Technical Efficiency in Organic Farming: an Application on Italian Cereal Farms using a Parametric Approach

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TECHNICAL EFFICIENCY IN ORGANIC FARMING: AN APPLICATION ON ITALIAN CEREAL FARMS USING A PARAMETRIC APPROACH

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ABSTRACT

A stochastic frontier production model was applied to estimate technical efficiency in a sample of Italian organic and conventional cereal farms. The main purpose was to assess which production technique revealed higher efficiency. Statistical tests on the pool sample model suggested that differences between the two cultivation methods were significant from a technological viewpoint. Separate analyses of two sub-samples (93 and 138 observations for organic and conventional farms, respectively) found that conventional farms were significantly more efficient than organic farms, with respect to their specific technology (0.892 vs. 0.825). This implies that organic (conventional) cereal farmers could increase their income to 99.19 €/ha (40.95 €/ha). Analysis also estimated that land was the technical input with the highest elasticity for both technologies. Furthermore, findings indicated that 63.7% of the differentials between observed and best-practice output was explained by technical inefficiency for the conventional group, while this value was close to unity for organic farms. Some policy implications can be drawn from these findings.

Keywords: Organic farming, Comparison analysis, Cereal-growing, Technical efficiency, Stochastic frontier production models

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1. Introduction

Organic farming is a well-defined method of production that tends to minimize use of synthetic inputs, such as mineral fertilizers, pesticides, herbicides and medical products. Owing to this quality, since the early 1990s — when EEC Regulation 2092/91, establishing rules and indications regarding production and certification, was published — organic farming has become a significant element within the Common Agricultural Policy (CAP) of the European Union (EU). From an EU viewpoint, it serves some of the main objectives of the CAP as it stands today: improving food safety, promoting food quality, environmental protection, reduction in agricultural output surplus and re-orientation of agriculture towards the market (European Commission, 2000).

Since its institutional implementation, the main instrument adopted by the CAP to support organic farming has been the financial subsidy awarded through the '*Agri-environmental Programme*' (EEC Regulation 2078/92 and following modifications). This aid is granted to farmers who switch to organic farming to compensate them for yields and income reductions that should be expected over the first years.

The role of organic farming in the CAP is increasing within the Agenda 2000 Reform. EC Regulation 1257/99, which regulates rural development policies, recognizes organic farming in its strategy on environmental and sustainable development of the CAP.

The Mid-Term Review Reform seems to enforce this role, given that some of the main proposed objectives of the Reform (e.g. environmental sustainability, food quality and safety, more responsiveness to consumer demand) are, as mentioned above, fully served by organic farming (European Commission, 2002a). Furthermore, from European Commission indications, the future CAP should guarantee a more *market-oriented* and more rational support for organic farming (European Commission, 2002).

After different rounds of consultations and discussions in the European Parliament, Council and stakeholder groups, the EU recently published an *Action Plan* for organic farming (European Commission, 2004). It outlines some guidelines for the promotion of adequate programmes in the next CAP and, principally, in rural development policies. Among other actions, the Plan urges the EU to a greater policy effort on organic farming, applying specific measures in the organic sector, enforcing the role in the regional '*Agri-environmental programmes*' and improving the efficacy of horizontal measures (e.g. extension services, R&D, policy coherence).

It is clear, however, that every European effort to promote organic farming could be invalidated if individual farms do not reach adequate productive and efficiency levels (Lampkin and Padel, 1994; Offermann and Nieberg, 2000). This means that any policy effort in supporting conversion from conventional to organic farming — financial aid-oriented or not — needs an adequate level of efficiency of individual farms to achieve success (Tzouvelekas et al., 2002a). This would imply that organic farming must strive to be efficient both productively and economically.

Therefore, development of organic methods raises significant research questions related to productivity and efficiency. In spite of the relevance of these topics, literature on the performance of organic farming is still insignificant, primarily, due to the relative unavailability of data on organic farms (Oude Lansink et al., 2002; Zanoli et. al, 2002).

Above all, little attention has been paid to efficiency. Studies on productivity (yields, unit costs, etc.) are certainly relevant, but it is the general opinion that efficiency analysis provides more complete information on the convenience or otherwise of adopting organic techniques (Cembalo and Cicia, 2002). In comparative studies between organic and conventional farms, especially, efficiency analysis, more than any other approach, seems particularly suitable for assessing the farmers' relative ability in optimizing internal resources. Furthermore, the utilization of an efficiency estimation approach is advisable in studies aimed at providing policy indications (Coelli et al., 1996; Lovell, 1995).

Only in recent years has research literature proposed some comparative studies on technical and economic efficiency aimed at assessing performance differentials between organic and traditional farming. Several studies were conduct by Tzouvelekas et al. (2001a,b; 2002a) on Greek agriculture. The authors used a parametric approach towards the olive-growing, cotton and durum wheat farms, obtaining controversial results. In the analysis on cotton farms, Tzouvelekas et al. (2001b) found that technical efficiency, with respect to their specific technology (organic and conventional), was higher in conventional farming's favour. On the other hand, the studies on olive-growing and durum wheat-growing demonstrated the improved ability of organic farmers in minimizing inefficiency (regarding their specific technology). In these cases, the authors hypothesized a possible role for greater attention to be paid to input use under organic management. Constraints on input use, imposed by European regulations and lower profit margins, may drive organic farmers to use their inputs more efficiently, for example.

