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The productive efficiency of organic farming: the case of grape sector in Catalonia

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Abstract

Knowledge about productivity and efficiency differences between conventional and organic farms has important implications for the evaluation of the economic viability of these two agricultural practices. The main purpose of this study was to compare the efficiency ratings of organic and conventional grape farms in Catalonia. To do so, we fit a stochastic production frontier to cross sectional, farm-level data collected from a sample of 141 Catalan farms that specialize in grape growing. Results show that organic farmers, on average, are more efficient than their conventional counterparts (efficiency ratings are on the order of 0.80 and 0.64, respectively). Apart from adoption of organic practices, experience is also found to improve technical efficiency. Conversely, technical efficiency tends to decrease with the relevance of unpaid family labor, farm location in less favored areas, and farmers' strong environmental preservation preferences.

Additional key words: Spain; stochastic production frontier; technical efficiency.

Resumen

La eficiencia productiva de la agricultura ecológica: el caso del sector de la uva en Cataluña

Conocer las diferencias de productividad y eficiencia entre la agricultura convencional y la ecológica tiene implicaciones importantes para la evaluación de la viabilidad económica de estas dos prácticas agrícolas. El principal objetivo de este estudio fue comparar la eficiencia técnica de las explotaciones de uva ecológicas y convencionales en Cataluña. Para ello utilizamos el modelo de la frontera de producción estocástica. El análisis se basó en datos de corte transversal de una muestra de 141 explotaciones catalanas especializadas en la producción de uva. Los agricultores ecológicos fueron, de promedio, técnicamente más eficientes que los convencionales (los ratios de eficiencia fueron 0,80 y 0,64, respectivamente). Además de la adopción de técnicas ecológicas, la experiencia también incrementa la eficiencia técnica. En cambio, las explotaciones con una mayor proporción de trabajo no remunerado, que se encuentran en una zona desfavorecida y/o que tienden a tener fuertes preferencias por preservar el medio ambiente, son generalmente menos eficientes.

Palabras clave adicionales: eficiencia técnica; España; frontera estocástica.

Introduction

Intensive agricultural systems have caused several negative externalities on humans, animals and the environment. Impacts on human health, pollution of underground and surface water, loss of biodiversity, or overutilization of natural resources are just a few examples of these externalities. Social concerns regarding the negative externalities derived from conventional agriculture have been growing. Over the last few years, there has also been an increase in consumer awareness pertaining to the consequences of food choices on their

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Abbreviations used: CCPAE (Consell Català de la Producció Agrària Ecològica); DEA (data envelopment analysis); EU (European Union); PDO (protected designations of origin); SFA (stochastic frontier analysis); SPF (stochastic production frontier); TE (technical efficiency); UAA (utilized agricultural area).

health and the environment. These concerns have led to changes in European Union (EU) agricultural policies that have progressively incorporated environmental considerations. Interest in alternative agricultural practices that are more environmentally friendly has also been growing. Organic farming, which replaces chemical inputs with organic fertilizers and non-chemical crop protection inputs, has received substantial attention within the EU.

Since the beginning of the 1990s, the EU has made a significant effort to enhance and develop organic agriculture. In order to increase the supply of organic products, EU countries have provided financial assistance for organic producers. Conversion subsidies have been introduced to compensate for the lower incomes obtained during the early stages of conversion. As a result, organic farming has quickly grown within the EU-27 countries from 0.70 million hectares in 1993 to 7.20 million hectares in 2007 (Eurostat, 2007; Willer & Kilcher, 2009). The organic area share over the total utilized agricultural area is around 4% in the EU-27, which is among the highest in the world. Organic farming in Spain has grown faster than in other EU-27 member states. While Spain ranked 10th in the EU's organic area distribution with 4,235 ha in 1991, it currently ranks second with almost one million ha (Lampkin, 1996; MARM, 2008; FiBL, 2009). Spain was the first contributor to the increase in the EU's organic area in 2006 (FiBL, 2009). The rapid and substantial increase is mainly explained by economic strategies adopted by farmers who consider organic production to be profit maximizing when accounting for subsidies received and price premiums for their produce (Armesto-López, 2008).

Despite the prominent position of Spain in the EU, the share of organic farming in the Spanish utilized agricultural area (UAA) (3.70%) is still below the EU-27 average (4%). As in Europe, more than 60% of the Spanish organic area is devoted to grassland, while arable crops are the most important organic crop with almost 275,823 ha, representing more than one third of the organic crop area. Olive groves are the second most common organic crop (22%), followed by dried fruits (15%) and grapes (7%) (MARM, 2008).

Grape is a perennial crop that, compared to other crops, has relatively low nutritional needs and adapts well to marginal soils (Winkler *et al.*, 1974; Pongracz, 1978). This feature is considered very relevant to produce organically and makes conversion easier than for other crops. While other crops suffer many problems over the period of transition from conventional to organic, grape cultivation does not as long as the minimum level of nutrient needs is guaranteed to avoid productivity loss. These features make organic grape production a technically feasible, economically attractive and sustainable activity. Selection of resistant varieties in organic viticulture plays a vital role in ensuring high immunity against pests and diseases, high adaptation to the environmental conditions (rainfall, temperature, frost, humidity and soil quality), high productivity and profitability. Other operations are considered important to guarantee an excellent growing season for organic grape. Organic vineyard requires correct training operations to facilitate pruning (a critical practice), spraying and harvesting.

By the end of the 2000s decade, 70% of the worldwide organic grape production area was located in the EU-27, where Italy, France and Spain were the main producers. Within the EU-27, Spain represented 33% of the total (organic and conventional) vineyard area (Eurostat, 2008) and 15% of the organic vineyard area, behind Italy (32%) and France (17%). The Spanish organic grape area represented 1.70% of total grape area. In terms of production, Spain generated 23% of total grapes produced in the EU-27 and 9% of worldwide production.

