proposed by Hallam and Machado (1996), Weersink *et al.*(1990) and Ahmad and Bravo-Ureta (1996). A high level of the first variable (FAB) describes the presence of a low level of utilisation of farm buildings or the presence of an overcapitalisation. According to Weersink *et al.*(1990), this variable is expected to have a negative effect in technical efficiency. The second variable describes the presence of hide unemployment, few utilisations of labour saving technologies or absence economies of scale, is expected to have a negative effect on TE (Ahmad and Bravo-Ureta, 1996).

The variable LAVF could have a double meaning. On the one hand, it describes the effect in technical efficiency of the presence of hired labour (Weersink *et al.*,1990; Moreira, Bravo-Ureta *et al.*, 2004), on the other, considering the family characteristic of farms analysed, it could be an index of complete employment of family labour. Moreira, Bravo-Ureta *et al.* (2004) have found a positive relationship between technical efficiency and presence of hired labour.

The gross production value per LSU, expressed by PL, is introduced as an index of quality of finished beef cattle. No applications on beef cattle farms could be found in literature but a similar specification is given by Weersink *et al.*(1990), applied to dairy farms, where a yield variable is used to explain management capability of farms. A positive relation between technical efficiency and milk yield is found in literature.

The size variables are widely used and UBA in this work represent the effect of herd dimension in technical efficiency. Even if most of the published works show a positive relation between herd size and TE (Boatto, 1987; Weersink *et al.*,1990), there is no a univocal results in this direction (Ahmad and Bravo-Ureta, 1996).

The share of concentrated feed purchased from the market is proposed also by Weersink *et al.* (1990) and in the dairy farm application it results to have negatively correlated with TE. The variable Q_FOR describes the relative level of concentrated feed in the diet. A similar variable is used by Boatto (1987) and Ahmad and Bravo-Ureta (1996).

Table 4 – Descriptive statistics of variables in the model

Variables	**Min.**	**Max.**	**Mean**	**S.D.**
Gross production value (€*)	944	493.856	34.053	39.871
User cost of fixed capital (€)	469	28.854	4.303	3.759
User cost of no-fixed capital (€)	247	22.508	3.077	2.549
Total labour hour	1.316	10.670	4.002	1.742
Annual depreciation of farm building (€)	1,03	143,8	20,6	21,4
Total labour hour per LSU	12,4	1.316,7	165,9	185,9
Share of family hour over total	0,52	1,00	0,99	0,06
Number of LSU	2,6	358,3	50,6	51,5
Gross production value per LSU (€)	218,9	2.158,0	690,7	255,6
Share of concentrated feed purchased	0,00	1,00	0,80	0,25
Share of fodder expenditure over total feed expenditure	0,00	0,93	0,46	0,20

* Values are expressed with 1980 price base.

4 Results and discussions

The Generalised Likelihood-Ratio (GLR) test has been adopted to evaluate the better model specification between the models purposed in literature. The GLR compare the restricted model with respect to the adopted model. The statistic associated with this test is defined as:

$$\lambda = -2 \ln \Lambda = -2 \left[\ln \frac{L(H_0)}{L(H_1)} \right] = -2 [\ln L(H_0) - \ln L(H_1)]$$

where $L(H_0)$ is the Log-L value of the restricted model specified by the formulation of null hypothesis, and $L(H_1)$ id the Log-L value of the alternative model hypothesis (the adopted model). The statistic λ has approximately a chi-square distribution with a number of degrees of freedom equal to the number of restrictions. When λ is lower than the correspondent critical value for a given level of significant, we cannot reject null hypothesis.

The first null hypothesis, that aims to test if inefficiency effect are absent from the model, is strongly rejected from the model.

Following tests aims to evaluate if the heteroscedastic, non-neutral SPF could be significantly accepted with respect to reduced model previously proposed in literature (Table 5). The restricted model is significantly rejected with a 95% level of confidence. We cannot reject the hypothesis of null constant in mean and variance model of inefficiency term because of the singularly estimation of the models that include the constant.