In a study of Finnish agriculture, Oude Lansink et al. (2002) reported similar findings to Tzouvelekas et al. (2001a, 2002a). Applying a non-parametric technique, Oude Lansink et al. (2002) found that traditional farms were, on average, more productive than organic farms, but efficiency was higher under organic management. This indicates that organic farms use less productive technology than conventional farms, but compensate for their technical disadvantage with higher efficiency in input use. Oude Lansink et al. (2002) also carried out an aggregate technical efficiency estimation, evaluating analysis from a unique reference group, to verify which types of farm were absolutely more efficient. Results showed that differences in aggregate technical efficiency was not higher in conventional farms, despite their superior productivity. On average, difference in global technical efficiency was not significant for crops (0.65 organic vs. 0.66 conventional), while it was significantly in favour of organic management in livestock farms (0.67 organic vs. 0.63 conventional).

The study proposed in this paper aimed to estimate technical efficiency in a sample of Italian organic cereal farms. A comparative analysis with a sample of conventional farms was carried out to assess, from a technical point of view, which method was more efficient. A stochastic frontier production model was applied on cross-sectional data of 93 organic and 138 conventional farms cultivating cereals.

Section 2 illustrates the criteria for selection of analysis variables and the empirical model used in the analysis. Section 3 concerns the estimation of efficiency levels and discussion of the findings. Section 4 concentrates on policy implications identified from the results. Finally, conclusions are presented in Section 5

2. Methodology

According to the Farrell (1957) model, Technical Efficiency (TE) is defined as the measure of the ability of a firm to obtain the best production from a given set of inputs (*output-increasing oriented)*, or as the measure of the ability to use the minimum feasible amount of inputs given a level of output (*input-saving oriented*) (Greene, 1980; Atkinson and Cornwell, 1994). Consequently, technical inefficiency is defined as the degree to which firms fail to reach the optimal production.

Farrell (1957) proposed to measuring TE of a firm by comparing its observing output to that output which could be produced by a *fully efficient* firm, given the same bundle of inputs. In Farrell (1957) model, inefficiency is measured as the distance from the observed output point to the best production point.

Basing on Farrell (1957) model, several procedures have been proposed in literature to estimate TE. Remanding to Førsund et al. (1980); Bauer (1990); Battese (1992); Pascoe et al. (2000) for a more comprehensive review of the most important methods proposed in literature, this section is dedicated to the Stochastic Frontier Production (SFP) Function Models, originally and independently proposed by Aigner et al. (1977) and Meeusen and van der Broeck (1977). In the SFP models the production frontier is specified which defines output as a stochastic function of a given set of inputs. The presence of stochastic elements makes the models less vulnerable to the influence of outliers than with deterministic frontier models, where the production function frontier is not subject to statistical noise, i.e. it is fixed [Examples of deterministic frontier models are that proposed by Aigner and Chu (1968); Timmer (1971); Afriat (1972); Richmond (1974); Schmidt (1976); Greene (1980)]. It concerns that the error term ε may be separated in two terms: a random error and a random variable explanatory of inefficiency effects:

$$y_i = f(x_i, \beta) + \exp \varepsilon \qquad (1)$$

$$\varepsilon = (v_i - u_i) \qquad i = 1,2,\dots N \qquad (2)$$

where y_i denotes the level of output for the i-th observation; x_i is the row vector of inputs; β is the vector of parameters to be estimated; f (.) is a suitable functional form for the frontier (generally Translog or Cobb-Douglas); v_i is a symmetric random error assumed to account for measurement error and other factors not under the control of the firm; and u_i is an asymmetric non-negative error term assumed to account for technical inefficiency in production. The v_is are usually assumed to be independent and identically distributed normal random variables with mean zero and variance σ_v^2:

$$v_i \sim N(0, \sigma_v^2) \qquad i = 1,2,\dots N \qquad (3)$$

Several distributions has been proposed for u, but u_is are usually assumed to be independent and identically distributed and truncations (at zero) of the normal distribution with mean μ and variance σ_u^2:

$$u_i \sim |N(0, \sigma_u^2)| \qquad i = 1,2,\dots N \qquad (4)$$

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

$$TE = \frac{y_i}{y^*} = \exp(-u_i) \qquad (5)$$

where y* is the output that lie on the frontier. The MLE (Maximum Likelihood Estimation) of (1) consents to estimate the vector β and the variance parameters:

$$\sigma^2 = \sigma_u^2 + \sigma_v^2; \tag{6}$$

$$\lambda = \frac{\sigma_u}{\sigma_v} \tag{7}$$

that permit to obtain σ_v^2 and σ_u^2. Furthermore, assuming a semi-normal distribution for u_i and according to Jondrow et al. (1982), the TE level of each firm could be estimated.

Most of the SFP Function Models proposed in literature are inappropriate to estimate the inefficiency effects caused by factors that affect efficiency. In other words, these models are suitable in estimating the inefficiency level, but they do not consent estimation of the influence of some factors in inefficiency determination.

In order to estimate these effects, some authors proposed a *two-stage* method, in which the first stage consists in TE estimation using a SFP approach, and the second stage involves the specification of a regression model that relaxes TE with some explanatory variables of inefficiency (Pitt and Lee, 1981; Kalirajan, 1982; Parikh and Shah, 1994). An alternative approach regards *one-stage* procedures, through methods that involve an inefficiency effects model inside the stochastic function specification (Kumbhakar et al., 1991; Reisfschneider and Stevenson, 1991; Huang and Liu, 1992). In these models, inefficiency effects are modelled in terms of other observable explanatory variables and all parameters – frontier production and inefficiency effects – are estimated simultaneously.