Catalonia plays a significant role in organic farming in Spain, recording an average annual growth rate of 37% since 1995 (CCPAE, 2009). While the major organic producer in Spain is Andalucía (with around 60% of total area), Catalonia ranked fourth with 62,331 ha farmed by 909 producers in 2008. Further, 19% of the total Spanish organic food industry was concentrated in Catalonia. The Catalan organic vineyard area represented around 7% of the total organic grape area in Spain (being the fourth most relevant share). Since 1995, this area rapidly grew with an average annual growth of about 21%. The area increased from 207 ha in 1995 to 2,241 ha in 2008 (CCPAE, 2009). In terms of production, Catalonia contributes 7% to total Spanish vineyard production. We aim to study the technical efficiency (TE) with which Catalan grapes operate.

While conversion subsidies are useful in promoting organic conversion, they do not guarantee that converting farms will be economically viable in the future. An important first step towards economic viability is to ensure that organic production processes are technically efficient. TE is a prerequisite for economic efficiency, which is also a necessary condition for economic sustainability (Tzouvelekas *et al.*, 2001).

Knowledge about productivity and efficiency differences between conventional and organic farms is important for policy makers who are interested in promoting sustainable farming practices, farmers who try to optimize their production decisions, as well as other economic agents such as food processors and retailers who process and sell organic food. In the following lines a literature review on organic farming is presented.

The relevance of the organic farming movement has led many authors to evaluate the current situation and expectations on the future development of organic farms. Among these studies, the analyses on the adoption of organic farming practices have gained special relevance. Different methodologies, ranging from descriptive qualitative analyses to highly sophisticated econometric exercises, have served this purpose. Within the adoption literature, a first group of studies has been interested in understanding the determinants that motivate farmers to adopt the organic technology (Fairweather, 1999; Lohr & Salomonson, 2000; Pietola & Oude Lansink, 2001; Acs *et al.*, 2007). A second group has focused on the amount of time it takes a farmer to adopt organic practices (Padel, 2001; Parra *et al.*, 2007).

Despite the development of organic farming worldwide and especially in Europe, the literature on the TE performance of organic farming is sparse, which is mainly due to data scarcity on organic farms (Oude Lansink *et al.*, 2002). In recent years there have been a few attempts to study this issue. Different approaches have been used to estimate the differences in TE between conventional and organic farms and different results have been derived. While some authors have utilized a parametric approach, specifically a Stochastic Frontier Analysis (SFA), others have relied on nonparametric methods, specially the Data Envelopment Analysis (DEA).

Oude Lansink *et al.* (2002) used DEA to compare organic and conventional crop and livestock farms in Finland and found that organic producers have higher efficiency than conventional farms (efficiency ratings for organic and conventional producers were 0.96 and 0.72, respectively), but use a less productive technology. In another recent DEA-based study, Bayramoglu & Gundogmus (2008) suggested that conventional raisin-producing households in Turkey are superior to organic producers in terms of TE (0.90 *vs.* 0.86). Both studies assumed variable returns to scale in order to compute TE.

Tzouvelekas *et al.* (2001; 2002a,b) used the Stochastic Production Frontier (SPF) approach to evaluate the TE ratings achieved by Greek organic and conventional farms. They found organic producers to be more efficient than conventional ones. In contrast with this finding, Madau (2007) applied a SPF model and found that Italian conventional cereal farms were significantly more efficient than organic farms (0.90 *vs.* 0.83). Serra & Goodwin (2009) is the only study that compares the efficiency ratings of organic and conventional arable crop farming in Spain. In this analysis, the SPF model was estimated by a local maximum likelihood approach. Results showed that organic farms have efficiency levels that are slightly below conventional farms (0.94 *vs.* 0.97). The output-oriented measure of efficiency is the most widely used method to determine TE levels.

In spite of the recent relevant growth of organic farming in Spain, the literature on the TE of organic farming in this country is very thin. Our work contributes to the scarce literature on organic farming in Spain by carrying out a comparative study of TE ratings for organic and conventional grape farms in Catalonia. Additionally, we attempt to identify the factors that affect TE levels. SPF methodology is used for this purpose. By measuring efficiency we can assess whether economic agents use their resources optimally to reach their production objectives. Productivity differences between the two agricultural practices are also assessed by means of computing the output elasticity of different inputs and the productivity measure proposed by Kumbhakar *et al.* (2009).

Material and methods

The assessment of farm TE and the factors that explain TE provides valuable information to improve farm management and economic performance. In the presence of technical inefficiencies, farmers can increase their production levels without the need to increase the use of inputs that are usually scarce, or to adopt new technologies or practices. Avoiding sources of inefficiency and waste of resources is a requisite for economic sustainability. Generally, a farmer who operates with a high TE level obtains better economic results than a farmer who does not. In this regard, productive efficiency studies have important implications for economic performance, technological innovation and the overall input use in the agricultural sector.

There are two main approaches widely used in the literature to estimate TE: parametric (SFA or deterministic frontier analyses) and non-parametric methods (data envelopment analysis, DEA). Non-parametric techniques are more flexible than parametric approaches in that they can be implemented without knowing the true specification of the functional form characterizing the production technology. However, they do not allow the researcher to isolate inefficiency effects from random noise or random shocks.

To overcome the identification problem posed by non-parametric models, an alternative method can be used: SFA. This approach, that was introduced simultaneously by Aigner *et al.* (1977) and Meeusen & Van den Broeck (1977), distinguishes between exogenous shocks outside the firm's control and inefficiency. Contrary to DEA and deterministic frontier analyses, SFA accounts for random noise and can be used to conduct conventional tests of hypotheses. On the other hand, SFA requires the specification of a distributional form for the inefficiency term and a functional form for the production function. Results of SFA are sensitive to these assumptions. Since agricultural production outcomes are stochastically determined due to random climatic influences, and since agricultural production studies are likely to be affected by measurement and variable omission errors (Coelli, 1995; Chakraborty *et al.*, 2002; Oude Lansink *et al.*, 2002), it is necessary to choose a robust model that reflects and accounts for these issues. In this regard, we select SFA as a method to correctly and consistently estimate TE.