Table 6 – Generalised maximum likelihood test of different model hypothesis

H_0	Model	λ	Critical	
$u_i = \theta_m = \delta_n = \delta_m = \delta_t = 0$	No inefficiency effect	589.04	$\chi^2_{13} = 22.36$	Reject Ho
$\theta_m = \delta_n = \delta_m = \delta_t = 0$	Stevenson (1980)	321.72	$\chi^2_{12} = 21.03$	Reject Ho
$\theta_m = 0$	Huang and Liu (1994)	30.17	$\chi^2_4 = 9.49$	Reject Ho
$\theta_m = \delta_n = 0$	Battese and Coelli (1995)	247.50	$\chi^2_7 = 14.07$	Reject Ho
$\delta_n = 0$	Heteroscedastic, neutral SFP	99.08	$\chi^2_3 = 7.81$	Reject Ho
$\delta_n = \delta_m = \delta_t = 0$	Reifschneider and Stevenson's (1991)	625,13	$\chi^2_8 = 15,51$	Reject Ho
$\delta_0 = 0$	For $\delta_0 \neq 0$ the model is singular			Accept Ho
$\theta_0 = 0$	For $\theta_0 \neq 0$ the model is singular			Accept Ho

The ML estimation gives significant parameters of the frontier production function at 5% level of significance. For all variables the signs are positive as expected.

Since the Cobb-Douglas function coefficients give an elasticity interpretation, the value can be taken as a measure of elasticity. The estimate of parameters indicates that the user cost of no-fixed asset is the most important contributor to frontier production (0.304), followed by labour (0.221) and fixed asset (0.095). The sum of elasticity of parameters gives an indication on scale economy. Because of the exclusion of feed costs a correct evaluation on scale economy is not led. A time variable has been introduced in the frontier specification to evaluate the effect of technological progress on the production. The parameter estimated has a positive sign and its value (0.009) suggests an increase in the production of 0.9% per year that could be accounted as technological progress.

Table 6 – Maximum Likelihood estimation of stochastic production frontier

Parameter	Value	t-ratio	Sign.	Parameter	Value	t-ratio	Sign.
Stochastic frontier							
β_0	5,985	12,16	***	β_{LAV}	0,221	3,31	***
β_{SKFO}	0,095	2,39	***	β_T	0,009	3,02	***
β_{SKES}	0,304	8,63	***				
Efficiency effect model							
Mean model							
δ_{FAB}	0,027	2,34	***	δ_{UBA}	-0,046	-1,96	**
δ_{ULAV}	0,010	3,87	***	δ_{Q_MANG}	-6,132	-2,34	**
δ_{LAVF}	12,570	2,77	***	δ_{Q_FOR}	9,926	2,94	***
δ_{PL}	-0,004	-1,27		δ_{POLICY}	1,375	2,17	**
Variance model							
θ_{PL}	-0,001	-2,27	**	θ_{Q_MANG}	0,585	2,13	**
θ_{UBA}	-0,019	-3,48	***	θ_{Q_FOR}	-1,278	-2,78	***
λ	0,706	2,62	***	σ_u	0,212	2,73	***
Log-L	-129,05						

The significance of parameters is: 1% (***), 5% (**) and 10% (*).

The estimated output-oriented technical efficiency is, in average, 76.8%. This value indicates that on average firms concerned could increase their output by 23.2% using the same input bundle.

The parameter λ, that explain the ratio σ_u / σ_v , being significant at a 1% level allows to state that the inefficiency term contributes significantly to explain a part of variability in output of our sample. The significance of this parameter could also be taken as an index of presence of inefficiency effect in the model.

The variables introduced in the mean model of pre-truncate distribution of the inefficiency term (u_i) explain a correlation between them and the inefficiency value: a parameter with a positive sign indicates a positive correlation between the associated variable and the technical inefficiency, and consequently a negative relation with technical efficiency (TE). For the variance model the sign of the parameter is related in the same direction with the variance of inefficiency term and of technical efficiency.