According to Battese and Coelli (1995), the second approach should be preferred because of the *two-stage* procedures are inconsistencies in the assumption about distribution of inefficiency variables. Indeed, the specification of the regression of the second stage conflicts with the assumption that u_is are independently and identically distributed. Regards also to *panel data* applications, Battese and Coelli (1995) proposed an *one-stage* approach where the functional relationship between inefficiency effects and the firm-specific factors is directly incorporated into the MLE.

The inefficiency term u_{it} has a truncated (at zero) normal distribution with mean m_{it}:

$$u_{it} = m_{it} + W_{it} \tag{8}$$

where W_{it} is a random error term which is assumed to be independently distributed, with a truncated (at $-m_{it}$) normal distribution with mean zero and variance σ^2 (i.e. $W_{it} \geq - z_{it}$ such that u_{it} is non-negative).The mean m_{it} is defined as:

$$m_{it} = Z\,(z_{it},\ \delta) \qquad i = 1,2,\ldots.N \qquad t = 1,2,\ldots.T \tag{9}$$

where Z is the vector (Mx1) of the z_{it} firm-specific inefficiency variables of inefficiency; and δ is the (1xM) vector of unknown coefficients associated with z_{it}.

In this way, we are able to estimate inefficiency effects arisen from the z_{it} explanatory variables.

To facilitate estimation process and following the suggestion made by Battese and Corra (1977), the authors suggest to replacing the parameter λ defined in (7) with:

$$\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2} \tag{10}$$

because of it can be searched between zero and one and this property permit to obtain a suitable starting value for an iterative maximisation process.

3. Data and empirical model

3.1. Data

The information used in this study were collected from cross-sectional data of Italian specialized cereal farms. All the observed farms were in Sardinia and they participated in the official Farm Accountancy Data Network (FADN) during 2001 and 2002.

The FADN was established in 1995 by the EU with the brief to collect farm account information. Using the same return form, yearly data are collected from each Member State. Since 2001, FADN data have included some information on organic practices, and, for this reason, they represent a suitable farm database for studies on the organic sector and efficiency analyses (Oude Lansink et al., 2001; Scardera and Zanoli, 2002).

This study focused on Sardinia because the region plays an important role in Italian organic agriculture. Based on the Agricultural Census 2000, the Sardinian land area under organic crops amounted to 27.7% of the national organic area (ISTAT, 2002). The 235,000 ha cultivated under organic management corresponded to about 23% of total agricultural regional land. In the Sardinian organic sector, cereal-growing occupies a significant position. About 23,000 ha of cereals were cultivated under organic technology, equal to 15.8% of the overall Sardinian area under cereals. In Sardinia, most of the organic cereal production is for animal feed.

The dataset consists of 231 observations. Among these, 93 farms had switched to organic cereal-growing. In the remaining 138 observed farms, cereals were cultivated with conventional methods.

To reduce the risk of including farms in which the organic system was not a well-established agronomic practice, all selected organic farms were '*in maintenance'* phase. Furthermore, organic and conventional farms showed similar input endowment (for example, land area was equal to, on average, 8.7 and 8.5 ha for organic and conventional farms, respectively).

The farms specialized in durum wheat, oats and barley cultivation. More exactly, durum wheat was grown in 117 farms (65 and 52 under conventional and organic technology, respectively), oats were cultivated in 64 farms (40 conventional and 24 organic farms) and barley in 50 farms (33 conventional and 17 organic farms).

3.2. Frontier production model specification

In this study, we assumed a Cobb–Douglas functional form as frontier technology specification for the farms. Using the Battese and Coelli (1995) procedure, the Cobb–Douglas SPF is specified as follows:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{10} \beta_j x_{ji} + (v_i - u_i) \tag{11}$$

where the subscript i =1,2…N denotes the observation for the ith firm and j,k = 1,2…J stand for used inputs.

The dependent variable (Y) represents the value (in euro) of total cereals produced by the ith firm. The aggregate inputs, included as variables of the production function, are described in Table 1.

Analysis was conducted with respect to six production inputs. The first variable is the land area that each farm devotes to cereals (β_1). The second and third variable consider the total expenditure in seeds (β_2) and in fertilizers, pesticides, etc. (β_3). The fourth variable reflects the total amount of financial and fixed capital stock (β_4) of each farm, while the fifth concerns annual farm labour (β_5) measured in hours. Finally, the sixth variable considers other farm expenditures (β_6).

All the input variables were in their natural logarithmic form.

As a first step, we assumed a unique technological frontier for both organic and conventional farms. Contrary to most efficiency studies in this field, our purpose was to test the hypothesis on technological homogeneity between organic and conventional cereal-growing. Thus, the original model includes a *dummy* variable (β_7) in the frontier model that reflects the management type (organic or conventional).

Furthermore, the rationale underlying the basis of the proposed model is that the three observed cereal species (durum wheat, oats, barley) might lie on different production frontiers. For this reason, the pool production function involves three *dummy* variables (β_8; β_9; β_{10}) linked to the cereal species.

