Technical Efficiency Of Portuguese Wine Farms

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Jel classification: Q120, D200

Abstract

The objective of this study is to measure the levels of technical efficiency of a sample of wine-making farms, in the Portuguese Alentejo region, and relate these efficiency levels to some farm characteristics such as: physical and economic size, farmers' age, land property, irrigation, labour use, and area and product specialization. The methodology chosen to measure the individual levels of efficiency was non-parametric due to the advantage of not defining a functional form for the production technology.

Results show that wine-producing farms could increase the efficiency of input use. The scale and congestion inefficiencies are responsible for most of the observed technical inefficiency. The technical efficiency increases with specialization.

Keywords: technical efficiency, non-parametric, vineyard, wine.

Résumé

Cette étude a l'objectif de mesurer les niveaux d'efficience technique d'un échantillon d'exploitations productrices de vin appartenant à la région de l'Alentejo et de les mettre en relation avec certaines caractéristiques de ces mêmes exploitations, telles que: la dimension physique et économique, l'âge, les formes de propriété foncière, l'irrigation, le type de main-d'œuvre et la spécialisation culturale et productive. En tenant compte de l'avantage de ne pas définir une forme fonctionnelle pour la technologie de production, la méthodologie non-paramétrique a été choisie afin de mesurer les niveaux individuels d'efficience.

Les résultats obtenus montrent que pour ces exploitations il y a de la marge pour augmenter les niveaux d'efficience dans l'utilisation des facteurs de production, les inefficiences d'échelle et de sur-utilisation provoquant une grande partie de l'inefficience technique observée.

Une augmentation de l'efficience technique a été constatée en relation avec l'augmentation de la spécialisation exprimée en termes de la surface de la vigne ou de la valeur du produit de la vigne par rapport au produit total.

Mots-clés: *efficience technique; non-paramétrique; vignoble; vin.*

1. Introduction

Vineyard activities and wine production play an important role in the production structure of the Portuguese agriculture, since they represented 10% of total production in 2000 and 13.9% in 2004. Between 2001 and 2003, domestic wine consumption accounted for 118%, wine exports were 1.76 times higher than imports and per capita wine consumption equalled 49.3 litres.

Alentejo is one of the five mainland Portuguese regions accounting for 15.7% of the total Portuguese agricultural production. The production technology is predominantly based on dry farming with crop activities being 60% of the region output. In 1999, grapevine-growing farms were 14.7% of the total number of farms with permanent activities and 10.3% of the area of permanent activities. Between 1989 and 1999, the grapevine-cultivated area increased of nearly 30% and, in 2000, wine production accounted for 5% of the total agricultural production of Alentejo.

In 2000, the region contributed with 7% of the volume and 8% of the product value of the Portuguese wine production. Table-wine production is a marginal activity in Alentejo (2.2%), differently from the country as a whole where, with lower added value, it accounts for 33.2% of the total output. The region produces wines of superior quality, mostly VQPRD and regional wine, accounting for 44.9% and 52.7% in total, respectively. The proportion between red wine and white wine was of 60% in 2000, lower than the national average (67%).

During the last decade, with the entrance of new producers, the production and marketing structure has changed, with an increase in the number of wine producers. Some of the established producers made their production autonomous from the co-operatives with the creation of their own cellars and brands. The importance of grapevine-growing activities and wine production have been increasing, thus demanding more attention to different aspects, in particular to farm efficiency.

Both at national and regional level, the importance of grapevine-growing activity and wine production has been increasing and wine production has been considered a strategic sector by the Portuguese government. These facts are sufficient enough to push us looking at different aspects of this activity, in particular at the efficiency of the wine grapes producers.

The concepts of technical efficiency and of price efficiency are part of a broader concept of economic efficiency. Technical efficiency can be defined as the capacity of a producer to obtain the maximum level of production for a given bundle of inputs using a given technology. This concept implies that producers are on the production frontier and their deviation from this frontier is a measure of tech-

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nical inefficiency. Price efficiency is defined as the choice of the optimum mix of inputs under given input and output prices. Price efficiency assumes that the farmer objective is to maximize the profit, and producers outside this expansion path are price inefficient. Technical efficiency can be further decomposed in pure technical, scale and congestion efficiency, concepts that will be developed in the next section.