The mean function of pre-truncated distribution of inefficiency is positively correlated with of buildings value (FAB) and labour (ULAV) by average LSU number. As pointed out before, a high value of buildings capital per LSU could be an expression of a low level of utilisation of available assets or a indication of overcapitalisation. In line with Weersink *et al.* (1990) an increase in this variable leads to a reduction of technical efficiency. A high availability of labour per LSU could be related with the absence economy of scale and with a limited utilisation of labour savings technologies. In addiction, considering the family characteristics of farms analysed, ULAV could be indicative of the presence of hidden unemployment (Ahmad and Bravo-Ureta, 1996). Positive correlation of this variable with technical inefficiency would induce to think that a reduction of labour intensity per LSU can improve technical efficiency.

The same suggestion is given by the LAVF coefficient. A positive sign suggests an increase in technical efficiency associated with an increase of hired labour. Considering the limited utilisation of hired labour, the presence could be better associated with the reduction of hidden unemployment of family labour, than with an efficiency effect of the high qualification of external worker. This is particularly true in the case of beef cattle farms where the management factor is more important than specialised job, in comparison with dairy where e.g. milking stage is a key element influencing milk quality, yield and sanity aspects.

Considering significant farms-specific variables, the inefficiency term is negatively correlated with herd size (UBA) and with share of purchased concentrated feed (Q_MANG). The herd size, being the main variable that influences the level of output, can be accounted as an index of scale efficiency effect. Following Weersink *et al.* (1990) and Bravo-Ureta and Reinger (1991) the scale has a positive effect in technical efficiency.

In contrast with Weersink *et al.*'s (1990) results, in this work the share of purchased concentrated feed is negatively correlated with inefficiency term, having positive effect to technical inefficiency level. On the other hand, technical inefficiency is positively correlated with the share in value of fodder feed over total feed (Q_FOR). The value of this variable depends mainly on the genetic characteristic of animals reared and on the level of expected daily gain in weight. This result suggests that a strategy oriented towards an intensification of rearing system leads to and increase in output oriented technical efficiency.

Finally the analysis of time dummy variable (POLICY) suggests that the introduction of the Mc Sharry Reform of CAP (that reduced price oriented policy through the introduction of partially decoupled direct payments) is correlated with a reduction in technical efficiency. We can argue that farms strategies in a context of a direct payment system are not simply oriented to maximize the factor productivity since a lower result could be accepted if there is the possibility to maximize the total income.

Table 7 –Variables effect on technical efficiency

Variables	Sign of δ	Effect on TE
FAB	+	Negative
ULAV	+	Negative
LAVF	+	Negative
UBA	−	Positive
Q_MANG	−	Positive
Q_FOR	+	Negative
POLICY	+	Negative

The variance model permits to correct for heteroscedasticity in σ_u giving, in addition, some indications on variables not significant in mean model. The gross output value per LSU was not significant in mean model but shows a significant negative sign in the variance one. An increase in value of this variable is correlated with a reduction of inefficiency/efficiency variance. Because the inefficiency term is positive truncated a reduction in variance has partial effect on reducing technical inefficiency. The same effect is observable for the herd size whereas for Q_MANG and Q_FOR the signs are opposite compared with those of the mean model.

Table 8 gives descriptive statistics of variables introduced in the model evaluating the differences in average value between the first and last technical efficiency's quartile. The average values are significantly different at 1% and give indications on farm strategy profile of best and worst performing farms in the sample. Results are coherent with model indications.

Table 8 – Mean values of variables introduced in the model of the first and last technical efficiency quartile.