The inefficiency effects model has the following form:

$$u_{it} = \delta_0 + \delta_1 Z_{i1} + \delta_2 \ln Z_{i2} + \delta_3 Z_{i3} + \delta_4 Z_{i4} + \delta_5 Z_{i5} + W_i \qquad (12)$$

Explanatory variables of the inefficiency effects were represented by age (δ_1) and gender (δ_2) of the farmer, by size of the farms (δ_3) measured in terms of land area (in the natural logarithmic form), by the altimetry (δ_4) and by the placement (or not) of each farm in a *less-favoured area* (δ_5), such as defined by the EEC Directive 75/268.

Table 1 – Variables used in the analysis

Variable		**Description**
FRONTIER MODEL		
Output	Y	Total cereals production (in euro) by each farm
Land	β_1	Total land area (ha) devoted to cereals
Seeds	β_2	Expenditure (euro) for seeds
Fertilizers	β_3	Expenditure (euro) for fertilizers, pesticides, etc.
Capital	β_4	Total amount (euro) of capital (financial, machineries, building, etc.)
Labour	β_5	Total amount of annual labour (h)
Other expenditures	β_6	Total amount (euro) of the other expenditure
Conventional / organic	β_7	*Dummy* that reflects the technology (0 = organic; 1 = conventional)
Durum Wheat	β_8	*Dummy* that reflects crop (1 = durum wheat; 0 = other cereals)
Oats	β_9	*Dummy* that reflects crop (1 = oats; 0 = other cereals)
Barley	β_{10}	*Dummy* that reflects crop (1 = barley; 0 = other cereals)
EFFICIENCY MODEL		
Age	δ_1	Age of the farmer
Gender	δ_2	*Dummy* that reflects the gender of the farmer (0 = female; 1 = male)
Size (land)	δ_3	*Proxy* variable that reflects the size of the farm
Altimetry	δ_4	*Dummy* that reflects the altimetry (1 = mountain; 2 = hill; 3 = plane)
Less-Favourite Area	δ_5	*Dummy* that reflects the placement of the farm in a Less-Favourite Area (0 = Less-Favourite Area; 1 = non Less-Favourite Area)

4. Analysis results

Parameters for the function and inefficiency model were estimated simultaneously. Owing to space constraints, the ML estimates of the parameters of the SFP function, given the specification for technical efficiency effects defined by Eq. (11), are not presented. Estimation was obtained using the computer program FRONTIER 4.1, created by Coelli (1996).

4.1. Hypothesis tests

Statistical tests are needed to evaluate suitability and significance of the adopted model. Specifically, the nature of the problem suggests conducting two tests on the suitability of hypotheses on technological homogeneity regarding agronomic methods (conventional and organic techniques) and regarding crops (durum wheat, oats and barley cultivation).

An appropriate testing procedure is the generalised likelihood-ratio test, which permits the evaluation of a restricted model with respect to the adopted model (Bohrnstedt and Knoke, 1994). The statistic associated with this test is defined as:

$$\lambda = -2\ln \Lambda = -2\left[\ln \frac{L(H_0)}{L(H_1)}\right] = -2\,[\ln L(H_0) - \ln L(H_1)] \qquad (13)$$

where L(H_0) is the log-likelihood value of the restricted model specified by the formulated null-hypothesis, and L(H_1) is the log-likelihood value of the model under the alternative hypothesis (the adopted model). The statistic test λ has approximately a chi-square (or a mixed-square) distribution with a number of degrees of freedom equal to the number of parameters (restrictions), assumed to be zero in the null-hypothesis. When λ is lower than the correspondent critical value (for a given significance level), we cannot reject the null-hypothesis.

The generalised likelihood-ratio tests are shown in Table 2.

Table 2 - Tests of hypotheses for parameters of the pool model adopted

Restrictions	Model	L(H_0)	λ	$\chi^2_{0.95}$	Decision
None	Cobb-Douglas	-12.202			
$H_0 : \beta_7 = 0$	Technological homogeneity (cultivation)	-20.551	16.70	3.84	Rejected
$H_0 : \beta_8; \beta_9; \beta_{10} = 0$	Technological homogeneity (crops)	-12.467	0.93	7.82	Not rejected

The first test concerns the hypothesis of technological homogeneity between organic and conventional cereal-growing. The starting hypothesis is reflected by the presence of the parameter β_7 in the Cobb–Douglas model and it implies that the two methods are not homogenous bundles of defined technologies. In the alternative hypothesis (technological homogeneity), the coefficient of parameter β_7 would be zero (management not affecting production) and, therefore, the null-hypothesis is represented as $H_0 : \beta_7 = 0$. In a case where the null-hypothesis is not rejected, the test suggests that we could adopt a unique technological frontier for the organic and conventional data. The value of the likelihood ratio statistic for this restricted model is calculated to be 16.70 (log-likelihood function value is –20.551 vs. –12.202 of the adopted model) and it is significantly higher than 3.84, which is the critical value (at 5% significance level) from the χ^2 distribution.

Hence, the null-hypothesis of technological homogeneity can be rejected. This indicates that organic and conventional farms in the sample would lie on two different frontier production functions and, for this reason, the preferred function model would involve two separate models for describing organic and conventional methods.

The second test on frontier production aims to assess if there is a significant technological homogeneity among the three cereal crops. The null-hypothesis $H_0 : \beta_8; \beta_9; \beta_{10} = 0$ was not rejected and, hence, it implies that crop diversity would not be a significant factor in describing technology.

4.2. Organic and conventional models

Tests results suggest adopting separate frontier models for organic and conventional technologies. Results for both proposed models are shown in Table 3 in the third and fifth columns, respectively.