Among the several methods to measure technical efficiency levels, it is worthwhile to point out the parametric and the non-parametric methods. The parametric methods use statistical methods as basis and require the imposition of a functional form for the production frontier to be estimated, while the non-parametric methods are based on mathematical programming, do not require a functional form for the frontier, are easily generalized to a context of multi-product and multi-factor, but do not have statistical properties.

The majority of studies relate the efficiency levels with farm characteristics such as: family size, farmers' age, farmers' experience, farmers' level of education, farmers' professional training, land ownership, farm block dispersion, farm size, irrigation, extension services, credit access, farm location and on and off-farm work. In general terms, we expect to have a positive relation of efficiency with family size, farmers' level of education and professional training, credit access, farmers' experience, extension services, and a negative relation with farmers' age and farm fragmentation, while the relation is uncertain with farm size (Henriques, 1995).

Considering that there was no data on input and output prices, the objective of this study was to measure the levels of technical efficiency and of its three components for a sample of grapevine producers in the Alentejo region, Portugal, and to relate the levels of technical efficiency with a set of farm characteristics such as: farm size, farmers' age, land ownership, irrigation, labour type and farm specialization. The methodology chosen to measure technical efficiency was the non-parametric method, while the analysis of variance and Kruskal-Wallis assays were used to investigate the relationship between efficiency and farm characteristics.

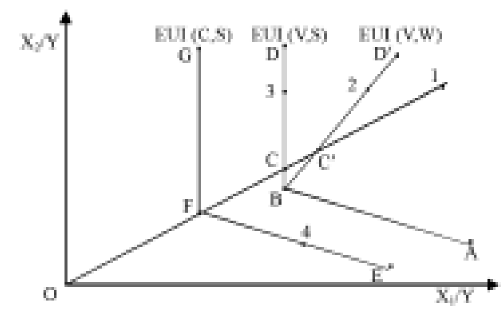
2. Methodology

The definition of technical efficiency (TE) was first conceptualized by Farrell (1957) and its decomposition in three mutually exclusive measures – pure technical (PTE), scale (SE) and congestion (CE) – was made by Färe, Grosskopf and Lovell (1985, 1994). The notion of technical efficiency assumes the long run optimal conditions such as constant returns to scale and production restricted to stage II. This last condition implies strong disposability of inputs, which means that output levels do not decrease when inputs are increased. To decompose TE in its three components it is required to relax the long run assumptions, allowing for variable returns to scale (increasing or decreasing) and situations of weak disposability where increase in one input can lead to a decrease in output.

Figure 1 illustrates the referred measures of technical efficiency using three efficient unit isoquants (EUI) and farms 1 to 4. The first isoquant, EUI(C,S), represents the long run technology with constant returns to scale (C) and strong disposability of inputs (S), the second isoquant, EUI(V,S) shows variable returns to scale (V), and the third isoquant, EUI(V,W), the least restrictive technology, has weak disposability of inputs on the segment BC'D' for the input X_2.

Farm 1 is inefficient because it is placed beyond the EUI,

Figure 1 – *Illustration of thechnical efficiency and its decomposition.*



and its TE measure is given by the ratio OF/O1. The distance between farm 1 and the least restrictive technology EUI(V,W) is a measure of PTE and is equal to the ratio of OC'/O1. If farm 1 was PTE efficient it would be located on C', being possible to increase output decreasing the congesting input X_2. The efficiency improvement from C' to C is a measure of congestion efficiency (CE) and is given by the ratio OC/OC'. If farm 1 was located on C, it would be PTE and CE efficient, but it will not operate on the long run optimal scale EUI(C,S). The improvement in production scale from C to F is a measure of SE and equal to OF/OC.