Variables	Description	First quartile	Last quartile	Total
(Fab)	Annual depreciation of farm building (€ base 1980)	10,1	31,8	20,6
(Lav)	Total labour hour per LSU	61,7	289,9	165,9
(Lavf)	Share of family hour over total	95,6	100	98,8
(Pl)	Gross production value per LSU (€ base 1980)	744	605	691
(Uba)	Number of LSU	114	19	51
(Q_mang)	Share of concentrated feed purchased	87,4	73,9	80,3
(Q_for)	Share of fodder used in fed diet	38,1	54,0	46,4
	Technical Efficiency	0,938	0,605	0,786
	Number of observation	122	122	487
	% of simple LSU	56,6	9,4	100,0

Further indications could be obtained analysing TE following different classification criteria:

i) TE increases with the size in LSU. Farms on the sample with less than 10 LSU have an average TE of 62.6%. This value progressively increases to 95.2% for farms with more than 100 LSU;

ii) The number of Annual Work Units[1] (AWU) is not associated with a clear trend to TE. We can only say that a clear averagely higher level of technical efficiency is associated with farms with more than 2 AWU (85.8%);

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[1] On considering the variation of AWU definition along the analysed period, the number of hours are standardized to 2200 hours per year,

iii) The level of TE appears to be higher in average for farms located in lowland (79.2), that make use of credit (85.0%) and hire external labour (91.6%) compared with those located in mountains or hills (74.2%), that do not make use of credit (78.0%) and use only family labour (77.5%);

iv) Farms that manage rented land have not particularly different value on average TE compared with others.

Table 9 – Mean value of technical efficiency based on different classification criteria.

Classification	Mean	% LSU	% Observation
LSU classes			
< 10 LSU	0,626	1,4	11,5
10 - 50 LSU	0,753	30,9	56,5
50 - 100 LSU	0,863	24,3	18,3
> 100 LSU	0,952	43,4	13,8
Classes of UAA			
< 5 ha	0,688	12,3	28,5
5 - 10 ha	0,785	26,7	33,3
10 - 20 ha	0,830	30,7	25,3
> 20 ha	0,918	30,3	12,9
Classes of AWU			
< 1 AWU	0,758	5,7	9,0
1 - 1,5 AWU	0,737	18,3	32,6
1,5 - 2 AWU	0,766	19,8	25,3
> 2 AWU	0,858	56,3	33,1
Geographic area			
Lowland	0,792	89,6	88,7
Hill and mountain	0,742	10,4	11,3
Credit access			
No	0,780	85,7	91,0
Yes	0,850	14,3	9,0
Rented land			
No	0,785	59,9	63,2
Yes	0,788	40,1	36,8
Hired labour			
No	0,775	80,7	92,2
Yes	0,916	19,3	7,8
Total	**0,786**	**100,0**	**100,0**

5 Conclusions

The results of the analysis allow to conclude that output-oriented technical efficiency is significant to explain part of variability in output of beef cattle farms of Veneto region. Among variables that explain the technical efficiency effect, the level of inputs (value of cattle buildings and labour) per LSU has a negative affect in TE. It seems that for more technically efficient farms the lower level of utilisation of inputs per LSU could be associated with: i) the utilisations of labour saving technologies, ii) the presence of economy of scale and iii) a reduction of hidden unemployment and overcapitalisation (Weersink *et al.*, 1990).

Among firm-specific variables the farms size, expressed by the number of LSU, plays an important role in explaining technical efficiency with a positive effect. Also the market orientation for the provision of concentrated feed and their share on whole diet has a positive effect on TE. It seems that strategies oriented toward an increase in herd size and towards the intensification of process (market orientation and high energetic diet) allow farms to improve their efficiency.

The recent evolution of the sector follows described orientation through an increase of herd size of farms still in the market and the exit of smaller and marginal ones as observed in the last two structural surveys (1990 and 2000). The results of the model seem to be consistent with the sector strategies in act.