Several tests on the inefficiency model were conducted to assess suitability of the adopted model for organic and conventional technologies (Table 4).

The first test aims to assess if inefficiency effects are absent from the model. If the null-hypothesis $H_0 : \gamma = \delta_0;\ \delta_1 \ldots \delta_5 = 0$ is accepted, then the model will revert to other stochastic models proposed in literature, in which an inefficiency model is not incorporated (omission of the u_{it} term). Rejection of this null-hypothesis for both organic and conventional data indicates that the specification of a model, which incorporates an inefficiency model, is an adequate representation of these data.

The second test concerns the nature of the inefficiency effects (stochastic or not). If the inefficiency effects are not random, parameter γ will be zero — because the variance of inefficiency is zero — and the model will be reduced to a traditional mean-response function, in which the explanatory variables are included in the function model. On the other hand, parameters δ_0 and δ_3 must be zero in the case of non-random effects, because the frontier model already involves an intercept and the parameter associated with the proxy, represented by δ_4. In other words, the specification of non-stochastic inefficiency effects is expressed by the null-hypothesis $H_0 : \gamma = \delta_0;\ \delta_3 = 0$, which, in this case, was rejected in favour of the stochastic specification for both organic and conventional technologies.

The third test regards the hypothesis $H_0 : \delta_0 = 0$, where inefficiency effects do not have an intercept. This null-hypothesis was rejected for the conventional model, while it was not rejected for the organic data ($\lambda = 1.63$).

Table 3 – ML Estimates for SFP parameters for the organic and conventional data

Variable	Parameter	Conventional		Organic	
		(1)	(2)	(1)	(2)
FRONTIER MODEL					
Constant	β_0	0.377	**0.371**	0.430	**0.434**
		(0.253)	*(0.216)*	*(0.237)*	*(0.207)*
Land area	β_1	0.832	**0.796**	0.837	**0.839**
		(0.091)	*(0.081)*	*(0.072)*	*(0.077)*
Seeds expenditure	β_2	0.210	**0.224**	0.047	**0.046**
		(0.076)	*(0.067)*	*(0.058)*	*(0.065)*
Fertilizer expenditure	β_3	-0.001	**-0.002**	0.102	**0.101**
		(0.015)	*(0.014)*	*(0.039)*	*(0.038)*
Capital	β_4	0.056	**0.031**	0.049	**0.051**
		(0.048)	(0.027)	(0.028)	(0.025)
Labour	β_5	-0.005	**-0.046**	0.024	**0.015**
		(0.048)	*(0.048)*	*(0.056)*	*(0.049)*
Other expenditures	β_6	0.005	**0.006**	0.022	**0.023**
		(0.015)	*(0.013)*	*(0.016)*	*(0.016)*
EFFICIENCY EFFECTS					
Constant	δ_0	0.235	**0.283**	0.169	-
		(0.071)	*(0.072)*	*(0.202)*	
Age	δ_1	-0.000	-	-0.029	**-0.013**
		(0.005)		*(0.068)*	*(0.036)*
Gender	δ_2	0.052	-	-0.109	**-0.207**
		(0.099)		*(0.151)*	*(0.164)*
Size (labour)	δ_3	-0.284	**-0.294**	-0.002	**-0.002**
		(0.084)	*(0.084)*	*(0.004)*	*(0.003)*
Altitude	δ_4	-0.118	**-0.247**	-0.833	**-0.717**
		(0.218)	*(0.198)*	*(0.129)*	*(0.442)*
Less-Favourite Area	δ_5	-0.207	**-0.298**	-0.282	**-0.294**
		(0.055)	*(0.059)*	*(0.329)*	*(0.282)*
VARIANCE PARAMETERS					
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	σ^2	0.073	**0.079**	0.108	**0.104**
		(0.021)	*(0.020)*	*(0.189)*	*(0.155)*
$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$	γ	0.293	**0.389**	0.979	**0.978**
		(0.224)	*(0.171)*	*(0.038)*	*(0.031)*
$\gamma^* = \gamma / \left[\gamma + \frac{1-\gamma}{\pi/(\pi-2)} \right]$	γ^*	0.533	**0.637**	0.992	**0.992**
Log-likelihood function		41.175	**39.736**	16.313	**15.498**
Mean TE		0.891	(*) **0.892**	$^{(}$0.826	(*) **0.825**
		(0.117)	*(0.124)*	*(0.123)*	*(0.123)*
Returns of scale		1.097	**1.009**	1.081	**1.075**

(1) Adopted Model (2) Preferred model

(*) Difference between means significant at 0.01 *t*-test level (P = 6.8 E-05)

In the fourth test, we assessed the influence of the selected variables on the degree of firm efficiency. Testing the null-hypothesis $H_0 : \delta_1; \delta_2; \ldots; \delta_4 = 0$, we can verify if the joint effect of the four selected variables is significant, irrespective of the significance of each variables. The fact that this null-hypothesis was rejected, together with the statistical significance of each variable, would be taken as confirmation that the selected variables are actually illustrative of the efficiency in both models.