Once PTE, SE and CE are mutually exclusive, then

$$TE = PTE \times CE \times SE = \frac{OC'}{O1} \times \frac{OC}{OC'} \times \frac{OF}{OC} = \frac{OF}{O1} .$$

Farm 2 is PTE efficient and SE and CE inefficient, farm 3 is PTE and CE efficient and SE inefficient and farm 4 is TE efficient.

To measure the efficiency levels, the chosen method was the non-parametric one, due to the fact that it is not necessary to impose a functional form to the production technology. This method is based on the studies of Charnes *et al.* (1978) and Färe *et al.* (1985 e 1994), where the production technology is made of linear segments and the efficiency of a given producer is evaluated in relation to the production frontier. This frontier is built from the available farms by the envelope of the most efficient farms.

The non-parametric production frontiers can be represented by three types: 1) input correspondence; 2) output correspondence; and 3) input-output (graph) correspondence. Considering the input correspondence, where output is given and input substitution is modelled, assuming constant returns to scale and strong disposability of inputs, the piecewise linear technology is defined by:

$$Y_m \leq \sum_{j=1}^{J} Z_j Y_{jm}, \quad m = 1,2,\ldots,M,$$

$$\sum_{j=1}^{J} Z_j X_{nj} \leq X_n, \quad n = 1,2,\ldots,N,$$

where J, M and N are the numbers of producers, Y refers to output, X refers to inputs and Z_j represents the intensity variables that denote intensity levels at which the input and output values of each producer might be conducted, through the shrinkage and expansion of observed values, with the objective of constructing unobserved but feasible observations, that make the segments of the piecewise linear boundary of the technology.

Based on this technology in which inputs and the choice variables are adjustable, the efficiency of a producer is measured through the reduction in input vector for a given level of output. In this context, TE of a producer (farm 1) is measured as the solution of the following linear programming problem:

$$TE(C,S) = \min \lambda = \frac{OF}{O1}$$

$$(1) \quad Y_m \leq \sum_{j=1}^{J} Z_j Y_{jm}, \quad m = 1,2,\ldots,M,$$

$$\sum_{j=1}^{J} Z_j X_{nj} \leq \lambda X_n, \quad n = 1,2,\ldots,N,$$

$$Z_j \geq 0, \quad j = 1,2,\ldots,J,$$

where measures the maximum contraction in input vector for the producer J.

To evaluate PTE, SE e CE, it is necessary to consider variable returns to scale and weak disposability of inputs. The measurement of efficiency, including variable returns to scale, is given by the solution of the following linear programming problem:

$$TEV(V,S) = \min \lambda = \frac{OC}{O1}$$

$$(2) \quad Y_m \leq \sum_{j=1}^{J} Z_j Y_{jm}, \quad m = 1,2,\ldots,M,$$

$$\sum_{j=1}^{J} Z_j X_{nj} \leq \lambda X_n, \quad n = 1,2,\ldots,N,$$

$$\sum_{j=1}^{J} Z_j = 1, \quad j = 1,2,\ldots,J,$$

$$Z_j \geq 0, \quad j = 1,2,\ldots,J,$$

and with variable returns to scale and weak disposability of inputs by the following nonlinear programming problem:

$$PTE(V,W) = \min \lambda = \frac{OC'}{O1}$$

$$(3) \quad Y_m \leq \sum_{j=1}^{J} Z_j Y_{jm}, \quad m = 1,2,\ldots,M,$$

$$\sum_{j=1}^{J} Z_j X_{nj} = \sigma \lambda X_n, \quad n = 1,2,\ldots,N,$$

$$\sum_{j=1}^{J} Z_j = 1, \quad j = 1,2,\ldots,J,$$

$$0 < \sigma < 1,$$

$$Z_j \geq 0, \quad j = 1,2,\ldots,J,$$

which is the PTE measure. This last problem can be converted into a linear programming problem by taking =1 without altering the optimal values of and Z. The congestion efficiency measure is given by the ratio PTE/TEV and scale efficiency by the ratio TE/TEV. A producer will be TE efficient when PTE, CE and SE are equal to one.