The SPF proposed by Aigner *et al.* (1977) and Meeusen & Van den Broeck (1977) can be specified as:

$$y_i = f(X_i;\beta)\exp\left(e_i\right);\ e_i = v_i - u_i,\ i = 1,2,...,N \quad [1]$$

where y_i denotes the level of output for the *i*-th observation (firm); X_i is the vector of input quantities used by the *i*-th firm in the production process; β is the vector of parameters to be estimated; and $f(X_i;\ \beta)$ is a suitable functional form for the frontier. The error term e_i in equation [1] can be decomposed into two components, u_i and v_i; it is assumed that u_i and v_i are independently distributed from each other. The first component, v_i, is a standard random variable capturing the random variation in output due to statistical noise that arises from (a) the unintended omission of relevant variables from vector X_i; (b) from measurement errors and approximation errors associated with the choice of the functional form; (c) unexpected stochastic changes in production (weather influences, for example); and (d) other factors that are not under the control of the farm. Component v_i is usually assumed to be symmetric, independent and identically distributed as $N(0, \sigma_v^2)$. The second component $u_i \sim N^+(\mu, \sigma_u^2)$, is a one-sided, non-negative random variable representing the stochastic shortfall of the *i*-th farm output from its production frontier, as a result of the existence of technical inefficiency.

The output oriented measure of TE can be expressed as the ratio of observed output to the corresponding stochastic frontier output, a measure that takes a value between 0 and 1:

$$\mathrm{TE_i} = \frac{y_i}{f\left(X_i;\beta\right)\exp\left(v_i\right)} = \exp\left(-u_i\right) \quad [2]$$

Reifschneider & Stevenson (1991), Huang & Liu (1994) and Battese & Coelli (1995) proposed stochastic frontier models in which the inefficiency effects (u_i) are expressed as a linear function of explanatory variables reflecting farm socio-economic and demographic characteristics and a random error. Following Battese & Coelli (1995) we used the following TE effects model:

$$u_i = \delta_0 + \sum_{m=1}^{M} \delta_m Z_{mi} + \varepsilon_i \quad [3]$$

where Z_{mi} are farm-specific variables associated with technical inefficiencies; δ_0 and δ_m are parameters to be estimated; and ε_i is a random variable with zero mean and finite variance σ_ε^2, defined by the truncation of the normal distribution such that $\varepsilon_i \geq -\left[\delta_0 + \sum_{m=1}^{M} \delta_m Z_{mi}\right]$. The mean of u_i, $\mu = \delta_0 + \sum_{m=1}^{M} \delta_m Z_{mi}$, is farm-specific and the variance components are assumed to be equal ($\sigma_u^2 = \sigma_\varepsilon^2$).

Following Battese & Coelli (1995), we estimate the parameters of the model defined in equations [1] and [3] by maximum likelihood procedures. The log likelihood function and the derivation of TE estimates followed the approach used in Battese & Coelli (1995). The estimation was carried out using the parameterization by Battese & Corra (1977) who replace σ_v^2 and σ_u^2 with $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$. The next section is devoted to present research results.

Results

Characteristics of farms and farmers

Our analysis uses cross sectional, farm-level data collected from a sample of Catalan farms that specialize in grape growing. This research focuses on Catalonia because of the important role played by the Catalan vineyard sector within the Spanish organic agriculture and the exponential growth that this sector has experienced since 1995. It is thus relevant to investigate the characteristics of this type of farming and compare them with the characteristics of the conventional sector. Data were collected by face-to-face questionnaires during the period from March to June 2008 in the major Catalan organic grape-growing areas. These areas were identified based on organic farming systems certification by the Official Certification Organism in Catalonia (Consell Català de la Producció Agrària Ecològica, CCPAE). Geographically, our sample farms are concentrated in three different Catalan provinces (Barcelona, Tarragona and Lleida). For each organic farm, at least three neighboring conventional farms were also selected. This neighboring criterion allows for two subsamples (organic and conventional) with an analogous composition (Tzouvelekas *et al.*, 2001; Madau, 2007). Our final sample consists of 26 organic farmers and 115 neighboring conventional farms. The following lines provide a description of sample farms both from an agronomic and economic perspective, as well as the demographic characteristics of sample farmers. Summary statistics for sample farm and farmer characteristics are presented in Table 1.

Based on a scale from 0 to 10, farmers were asked to grade soil quality and erosion. Although both groups have similar perceived soil quality and erosion, a large number of organic farms (53%) are located in a less favored area or in an area with specific difficulties that limit agricultural productivity (Council Regulation EC 1257/1999). In contrast, only a quarter of conventional farms are located in these areas. On average, organically farmed soil is steeper (9%) than conventionally farmed soil (3%). The difference in slope is statistically significant. Although both farm types strongly rely on rainfed agriculture, irrigation practices are relatively more important within the organic group (16% *vs.* 7%).

Land use patterns do not differ greatly between organic and conventional farms. On average 64% of conventionally cultivated land is devoted to produce grapes. Arable crops are the second most common conventional crop (19%), followed by fruits (10%) and olive groves (9%). Organic farms devote, on average, 69% of their land to grape production, mainly at the expense of arable crops that now represent 11% of cultivated land. Many different cultivars, with different abilities to withstand climatic conditions and diseases, are used within organic and conventional farms. However, both farm types use a similar range of grape varieties. The most common varieties spread among all farmers are 'Macabeu' (69.50%), 'Parellada' (58.87%), 'Ull de llebre', (42.55%), 'Xarello' (37.59%), 'Merlot' (30.50%), 'Cabernet' (22.70%) and 'Garnatxa' (18.44%).

Contrary to conventional farms that have, on average, 45 ha of agricultural land, organic farms are mainly small holdings with only 19 ha. The land tenure status is similar between farm types, with owned land representing 46% (45%) of total organic (conventional) land. Farm output is defined as the quantity of grapes produced and expressed in physical units (kg). Conventional farms' total output averages 120,364 kg, which is twice organic farms' total output (59,969 kg). However, organic farms' yields are only 16% lower than conventional farms' yields. The difference in total output and yields is statistically significant.

The average price received by organic farms more than doubles the average conventional price, suggesting statistically significant organic price premiums. The proportion that agricultural revenue represents within total farmers' revenue, which measures the degree of diversification in income sources, is 68% (77%) for organic (conventional) farms. Hence, organic farmers have more diversified income sources. Subsidies (almost 70% of organic farms receive public subsidies) and price premiums compensate for the low yields and high costs in organic farming, leading to substantially higher incomes on a per hectare basis: € 4,004 *vs.* € 2,670.