Table 4 - Tests of hypotheses for parameters of two adopted models

Restrictions	Model	L(H_0).	λ	$\chi^2_{0.95}$	Decision
			Conventional		
None	Cobb-Douglas	41.175			
$H_0 : \gamma = \delta_0; \delta_1 \ldots \delta_5 = 0$	No inefficiency effects	-21.304	124.95	13,40*	Rejected
$H_0 : \gamma = \delta_0; \delta_3 = 0$	No stochastic effects	-89.433	261.22	7.05*	Rejected
$H_0 : \delta_0 = 0$	No intercept	-15.471	113.29	3.84	Rejected
$H_0 : \delta_1; \delta_2 = 0$	No age and gender effects	39.736	2.88	5.99	Not rejected
$H_0 : \delta_1 \ldots \delta_5 = 0$	No firm-specific factors	-20.367	123.08	11.07	Rejected
			Organic		
None	Cobb-Douglas	16.313			
$H_0 : \gamma = \delta_0; \delta_1 \ldots \delta_5 = 0$	No inefficiency effects	-63.152	158.93	13,40*	Rejected
$H_0 : \gamma = \delta_0; \delta_3 = 0$	No stochastic effects	-22.973	13.320	7.05*	Rejected
$H_0 : \delta_0 = 0$	No intercept	15.498	1.63	3.84	Not rejected
$H_0 : \delta_1; \delta_2 = 0$	No age and gender effects	12.952	6.72	5.99	Rejected
$H_0 : \delta_3 = 0$	No size effect	13.248	6.13	3.84	Rejected
$H_0 : \delta_1 \ldots \delta_5 = 0$	No firm-specific factors	-93.265	219.15	11.07	Rejected

* The statistic λ for these variables is distributed as a mixed χ^2 because the tests involves equality and inequality restrictions. The relative upper bounds are showed in Table 1 in Kodde e Palm (1986).

The fifth test concerns the degree of suitability of the model without age and gender effects. Both estimated parameters show an irrelevant magnitude in the conventional model, suggesting that these variables would be scarcely illustrative of efficiency.Not rejecting the null-hypothesis $H_0 : \delta_1; \delta_2 = 0$ confirms that age and gender of farmers do not significantly affect efficiency in the conventional model. This test was conduct also for organic technology because estimated values are, in general, small relative to their standard errors. The null-hypothesis was, however, rejected in favour of involving gender and age effects.

The last test involved size effects in the organic model, because these effects seem negligible. Results of the test on the null-hypothesis $H_0 : \delta_3 = 0$ lead to rejection of the null-hypothesis and involving size as an illustrative variable of efficiency.

To obtain the preferred form, both models were estimated in light of the *t*-test results. ML estimations for the more appropriate model (without age and gender effects for the conventional sub-sample and without intercept for the organic sub-sample) are shown in the fourth and sixth columns of Table 3.

Structure of production. All ML estimates of the production frontier parameters were found to be statistically significant at the 5% level in each group, except fertilizer expenditure and other expenditure in the conventional group. Four of the six variables have the expected positive sign in the conventional group (all except labour and fertilizer expenditure), while all variables show a positive sign in the organic group.

Since the Cobb–Douglas coefficients have an elasticity interpretation, the value of the parameters can be taken as a measure of elasticity. The production elasticity estimates indicate that land contributed the most to cereal production, both in conventional and organic samples. The magnitude is equal to 0.796 in conventional technology and increases to 0.839 in organic technology.

A particularly large difference appears regarding fertilizer expenditure. In the case of the conventional system, use of fertilizers, pesticides and other chemical products seem to make, as mentioned above, an insignificant contribution to production with respect to other inputs. On the other hand, organic technology elasticity is, on average, 0.101, i.e. it implies that a reduction of 1% in fertilizers, pesticides, etc. would result in a 0.1% reduction in output. The relative high elasticity of the chemical products in the organic cereal-growing process would be a consequence of their low use in this technology. It is stated that fertiliser use is non-flexible and scarce in organic farming, particularly during the '*in maintenance'* period.

Owing to its infrequent usage, chemical products would operate at an increasing marginal productivity level. For this reason, production tends to be sufficiently sensitive to this factor.

Returns of scale are slightly increased in the organic system (1.075), while they are substantially at a constant level in conventional technology (1.009).

Technical efficiency and inefficiency effects. The estimated TEs for conventional and organic practices are, on average, 0.892 and 0.825, respectively. This indicates that organic farmers are less efficient than conventional farmers, relative to their specific frontier technology. However, it does not indicate that conventional farms are more efficient than organic farms to the same degree, because the two practices are situated on different technological frontiers. It only implies that conventional farmers operate closer to their specific frontier than organic farmers.

Since in this study, TE scores are calculated as an output-oriented measure, results imply that both farming methods might increase production using the same input bundle. Organic farmers would be able to increase output by 17.5% with the present state of technology, using their disposable resources more effectively. The level of improvement is equal to 10.8% for conventional farms. From a monetary point of view, these levels correspond to an income increase of 99.19 and 40.95 €/ha for organic and conventional farms, respectively.

Analysis of parameters γ and δ_i gives information on the technical inefficiency structure. The ratio-parameter γ is significant at a 1% level both for organic and conventional farms. It follows that TE is significant in explaining output variability in both technologies. The parameter value could not be taken as a measure of the relative contribution of the inefficiency term to the total output variance, but this measure can be obtained by estimation of parameter γ^*, calculated as described in Table 3. In conventional farms, estimation suggests that 63.7% of the differentials between observed and best-practice output is due to the existing difference in efficiency among farmers, while this value is close to unity (0.992) for organic farms.