A given producer will be scale efficient if TE=TEV or if TE and TEV are equal to one. If a producer is scale inefficient, it could be due to increasing or decreasing returns to scale. To assess this, it is necessary to measure efficiency with respect to a technology with non-increasing returns to scale (N), which is done solving the following linear programming problem:

$$TEN(N,S) = \min \lambda$$

$$(4) \quad Y_m \leq \sum_{j=1}^{J} Z_j Y_{jm}, \quad m = 1,2,\ldots,M,$$

$$\sum_{j=1}^{J} Z_j X_{nj} \leq \lambda X_n, \quad n = 1,2,\ldots,N,$$

$$\sum_{j=1}^{J} Z_j \leq 1, \quad j = 1,2,\ldots,J,$$

$$Z_j \geq 0, \quad j = 1,2,\ldots,J.$$

The scale inefficiency is due to increasing returns to scale if TE=TEN and decreasing returns to scale when TE<TEN.

To relate the efficiency levels with farms characteristics (size, experience, land ownership, irrigation, labour, specialization) the analysis of variance (that compares the within and among group variation) and the Kruskal-Wallis tests (a one-way-analysis variance based on ranks) were used.

3. Data

Data used in this study belong to a sample of 22 farms of the Alentejo region, for the years 2001 and 2004. These farms are enrolled in the European Farm Accounting System. The selected farms have a grape product value of more than 40% of total farm product value. The variables used to define the production technology and to measure technical efficiency were the following:

PRO – total output in value;
TER – agricultural area in hectares;
MAO – labour quantity in annual hours;
CME – machinery and equipment costs in value;
CPV – vegetal production costs in value;
OC – other costs in value.

The variables PRO, CME, CPV and OC resulted from the aggregation of several items. Table 1 presents a data summary of the several variables considered.

Table 1 – *Statistical Summary for the Used Variables.*

Variable	*Sample Average*		*Standard Deviation*		*Maxium Value*		*Minimum Value*	
	2001	**2004**	**2001**	**2004**	**2001**	**2004**	**2001**	**2004**
PRO	16653.9	72051.0	27411.0	115599.2	133596.0	574852.0	2535.0	4644.0
TER	50.0	47.0	46.3	44.0	180.5	171.0	7.1	7.1
MAO	4906.9	5571.3	5040.1	8378.3	21672.0	37176.0	1872.0	1008.0
CME	2479.6	14080.2	2014.3	15323.5	8520.0	75907.0	784.0	3097.0
CPV	2294.2	9962.5	4602.0	19292.8	21874.0	93114.0	157.0	1703.0
OC	643.6	4092.2	584.3	4043.8	2253.0	17224.0	0.0	489.0

4. Results

In order to obtain the efficiency levels, the mathematical programming problems given by the equations 1, 2 and 3 were solved for each one of the 22 analysed farms. Figure 2 shows the individual levels of technical efficiency (TE, PTE, SE and CE) by year, while Table 2 presents the average levels of efficiency and the percentage of efficient farms. From its analysis we can conclude that farms present an average technical efficiency equal to 60.7%, meaning that it would be possible to produce the same quantity of product with a reduction in inputs of 39.3%. In 2004, average technical efficiency was slightly higher than in 2001.

Figure 2 – *Average levels of Efficiency by Farm.*

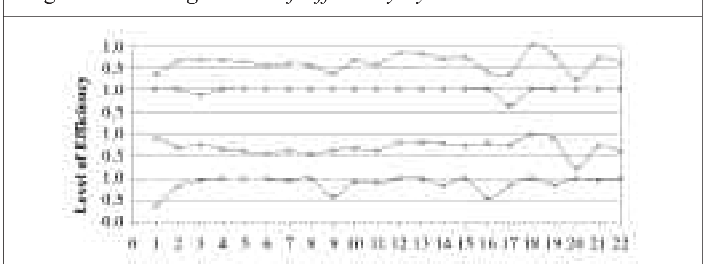


Table 2 – *Average levels of Efficicency by Year and Percentage of Efficient Farms.*