Consistent with previous research, statistically significant differences regarding input use are found between the two groups: our organic sample farms are more labor intensive than conventional farms. Both types of farms strongly rely on unpaid family labor which represents 69% (73%) of total labor in organic (conventional) farms. On a per hectare basis, expenses in fertilizers and crop protection products are much higher in organic farms (381 € ha^{-1} *vs.* 294 € ha^{-1}). Total costs per hectare are € 1,814 (€ 1,509) for organic (conventional) farms. Consistently with higher per

Table 1. Sample farms' agronomic, economic and demographic characteristics

Variable name	Unit of measure	Organic		Conventional		T-test of mean difference Significance level[2]
		Average	SD[1]	Average	SD[1]	
Agronomic characteristics						
Total land	ha	18.90	12.82	45.33	75.68	0.00*
Proportion of land devoted to grape	%	68.48	28.49	63.48	30.43	0.43
Proportion of land devoted to arable crops	%	10.58	16.94	19.11	29.03	0.05*
Proportion of land devoted to fruits	%	10.76	18.78	10.12	14.75	0.87
Proportion of land devoted to olive groves	%	10.18	15.33	8.61	11.93	0.63
Total output	kg	59,969.04	45,217.33	120,364.27	8,2454.49	0.00*
Soil quality	(0 low, 10 high)	6.71	1.47	6.38	1.44	0.31
Erosion	(0 low, 10 high)	3.23	1.96	3.67	1.94	0.31
Soil slope	%	8.93	9.41	3.13	3.05	0.03*
Proportion of irrigated land	%	15.62	30.26	7.15	19.78	0.18
Farms in LFA[3]	(1 yes, 0 no)	0.53		0.25		0.00**
Economic, structural and other characteristics						
Output	€	33,933.52	28,062.50	36,613.27	24,474.25	0.67
Price	€ kg^{-1}	0.75	0.58	0.33	0.19	0.00*
Share of agricultural income in total income	%	68.65	27.66	77.32	24.10	0.15
Share of output sold to processing companies and cooperatives	%	73.08	42.51	70.70	42.82	0.80
Proportion of owned land	%	46.31	45.81	44.56	37.94	0.86
Family labor share	%	68.85	29.71	73.02	25.48	0.51
Subsidy	(1 yes, 0 no)	0.69		0.58		0.30
Credit	(1 yes, 0 no)	0.27		0.50		0.03**
PDO[4] association	(1 yes, 0 no)	0.60		0.68		0.47
Economic profit preferences	(1 = 10, 0 otherwise)	0.46		0.54		0.47
Environmental preservation preferences	(1 if ≥ 8, 0 otherwise)	0.92		0.70		0.02**
Demographic characteristics						
Age	year	43.31	13.78	44.56	10.66	0.67
Years of experience	year	15.42	9.90	18.16	11.63	0.23
Family size	number of person	3.35	1.35	3.85	1.36	0.09
Statistics on a per hectare basis						
Yield	kg ha^{-1}	6,848.31	3,261.73	8,173.19	3,177.51	0.02*
Revenue	€ ha^{-1}	4,004.43	2,478.48	2,670.09	1,971.22	0.00*
Total revenue (revenue from grape and other farm activities)	€ ha^{-1}	4,232.73	2,314.79	2,791.54	1,985.31	0.00*
Labor	hours ha^{-1}	458.93	240.41	285.76	303.34	0.00*
Machinery	N ha^{-1}	0.66	0.53	0.49	0.71	0.18
Other variable inputs (farming overheads and young vine plant expenditures)	€ ha^{-1}	860.51	751.98	834.94	1822.24	0.91
Fertilizers and crop protection	€ ha^{-1}	380.92	579.56	294.12	399.34	0.48
Total cost (specific grape production costs, farming overheads, labor costs)	€ ha^{-1}	1,813.93	1,421.67	1,508.55	1,922.69	0.38
Profit (total revenue minus total cost)	€ ha^{-1}	2,435.07	2,293.04	1,282.99	2,805.43	0.04*

[1] SD: standard deviation. [2] *, ** indicate statistical significance at the 5%, and chi-square statistical significance at the 5%, respectively. [3] LFA: less favored areas. [4] PDO: protected designations of origin.

hectare input costs borne by organic farms, this group uses 0.66 agricultural machines per hectare (machines include any farm equipment: tractors, manure spreaders, pre-pruning, cultivators, shredders, etc.), while conventional farms use 0.50 machines. Organic farmers appear to have less access to bank loans than conventional counterparts. A 50% of the latter are able to get credit, while less than 30% of the former have access to bank loans. Farmers mainly use the loans for operation and investment.

The difference between income and costs per hectare leads to profits per hectare of € 2,435 for organic farms and € 1,283 for conventional ones. Hence, organic profits per hectare almost double conventional profits. Regarding the marketing of agricultural output, both organic and conventional farms strongly rely on sales to processing companies and cooperatives. These sales represent around 71% and 73% of conventional and organic production sales, respectively. Conventional and organic farmers are members of different agricultural associations such as cooperatives, farmers' associations and syndicates, organic farming associations and protected designations of origin (PDOs). PDOs constitute the most attractive form of association: 68% and 60% of conventional and organic farmers respectively, engage with these organizations which increase the market outlets for their production.

There is a predominance of 45 years old male farmers. While organic farmers have an average of 15 years of experience managing the farm, conventional farmers have typically been managing the farm for about 18 years. Primary and unfinished secondary education is the most common educational profile characterizing both organic and conventional farmers. The family size for both groups is similar and between 3 and 4 members. Organic and conventional farmers differ in terms of their preferences[1], which helps to better understand production and adoption decisions. When it comes to production decisions, conventional farmers are more worried about farm economic performance (profit), whereas the organic group is more concerned about protecting the environment.