Table 5 – Mean of TE for cereals species

ET	**CEREALS**					
	Durum Wheat		**Barley**		**Oats**	
	Conventional	***Organic***	***Conventional***	***Organic***	***Conventional***	***Organic***
Observations	65	52	33	17	40	24
Mean	0.912	(*)0.869	0.839	(**)0.789	0.906	(*)0.755
S.d.	*(0.078)*	*(0.093)*	*(0.174)*	*(0.103)*	*(0.126)*	*(0.154)*
Maximum	0.979	0.955	0.972	0.906	0.976	0.944
Minimum	0.681	0.501	0.473	0.541	0.482	0.338

(*) Difference between means significant at 0.01 t-test level (durum wheat: $P = 0.009$; oats: P = 7.1 E-05)

(**) Difference between means significant at 0.30 t-test level (barley: $P = 0.284$)

As regards inefficiency effects, ML estimation shows that all the five (three) variables involved are significant for organic (conventional) production. As expected all variables record a negative sign, implying that an increase in each variable positively affects TE. In conventional cereal-growing, the difference in magnitude among the three illustrative variables is not sensitive. Assignment to a *less-favoured area* is the factor that mainly affect TE (-0.298), followed by size (-0.294) and altitude (-0.247). It confirms the hypothesis that farms located in a less-favoured area and at high altitude level tend to be less efficient. Analysis also suggests that efficiency increases with farm size.

Altitude is the factor that influences TE (-0.717) most in organic farms. Contrary to conventional farms, farm size plays a negligible role in TE (-0.002). Stronger effects are associated with assignment to a less-favoured area (-0.294) and with gender of the farmers (-0.207, implying that male farmers tend to be more able than female farmers under organic management). Finally, estimations indicate that the age of farmers is not a sensitive illustrative variables of inefficiency in organic cereal farms (-0.013).

Furthermore, we estimated differences in TE between organic and conventional methods for each crop cultivated. Durum wheat and oats displayed a significant difference (at 1% level), while the higher TE (0.839) for conventional versus organic barley cultivation (0.789) is not significant (Table 5). Farmers that cultivate durum wheat could increase their output by 8.8 and 13.1% under conventional and organic management, respectively. It implies that organic durum wheat farmers would increase their income to 88.45 €/ha, while the improvement for conventional farmers amounts to 40.56 €/ha. More sensitive is the range in oat-growing, because organic and conventional farms produce 75.5 and 90.6%, respectively, of the output that could be theoretically produced with the same input bundles (for their specific technology), implying that oat farmers would increase their income by 42.06 €/ha under traditional management and 120.49 €/ha under organic management.

5. Policy implications

Despite conclusive indications, regarding efficacy and suitability, that the current CAP policy on organic farming cannot be reached, analysis results reveal some considerations on policy implications, at least as far as cereal-growing is concerned.

The organic sub-sample used in this analysis is represented by '*in maintenance'* farms. This means that all the organic farms involved have switched to organic management over the years. Therefore, farmers would have achieved sufficient expertise in organic practices. Nevertheless, estimated technical efficiency scores suggest that production is not adequately efficient. Furthermore, it can be inferred that conversion from traditional to organic cereal-growing would lead to lesser efficiency. Indeed, organic farms are less efficient than conventional farms (with respect to their specific frontier). It also suggests that organic farmers could improve their economic viability more than traditional farmers. As emphasized in the above paragraph, it is clear that the inadequate efficiency of organic farming could invalidate any policy effort in support and, as a consequence, its development; especially, when a gap exists between conventional and organic practices in the former's favour.

In light of this, at least three policy indications can be suggested:

(1) The main instrument adopted by the CAP for encouraging organic farming is the temporary financial aid given to farmers within the agri-environmental schemes. This subsidy might help to compensate for probable falling yields and increasing costs due to conversion. On the other hand, it tends to lose its efficacy in middle and long term if not anchored with rigorous eligibility criteria, such as professional skill of farmers or profitability of farms.

Similarly, in Italian agriculture, eligibility criteria for receiving payment seem too unrestrictive. As evidenced by Tzouvelekas et al. (2001a), too many criteria may lead to distorted patterns in farmers. Some farmers could be forced to adopt an organic management, not because of an actual interest in organic production, but because of financial subsidies. It is common knowledge that, in reality, this pattern is widespread in Italy, and Sardinia is no exception (INEA, 1998). If aid is not related to a sufficient level of knowledge regards organic methods, it could happen that farmers, attracted by organic practices, receive subsidies despite their ignorance of cultivation processes. In both cases, the inefficacy of financial aid for improving efficiency and profitability is evident. For this reason, more rigorous eligibility criteria for distributing aid, combined with a revision of the payment scheme, are needed.

The EU is also conscious of the inadequacy of the actual system, and is attempting to modify the criteria. The future CAP should guarantee a more market-oriented and a more rational support for organic farming (European Commission, 2002a). On the one hand, the EU intends to encourage a *market-orientation* approach, anchoring aid to certified organic products. This issue is already a prerogative of the new CAP, provided by EEC Regulation 1782/2003. On the other hand, it would promote additional temporary and degressive aid to farmers to encourage a more rapid adoption of the demanding standards imposed by the EU.

In the light of our findings, it is our opinion that another principle could be adopted by the CAP. Indeed, it may be advisable to adjust subsidy components, not only on the basis of crops variety, but also taking into account the geographical and socio-economic characteristics of the area. This study found that altitude and assignment in an economically disadvantaged area are the variables that chiefly affect efficiency in the organic farms. Furthermore, results suggest that efficiency in organic farms is influenced by these variables more so than in conventional farms. Thus, it demonstrates that greater aid should go to areas proven to be not particularly fertile, owing to pedo-climatic, social or economic reasons, or where organic agriculture has been slow to take off.