Considering the results reached, the analysis proposed has some aspects that should be further investigated concerning model specification and applications. Regarding model specification it could be interesting to attempt at solving problems related with the high correlation of feed cost using a value added frontier in place of a production frontier. Further, in the available database there is a lack of some useful variables used in literature to explain technical efficiency like age, work experience, year of schooling (Weersink *et al.*, 1990; Bravo-Ureta and Reinger, 1991; Kumbhakar, Ghosh and McGuckin, 1991; Battese and Coelli, 1995; Maietta, 1998; O’Neill and Matthews, 2001; Karagiannis and Tzouvelekas, 2005).

As set out in Reg. CE 1698/2005 of new Rural Development Program, competitiveness in agriculture represents a primary objective for CAP. In this context, the competitiveness objective is subject to new regulations in animal welfare and environmental compliance as introduced by Mid Term Review. The newly-introduced higher standards influence the firm performance and consequently the efficiency in input use. In addition further regulations are going to be applied in Veneto region concerning conservation of water quality (e.g from Nitrogen pollution) and quantity. All these aspects are in contrast with the technical efficiency strategy proposed by the model and the recent orientation of beef cattle farms. If the increase in herd size and the market orientation in the input purchase result to be the key strategy to increase TE, they probably could increase the environmental impact of production, finding however limitations in the forthcoming legislation.

These restrictions, even if accepted in the context of an European model of agriculture and demanded by the community, are clearly a disadvantage for local farms in terms of production cost especially in a context of a keen price competition.

Even if the present situation in the Veneto Region results to be well managed by farmers, thanks to the wide diffusion of agreements for manure distribution in nearby farmland, some interesting results could arise from the evaluation of relationships between technical efficiency and environmental efficiency to evaluate if more economically competitive farms are at the same time able to reach a better environmental compliance.

6 Appendix

Table 10 – Review of technical efficiency explanatory variables applied to livestock farms.

Variables	**References**
Labour quality	
Drives and motivation	
-off-farm income	Kumbhakar and Hjalmarsson (1993); Maietta (1998); O'Neill and Matthews (2001)
Abilities and capacities	
- education/schooling years	Weersink *et al.* (1990); Kumbhakar, Ghosh and McGuckin (1991); Battese and Coelli (1995); Karagiannis and Tzouvelekas (2005)
- extension services	Bravo-Ureta and Reinger (1991); Maietta (1998)
Background and experience	
- age	Battese and Coelli (1995); Maietta (1998); O'Neill and Matthews (2001); Karagiannis and Tzouvelekas (2005)
- years of farm management	Weersink *et al.* (1990); Bravo-Ureta and Reinger (1991)
Input specification	
Feed per head, land per head	Hallam and Machado (1996)
Concentrate feed per head	Boatto (1987); Ahmad and Bravo-Ureta (1996)
Share feed purchased	Weersink *et al.* (1990)
Feed/veterinary costs over gross production value	Giacomelli (1987)
Labour per head	Ahmad and Bravo-Ureta (1996)
Hired labour utilisation	Weersink and alt. (1990), Moreira, Bravo-Ureta *et al.* (2004)
Output specification	
Specialisation	Hallam and Machado (1996); Maietta (1998); Moreira, Bravo-Ureta *et al.* (2004)
Milk yield	Giacomelli (1987); Weersink *et al.* (1990)
Size specification	
Herd size	Boatto (1987); Weersink *et al.* (1990); Ahmad and Bravo-Ureta (1996); Karagiannis and Tzouvelekas (2005)
Farm size (area or economic)	Boatto (1987); Bravo-Ureta and Reinger (1991); Kumbhakar, Ghosh and McGuckin (1991); Hallam and Machado (1996); O'Neill and Matthews (2001)
Physical environment	
Regional Dummies	Weersink *et al.* (1990); Kumbhakar, Ghosh and McGuckin (1991); Hallam and Machado (1996); O'Neill and Matthews (2001); Karagiannis and Tzouvelekas (2005)
Institutional environment	
Dummy for credits	O'Neill and Matthews (2001)
Dummy for rented farms	Hallam and Machado (1996); Moreira, Bravo-Ureta *et al.* (2004)

Source: update of Reinhard (1999) classification.

7 References

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