Model specification and research results

In order to study productivity and efficiency of our sample of organic and conventional Catalan grape farms, we specify our SFA as follows:

$$\ln y_i = \left(\beta_0 + \beta_0^o\right) + \sum_{j=1}^{4}\left(\beta_j + \beta_j^o . D_{c/o}\right)\ln X_{ji} + \\ + \frac{1}{2}\sum_{j=1}^{4}\sum_{k=1}^{4}\left(\beta_{jk} + \beta_{jk}^o . D_{c/o}\right)\ln X_{ji} . \ln X_{ki} + \left(v_i - u_i\right) \qquad [4]$$

where the subscript $i = 1,2,\ldots\ldots,N$ denotes the firm number and $j, k = 1,2,\ldots\ldots,J$ agricultural inputs. The dependent variable (y_i) represents grape production (in kg) by the i-th farm. Inputs included are: (X_1) total land devoted to grape, measured in hectares; (X_2) total labor (both hired and family labor), expressed in hours; (X_3) total amount of capital, measured as the number of machines used in the farm; and (X_4) the expenditure in fertilizers and crop protection products (in €).[2] $D_{c/o}$ is a dummy variable that reflects the agronomic technique (1 = organic; 0 = conventional). Summary statistics for the variables used in the analysis are presented in Table 2.

The inefficiency model is specified as

$$u_i = \delta_0 + \sum_{m=1}^{M}\delta_m Z_{mi} + \varepsilon_i$$

with $M = 10$. The selection Z_{mi} of variables is based on previous literature, data available and our knowledge of the sector studied. Since previous research has widely shown that organic practices differ from conventional ones regarding efficiency ratings, (Z_1) is defined as a dummy variable that reflects the agronomic technique ($Z_1 = D_{c/o}$). Farmers' experience, usually included in TE studies (either as age or years of experience), is considered as the number of years dedicated to agriculture (Z_2). In line with Karagiannias *et al.* (2006) who shows that TE of both organic and conventional milk farms depends on specialization, the degree of specialization measured as the proportion of vineyard revenue to total agricultural revenue is reflected in (Z_3). Madau (2007) advocates that farms located in less fa-

[1] Farmers were asked to rate their preferences for economic profit and environmental preservation from 1 to 10 (1 = not important, 10 = very important). The median of the responses is used to define a dummy variable for each type of preferences. The first dummy takes the value of 1 if the farmer rated the relevance of economic profit with the highest punctuation, *i.e.,* 10 and zero otherwise, while the second dummy is one if the punctuation was above 8.

[2] To keep the model size manageable and due to the limited number of observations available, most of the inputs considered are aggregate inputs.

Table 2. Summary statistics for the variables used in the analysis

Variable name		Unit of measure	Organic Average	Organic SD[1]	Conventional Average	Conventional SD[1]	T-test of mean difference Significance level[2]
Output	y	kg	59,969.04	45,217.33	120,364.27	8,2454.49	0.00*
Grape land	X_1	ha	8.44	4.94	14.22	7.55	0.00*
Labor	X_2	hours	3,084.52	1,109.65	2,891.92	1,461.70	0.46
Capital	X_3	machines	4.38	2.45	4.77	2.21	0.47
Fertilizers and crop protection	X_4	€	3,520.42	6,638.52	3,776.70	3,930.05	0.85
Agronomic technique	Z_1	(1 organic, 0 non-organic)	0.18		0.82		
Experience	Z_2	years	15.42	9.90	18.16	11.63	0.23
Specialization	Z_3	%	72.19	29.76	74.41	26.43	0.73
Farms not in LFA[3]	Z_4	(1 yes, 0 no)	0.46		0.75		0.00**
Credit	Z_5	(1 yes, 0 no)	0.27		0.50		0.03**
Subsidy	Z_6	(1 yes, 0 no)	0.69		0.58		0.30
Family labor share	Z_7	%	68.85	29.71	73.02	25.48	0.51
Economic profit preferences	Z_8	(1 = 10, 0 otherwise)	0.46		0.54		0.47
Environmental preservation preferences	Z_9	(1 if ≥ 8, 0 otherwise)	0.92		0.70		0.02**
Owned land share	Z_{10}	%	46.31	45.81	44.56	37.94	0.86

[1] SD: standard deviation. [2] *, ** indicate statistical significance at the 5%, and chi-square statistical significance at the 5%, respectively. [3] LFA: less favored areas.

vored areas or in mountain areas have lower TE scores than the rest. A dummy variable that indicates whether the farm is located in a less favored area or not (Z_4) is used. In line with Karagiannias *et al.* (2006) findings, debt is also considered through (Z_5), defined as a dummy variable equal to 1 if the farmer has financial debt and zero otherwise. Tzouvelekas *et al.* (2002b) conclude that organic farming subsidies tend to negatively affect efficiency levels. A dummy variable equal to 1 if the farm receives subsidies and zero otherwise is thus included (Z_6). Tzouvelekas *et al.* (2001) show that family-operated organic and conventional olive-growing farms tend to be less efficient than farms with strong dependence on hired labor. We thus define (Z_7) as the proportion of family labor to total labor. The two dummy variables described above that reflect farmers' preferences for economic profit and for environmental preservation (Z_8 and Z_9) are also considered. Farmers' preferences have not been used by previous literature when explaining efficiency, which represents a contribution of our analysis. The proportion of owned land to total land (Z_{10}) is also included as previous research has shown that the share of rented land is related to TE (Larsen & Foster, 2005). The model is estimated using Frontier 4.1 software (Coelli, 1996).

A series of specification tests were carried out to ensure that the model specification correctly represents our sample farms (see Table 3). In being a parametric approach, SFA requires specification of the functional form representing the production technology. Since this form is unknown, we have selected a flexible functional form (a translog, see Eq. [4]) and compared it against another more restrictive and parsimonious specification: the Cobb-Douglas. At the 5% level of significance, we reject the null hypothesis ($H_0 : \beta_{ij} = 0$), which suggests that the translog form is the suitable specification for our data. This implies that output elasticities and substitution elasticities depend on input levels. Further it also involves the relevance of input interactions when explaining production. The second test ($H_0 : \delta^*_{jk} = 0$) indicates that the neutral stochastic frontier model (Huang & Liu, 1994) is the adequate representation, *i.e.,* that input use does not interfere with the variables found to explain inefficiency. Concerning the nature of the inefficiency effects, we test whether these are stochastic or not. We reject the null hypothesis ($H_0 : \gamma = 0$) implying that the technical inefficiency effects are stochastic and farmers are not fully technically efficient. The fourth test ($H_0 : \gamma = \delta_m = 0$) that aims to assess whether inefficiency effects are