(2) Economic subsidies, such as now provided in the CAP, cannot represent the only policy measure in favour of organic farming. During consultations for the *Action Plan* in organic farming (European Commission, 2004), several stakeholders proposed to include a separate chapter on organic farming into the rural development policy. This chapter would contain a set of specific measures for organic production, fully integrated and compatible with the CAP issues and instruments. In the Commission's view, insertion of a specific chapter could not guarantee real benefits owing to the fact that the rural development policy '*… can already cover almost all aspects for organic production under different criteria…*' (European Commission, 2004, page 15). On the other hand, the Commission encourages Member States to introduce a coherent set of measures on organic farming, especially to guarantee the same possibilities of receiving investment support as conventional farmers.

The estimated efficiency scores in our analysis suggest that organic cereal farms have more problems (with respect to farms under conventional management) from a structural viewpoint. Analysis also indicates that inefficiency affects production in organic farms more so than in conventional farms (parameter γ^*). In all probability, the single agri-environmental subsidy is not sufficient to compensate for the structural inadequacies in organic units. From the perspective of improving efficacy in organic farming policy, integration of agri-environmental aid with other rural development measures could enlarge the disposable mechanism for ensuring rational development of the sector. A possibility could be to provide special terms, in favour of organic farms, in distributing financial aid, granted with specific rural development measures, to support organic farming. For example, measures such as 'Investments in Agricultural Holdings' and 'Setting up of Young Farmers' (article 4 and 8 of CE Regulation 1257/99, respectively) could provide increasing aid or credit facilities for organic farms and/or organic management, as priority criterion in selecting beneficiaries. According to *Action Plan* guidelines, another hypothesis could be to target organic farming as the preferred management option in certain areas, such as the *less-favoured areas*. Both hypotheses are consistent with the CAP emphasis on issues, such as environmental sustainability, food quality and safety, reduction in agricultural output surplus. Furthermore, they would permit possible advances in structural improvements in organic farms and increasing efficiency.

(3) As highlighted above, efficacy of policy effort is linked with the specific professional skills of farmers. Farmers that intend switching from conventional to organic management must have the right technical and professional competency, so as to manage the activity efficiently. Generally, in areas, such as cereal-growing, conversion to organic practices requires more than slight changes in management.

Our analyses suggest that Italian cereal farmers have difficulties in implementing organic management practices, as the inferior technical efficiency (with respect to traditional techniques) reflects. Also, the increasing returns of scale that, on average, characterize the sample organic farms, represent an indicator of these difficulties. It implies, indeed, that unlike conventional farms, which registered constant returns of scale, organic farms are able to increase efficiency (and productivity), operating on a more appropriate productive scale. Therefore, it must be mentioned that organic farmers encountered greater problems in reaching an optimal productivity scale and, on average, lagged behind, with respect to conventional producers.

Enhancing professional skills could make farmers more knowledgeable, as regards organic methods, in overcoming these difficulties. As a consequence, a rational policy effort should be directed to enforcing professional training and extension services. Policies of this nature would be more suitable, rather than economic support alone. Indeed, both measures could furnish producers with the necessary skills and technical assistance for organic techniques to aid producers during the implementation phase and to ensure the necessary efficiency in the long-term. On the other hand, some studies have demonstrated the importance of extension services and professional training as efficacious measures for organic agriculture development. For example, in a recent study, Lohr and Salomonsson (2000) found that information given by extension services to farmers represented a more influential factor than financial subsidies in encouraging farmers to adopt organic management practices. On the other hand, other studies confirm that financial subsidies should represent the main incentive to farmers to adopt organic management practices (Pietola and Oude Lansink, 2001).

Some of these features have just been implemented into the future CAP. In the *Action Plan* for organic farming (European Commission, 2004), the EU recognizes the relevance of enforcing farmers' professional skills. Among other actions, the Plan urges more EU policy effort on organic farming, applying specific measures on the organic sector, such as improving extension service efficacy. It is our sincere hope that the CAP will now actually move towards enhancing professional training and extension service.

6. Conclusions

The present study involves a comparative analysis of organic and conventional cereal-growing to evaluate their technical efficiency. Using a stochastic frontier production (SFP) approach, the analysis – focused on a sample of 231 Italian farms - found that organic practices are, on average, significantly less efficient than traditional methods, with respect to their specific technological frontier. However, since conventional and organic cereal-growing represents different production technologies - as analysis seems to confirm - the gap in favour of conventional farming should not be interpreted as an absolute advantage of traditional cereal-growing over organic practices. It simply implies that organic farmers operate less closely, than conventional farmers, to their production frontier. In other words, they use their available resources less effectively than traditional farmers. Findings also show that this pattern is common to the three analysed cereal crop varieties (the difference for barley, however, is not significant).

Although categorical policy suggestions cannot be reached, some considerations on the efficacy of the present CAP and future perspectives can be identified. Results suggest the enforcing of professional training and extension services as a means of improving the technical ability of organic farmers, thereby guaranteeing efficiency in the long-term. Furthermore, a revision of eligibility criteria for distributing Community subsidies to organic farmers and their integration with other rural development measures are necessary.

However, this study represents only a partial contribution and, as mentioned previously, the results cannot lead to generalization. More empirical research needs to be done to gather further information, for policy implications, on the efficiency of organic farming.

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