Item	TE	PTE	SE	CE
		Average Levels of Efficiency		
2001	0.595	1.000	0.683	0.881
2004	0.619	0.954	0.731	0.893
Average	0.607	0.977	0.707	0.887
		Percentage of Efficient Farms		
2001	13.6	100.0	13.6	63.6
2004	22.7	86.4	22.7	59.1
Average	18.2	93.2	18.2	61.4

The decomposition of the technical efficiency in its three components allows us to conclude that most of the observed technical inefficiency comes from scale (70.7) and congestion (88.7) efficiencies. For pure technical efficiency, in average, farms have values close to 1, with 93.2% of the farms being efficient. If we look at the number of efficient farms, we observe that 61.4% of farms are CE efficient and only 18.2% are SE efficient, which reinforces that scale inefficiency has a greater importance than the CE.

Table 3 presents the distribution of farms by four efficiency classes, for 2001 and 2004. With respect to TE, we observe that 41% of farms have efficiency levels lower than 50%, while 23% of farms have efficiency greater than 90%. Also, we verify that for PTE and CE most of farms are in the efficiency class 91-100, while for SE farm distribution by efficiency classes is quite uniform.

Table 3 – *Distribution of farms by Efficiency Classes.*

Item	TE	PTE	SE	CE
		2001		
0-50	9	0	5	2
51-70	6	0	7	2
71-90	2	0	4	3
91-100	3	22	6	15
		2004		
0-50	9	1	4	1
51-70	6	0	6	3
71-90	1	1	5	3
91-100	6	20	7	15

Once part of the observed technical inefficiency is due to the scale inefficiency, it would be interesting to know the causes of this inefficiency, that is, if it is due to increasing or decreasing returns to scale. If a farm is inefficient in terms of scale, this means that, in the short run, the farm is not located on the isoquant with constant returns to scale, but can have the maximum profit and be efficient in terms of PTE and CE (Byrnes, Färe, Grosskopf and Kraft, 1987). The resolution of the problem (4) allows us to identify the causes of the scale inefficiency. The results are shown in Table 4 where farms have been grouped by year, physical (area) and economic (total output) size. In overall terms, we conclude that the majority of scale inefficiency is due to increasing returns to scale. These results allow us to conclude that it is possible to improve efficiency by increasing farm size. However, farm size growth is limited by the legal constraints on the expansion of the vineyard area.

Table 4 – *Returns to Scale by Year, Class of Area and Economic Size.*

Item	Returns		
	Increasing	*Constant*	*Decreasing*
2001	86.4	13.6	0
2004	72.8	22.7	4.5
Class of Area [a]	**Average 2001/2004**		
Small	29.5	2.3	0
Medium	31.8	13.6	0
Large	18.2	2.3	2.3
Economic Size [b]	**Average 2001/2004**		
Small	52.3	2.3	0
Medium	4.5	2.3	0
Large	22.7	13.6	2.3

[a]Small: < 25 Hectares; Medium: 26 - 60 Hectares; Large: >60 Hectares.
[b]Small: Output Value<25,000 €; Medium: Output Value 25,000-35,000 €; Large: Output Value >35,000 €

Given the nature of the methodology used, i.e. the mathematical programming, it was possible to obtain the shadow prices for the inputs that constrained production and limited the levels of technical efficiency (TE). The shadow prices were obtained from the solution of problem (1) for each one of the farms. Table 5 shows average shadow prices for each input, as well as the percentage of farms where the input is constraining production. Land is the input with the highest shadow price, while other costs show the lowest value. For farms where land is binding, the availability of one more unit of land would increase the TE level by 0.04135, while for farms where the other costs are constraining, an increase in its availability would not significantly change TE. Vegetal production costs limit efficiency in 68.2%, land in 52.3% and machinery and equipment costs in 43.2% of the analysed farms.