Table 3. Model specification tests

Restrictions	Model	λ	$\chi^2_{0.95}$	Decision
$H_0 : \beta_{ij} = 0$	Cobb-Douglas	79.76	31.41	Reject
$H_0 : \delta^*_{jk} = 0$	Neutral Stochastic frontier	50.56	55.76	Accept
$H_0 : \gamma = \delta_m = 0$	No inefficiency effects	31.44	20.41	Reject
$H_0 : \gamma = 0$	No stochastic factor	90.27	5.14	Reject
$H_0 : \delta_m = 0$	No firm- specific factors	39.90	19.67	Reject
$H_0 : D_{Barcelona}; D_{Tarragona} = 0$	No regional dummies	2.00	5.99	Accept

absent from the model or not, is also rejected. In addition, through the fifth test ($H_0 : \delta_m = 0$), we study the influence of firm characteristics on TE levels. The null hypothesis is rejected, indicating that the variables included in the inefficiency effects equation significantly influence farms' efficiency.

Another specification test carried out concerns geographically induced differences among farms. Differences among areas not only refer to rainfall but also to winter freeze and spring frost patterns, diseases brought during hot seasons, sunlight exposure, land quality and slope, crop varieties used in different regions, etc. In order to capture these geographical differences, a set dummies representing provinces is included. Since our sample farms are concentrated in three different provinces of Catalonia (namely, Barcelona, Tarragona and Lleida), two dummies, one representing Barcelona and the other for Tarragona are included and a likelihood-ratio test is used to determine whether the two dummies are statistically different from zero. Results show that we cannot reject the null hypothesis ($H_0 : D_{Barcelona}; D_{Tarragona} = 0$), which involves that the model without regional dummies in the production equation adequately fits our data. Results of the estimation of the stochastic frontier are reported in Table 4.

Production function results are best interpreted by means of input elasticities. Contrary to the Cobb-Douglas functional form in which coefficients have a direct interpretation as input elasticities, deriving the marginal influence of inputs on output in a translog form is not straightforward. Input elasticities are computed for our translog model as follows:

$$\partial \ln(Y) / \partial \ln(X_k) = \beta_k + 2\beta_{kk} \ln X_{ki} + \sum_{j \neq k} \beta_{kj} \ln X_{ji}$$

Elasticities are computed at the data means and their standard deviations derived using the delta method (Snedecor & Cochran, 1989) (Table 5).

Production elasticity estimates indicate that land is the most productive input in conventional farming. In terms of productivity, land is followed by fertilizers and crop protection products, capital and labor. In organic farming, the highest productivity is achieved by fertilizer and crop protection inputs. Land area and capital display similar contribution to output increases, while labor presents the lowest contribution to organic grape output.

The high elasticity of the expenditures in fertilizers and crop protection products in organic farming contrasts with the relatively low elasticity of the equivalent inputs in conventional production methods (0.69 *vs.* 0.22). Land area elasticity is higher in conventional farming, which is compatible with conventional yields being above organic ones. Given the restrictions faced by organic farmers to use chemical inputs, mechanical methods are likely to become relevant, which is reflected in the higher productivity of capital in organic farms relative to conventional ones.[3] Regarding the average scale elasticity, organic farms exhibit increasing returns to scale while conventional farms operate under decreasing returns to scale. The small size of organic farms relative to conventional ones makes it especially beneficial to increase organic farm size and take advantage of economies of scale. The global productivity index proposed by Kumbhakar *et al.* (2009) suggests that conventional farms are, on average, 12% more productive than their organic counterparts. However, as will be seen below, the latter group of farms operates closer to their production frontier than the former.

In Table 4, we observe that the estimate of γ is close to one and highly significant, indicating that ineffi-

[3] While variable input use was collected distinguishing between grape and non-grape activities, capital was not. As a result, capital is not grape-specific. An alternative model weighting capital by the proportion of grape land on total land was estimated and results, available upon request, changed very little.

Table 4. Maximum likelihood estimates for the stochastic production frontier model

Variable[1]	Parameter	Estimate	SE[2]
Frontier production function			
Constant	β_0	0.524	0.021***
Constant°	β_0°	–0.060	0.082
Land area	β_1	1.199	0.033***
Labor	β_2	0.080	0.043*
Capital	β_3	0.054	0.010***
Fertilizer and crop protection	β_4	–0.205	0.009***
Land area°	β_1°	0.335	0.186*
Labor°	β_2°	–0.369	0.238
Capital°	β_3°	0.018	0.084
Fertilizer and crop protection°	β_4°	–0.338	0.245
(Land area) × (Land area)	β_{11}	–0.264	0.074***
(Labor) × (Labor)	β_{22}	–0.210	0.067***
(Capital) × (Capital)	β_{33}	–0.389	0.088***
(Fertilizer and crop protection) × (Fertilizer and crop protection)	β_{44}	–0.133	0.022***
(Land area) × (Labor)	β_{12}	–0.236	0.084***
(Land area) × (Capital)	β_{13}	0.535	0.104***
(Land area) × (Fertilizer and crop protection)	β_{14}	0.191	0.031***
(Labor) × (Capital)	β_{23}	–0.066	0.042
(Labor) × (Fertilizer and crop protection)	β_{24}	–0.018	0.099
(Capital) × (Fertilizer and crop protection)	β_{34}	–0.224	0.031***
(Land area) × (Land area)°	β_{11}°	0.628	0.189***
(Labor) × (Labor)°	β_{22}°	2.027	1.776
(Capital) × (Capital)°	β_{33}°	–0.437	0.326
(Fertilizer and crop protection) × (Fertilizer and crop protection) °	β_{44}°	–0.474	0.211**
(Land area) × (Labor)°	β_{12}°	–1.334	0.685*
(Land area) × (Capital) °	β_{13}°	0.563	0.231**
(Land area) × (Fertilizer and crop protection) °	β_{14}°	–0.043	0.099
(Labor) × (Capital) °	β_{23}°	–0.126	0.525
(Labor) × (Fertilizer and crop protection) °	β_{24}°	0.684	0.304**
(Capital) × (Fertilizer and crop protection) °	β_{34}°	–0.586	0.251**
Inefficiency effects model			
Constant	δ_0	–0.523	0.941
Dc/o	δ_1	–1.180	0.315***
Experience	δ_2	–0.020	0.010*
Specialization	δ_3	–0.450	0.560
Farm is not located in a less favored area	δ_4	–0.534	0.286*
Credit	δ_5	0.035	0.248
Subsidy	δ_6	0.402	0.297
Family labor share	δ_7	0.961	0.513*
Economic profit preferences	δ_8	0.007	0.260
Environmental preservation preferences	δ_9	0.712	0.285***
Owned land	δ_{10}	–0.648	0.394
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	σ^2	0.590	0.107***
$\gamma = \sigma_u^2/\sigma^2$	γ	0.999	4E-08***
log likelihood function		–24.607	

[1] Superindex ° represents the interaction of the variable with the organic farming dummy variable. [2] SE: standard error. ***, ** and * indicate statistical significance at the 1%, 5% and 10% respectively.

Table 5. Production and scale elasticities

Elasticities with respect to	Conventional		Organic	
	Estimate	SE[1]	Estimate	SE[1]
Land area	0.558	0.024***	0.323	0.138**
Labor	0.041	0.026	0.075	0.003***
Capital	0.165	0.017***	0.323	0.024***
Fertilizer and crop protection	0.219	0.028***	0.686	0.083***
Returns to scale	0.983		1.407	
Productivity differential (Kumbhakar *et al.*, 2009)		0.12		

[1] SE: standard error. *** indicates that the parameter is significant at the 1%.

ciency effects explain most of residual variation. As noted above, ten explanatory variables are used as determinants of the inefficiency effects. Parameter estimates of the inefficiency effects model are shown in Table 4. Apart from adoption of organic practices, our results identify experience, family labor share in total labor, farm location and farmer environmental preferences as the variables that are more relevant in explaining technical inefficiencies. Our analysis reveals that holdings located in less-favored areas are less efficient compared to the other farms. As expected, farmers with more experience tend to reach higher efficiency scores. This implies that TE increases with farmer's skills and practice. Farms that rely on a higher proportion of unpaid labor are found to be less efficient. Farms, whose manager has strong environmental preservation preferences, tend to be less efficient. Our results also show that the level of farm debt, subsidies, degree of farm specialization, tenure regimes of land and the preferences regarding economic profit do not have a significant impact on efficiency ratings. The dummy variable that reflects the agronomic technique by identifying organic farms has a negative and statistically significant sign, indicating that inefficiency decreases with the organic technology.

Technical efficiency scores for both farming methods are calculated as an output-oriented measure and results are presented in Table 6 with decile ranges from the computed frequency distribution. The histogram and kernel distributions of efficiency are plotted in Figure 1. The average TE score is 80% for organic farms and 64% for conventional ones. In other words, organic (conventional) farmers reach 80% (64%) of their maximum potential output. Moreover, these TEs range from a minimum of 17% (10%) to a maximum of 100% (100%) for organic (conventional) farmers, indicating a lower dispersion in organic farming. Almost 54% of organic farmers have efficiency ratings above 90%, whereas only

Table 6. Frequency distribution of technical efficiency (TE) for the conventional and organic farms

TE: Range (%)	Conventional	(%)	Organic	(%)
< 20	2	1.74	1	3.85
20-30	8	6.96	2	7.69
30-40	11	9.57	0	0.00
40-50	10	8.70	0	0.00
50-60	18	15.65	2	7.69
60-70	16	13.91	1	3.85
70-80	21	18.26	5	19.23
80-90	11	9.56	1	3.85
90-100	18	15.65	14	53.84
Sample size	115	100	26	100
Mean	64.25		79.63	
SE[1]	22.64		25.68	
Minimum	9.69		17.36	
Maximum	99.99		99.98	

[1] SE: standard error.

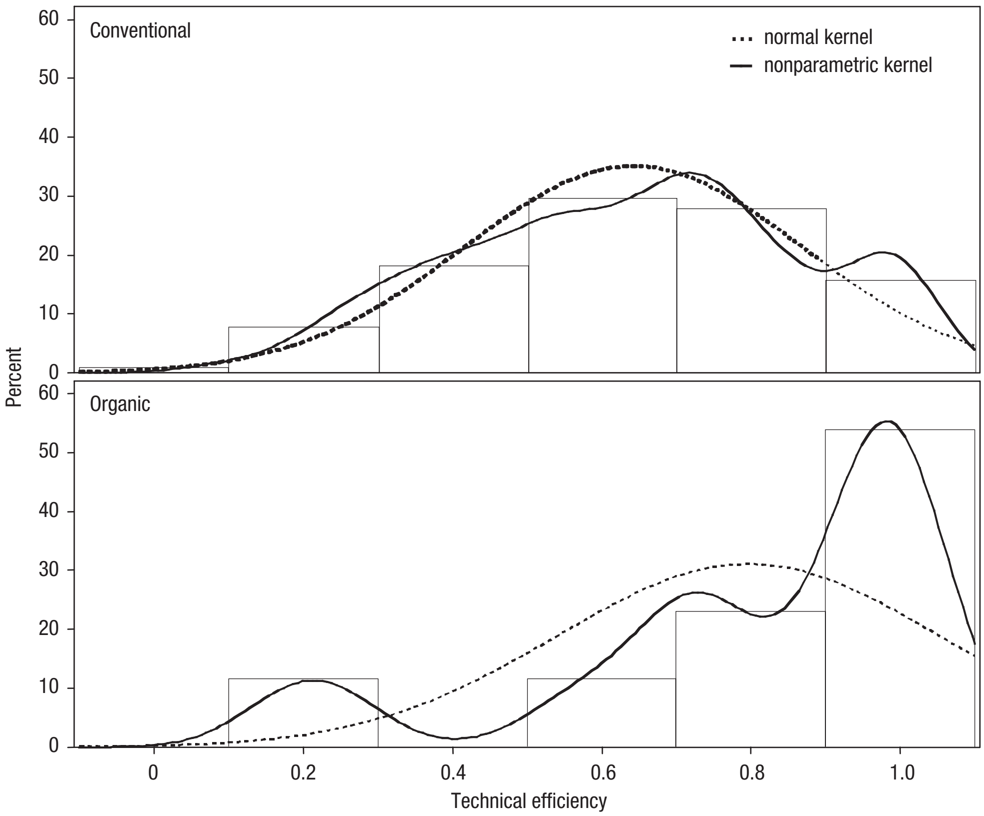

Figure 1. Histogram, normal and nonparametric densities of technical efficiency.

16% of conventional farmers show these high performance levels. Therefore, our results indicate that if organic (conventional) farms effectively used available resources and maintained current technology, they would be able to increase their output by 20% (36%) on average. Improving TE levels can reduce production costs and improve the economic viability of farms.

Discussion

The present study aims to compare technical efficiency of organic and conventional grape farms in Catalonia. Consistent with previous studies looking at the performance of organic farming (Offerman & Nieberg, 2000; Oude Lansink *et al.*, 2002; Oude Lansink & Jensma, 2003), we find that organic farming is on average 90% more profitable, on a per hectare basis, than conventional farming. However, organic farms face higher production costs per hectare and require more labor than conventional farms. This finding is compatible with previous research on organic farming in Spain (Serra *et al.*, 2008). Organic farms also exhibit increasing returns to scale, while conventional farms operate under decreasing returns to scale, meaning that organic farms could become more profitable with larger operations. However, in line with previous literature (Tzouvelekas *et al.*, 2001), conventional farmers are found to be more worried about farm economic performance (profit), whereas the organic group is more concerned about protecting the environment.

Our empirical findings suggest that organic farmers, on average, reach higher TE ratings than their conventional counterparts (80% and 64%, respectively). Our results differ from the findings by Bayramoglu & Gundogmus (2008), who assessed the efficiency of the Turkish grape sector, and are consistent with Tzouvelekas *et al.*'s results (2002a), who focused on the Greek grape sector. Higher efficiency scores attained by organic farms should warrant their economic viability in the agricultural sector. Several reasons may explain the higher average level of TE observed in organic farming. The higher costs per hectare supported by organic farming are likely to motivate farmers to effectively use their inputs and improve their agricultural performance. As noted by Tzouvelekas *et al.* (2001), information on how to adequately apply organic farming techniques may be expected to improve production performance. In this regard, the EU and national regulations concerning organic farming may help organic farmers to be more efficient relative to their conventional counterparts. Moreover, attractive organic price premiums can also explain the higher efforts by organic farms to increase TE, given the high marginal income derived from production.

An interesting finding is the high elasticity of the expenditures in fertilizers and crop protection products found in organic farming. Since organic farms cannot use non-authorized chemical fertilizers and pesticides, organic fertilizers and biological controls are important factors in organic grape production. Organic farms usually make a more rational and less arbitrary use of these inputs relative to conventional farms. A more restricted and well-managed use of these inputs contributes to explain the higher productivity that they display in organic farming.[4]

The low contribution of labor to farm productivity in both types of farms can be explained by the high share of family labor and the usual lack of qualified labor in this sector. Tzouvelekas *et al.* (2001, 2002a) found that family-operated farms are less efficient than farms with stronger dependence on hired labor. Larsen & Foster (2005) also suggested that the share of hired labor has a positive effect on TE for both organic and conventional farms. Another study conducted by Lambarraa *et al.* (2007) concluded that a higher level of inefficiency may be associated to a higher proportion of unpaid labor. More recently, Serra & Goodwin (2009) found a negative labor elasticity characterizing the conventional technology indicating an overuse of this input. The authors associated this result to the relevance of unpaid family labor in their sample of farms. As we have seen in the descriptive analysis of sample farms, organic farms are much more labor-intensive (on a per unit of land) than conventional farms. In spite of this intensive use, labor productivity is higher in organic than in conventional farming, which is compatible with organic methods being more labor demanding than conventional practices.

Both types of farms (organic and conventional) suffer from relevant technical inefficiencies. As suggested by previous findings (Tzouvelekas *et al.*, 2001; Madau, 2007), farms that are located in a less favored area tend to be less efficient. The finding is not surprising given the environmental and production constraints faced by the first group. A farmer who holds additional experience is more likely to have higher efficiency levels. This implies that TE increases with farmer's skills and practice. In line with the findings of Tzouvelekas *et al.* (2001), farms with a higher proportion of unpaid labor are found to be less efficient than farms with a stronger dependence on hired labor. Another interesting finding is adoption of organic practices can improve technical efficiency under which farmers are operating. However, organic farms show a lower productivity than conventional ones which is compatible with Oude Lansink *et al.* (2002) results. TE can be affected by farmers' preferences regarding the need to preserve the environment. Producers that place a higher value on preserving the environment through their production tend to be more inefficient.

Organic subsidies usually compensate organic farmers for reduced yields and adoption costs. Though subsidies have been often criticized for making economic agents less responsive to changing market conditions and increasing inefficiencies, our results show no statistically significant effect of subsidies on efficiency. There are, however, a number of things that policy makers can do to improve efficiency in grape farming. First, promoting extension services that transfer knowledge to farmers is expected to improve production performance through added education and experience. Second, since family labor is found to generate inefficiencies, promoting a more professionalized management of agricultural holdings by decreasing non-specialized family labor in favour of a more specialized labour force may enhance the performance of organic farming.

Improving TE allows for a reduction in production costs and increases competitiveness, which can help farmers face changing market conditions and economic hardships. Farm margins can be squeezed when market conditions change, consumers become more and more demanding and unwilling to pay higher price premiums, or middlemen in the marketing chain and retailers increase their marketing power. In this regard, improving TE can help farmers endure times of economic distress. Increasing profit levels can be achieved by means of increased organic price premiums and subsidies, or alternatively, by means of reduced production costs. A strategy based on cost reduction is especially relevant in the organic sector.

[4] The main difference between organic and conventional farms relies on the use of chemical inputs (mainly fertilizers and pesticides), which is controlled by different regulations. The legal framework of organic farming contributes to a rational use of these inputs.

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