As previously referred, the levels of technical efficiency tend to be dependent on the fundamental variables of each agricultural system, in particular on the production of wine grapes. The analysis of variance and of Kruskal-Wallis tests were used to associate the levels of technical efficiency with peculiar farm characteristics such as size (area and economic), age, land property, irrigation, labour type, and area and product specialization. The results presented in Table 6 show that technical efficiency levels are statistically significant and depend on area and product specialization. An increase in technical efficiency was observed together with the increase in specialization in terms of grapevine-growing area and in terms of percentage of value of grape product on total product. Even tough the levels of efficiency were not significantly depending upon the other considered items, we can say that medium farms are the most efficient with respect to physical and economic size, as well as those farms where the owner is 41 to 55 years old. Furthermore these farms are owned by the farmer, are mainly managed in dry farming and make predominant use of family labour.

Table 5 – *Input Average Shadow Prices.*

	TER	MAO	CME	CPV	OC
Average 2001/2004	0.04135	0.00043	0.00038	0.00034	0.00026
% of Farms	52.3	25.0	43.2	68.2	6.8

Table 6 – *Tests of Association between Technical Efficiency (TE) and Farm Characteristics.*

Item	Tests				Average Efficiency Level (TE) by Group		
	Variance Analysis		Kruskal-Wallis				
	F	Prob>F	χ	Prob>χ	1	2	3
Size (Hectares) [a]	0.737	0.492	1.44	0.487	0.571	0.639	0.556
Size (Output Value) [b]	0.202	0.818	1.052	0.591	0.573	0.635	0.610
Economic Size (GAV) [c]	0.286	0.754	0.408	0.815	0.582	0.601	0.608
Age [d]	0.495	0.617	0.853	0.653	0.560	0.643	0.565
Land Property [e]	0.083	0.773	0.028	0.867	0.595	0.617	
Irrigation [f]	0.086	0.773	0.070	0.792	0.620	0.597	
Labour Type [g]	0.423	0.534	0.522	0.457	0.621	0.559	
Cultural Specialization [h]	6.343	0.018	4.477	0.034	0.541	0.723	
Productive Specialization [i]	4.533	0.043	2.061	0.151	0.515	0.671	

[a]Group 1: < 25 Hectares; Group 2: 26 - 50 Hectares; Group 3: >50 Hectares.
[b]Group 1: Output Value < 25,000 €; Group 2: Output Value 25,000-35,000 €; Group 3: Output Value >35000€ ").
[c]Group 1: DE<6; Group 2:DE=7; Group 3: DE>7.
[d]Group 1: < 40 Years Old; Group 2: 41 - 55 Years Old; Group 3: > 56 Years Old.
[e]Group 1: Own Area < 50% of Total Area; Group 2: Owned Area > 50 % of Total Area.
[f]Group 1: Dry Land Farms; Group 2: Irrigated Land Farms.
[g]Group1: Family Labour >50% of Total; Group 2: Hired Labour>50% of Total.
[h]Group 1: Vineyard Area <30% of Area; Group 2: Vineyard Area >30% of Area.
[i]Group1: Vineyard Output<75% of Total; Group 2: Vineyard Output >75% of Total.

5. Conclusion

The non-parametric methods were used to measure the level of technical efficiency, as well as of its three components (pure technical, scale and congestion efficiencies) for a sample of wine-making farms in the Portuguese Alentejo region. For these farms, there is room to improve efficiency in input use. Scale and congestion inefficiencies are responsible for most of the observed technical inefficiency.

The scale inefficiency is due to the fact that farms are in the increasing returns to scale zone, meaning that an increase in farm size would improve efficiency.

Among the inputs that were scarce and limiting factors for production, land was the factor that would allow the largest increase in efficiency if an additional unit was available, while plant production costs were a binding input for a large number of farms.

Technical efficiency levels significantly depend upon specialization. We verify a growth of technical efficiency when specialization increases, in terms of either grapevine-growing area or grapevine output. Despite the efficiency levels were not statistically significant with respect to the other considered items, we can say that farms have a higher level of efficiency if farmers' age is between 41 and 55, if farms are owned by farmers and managed in dry farming, and if labour use is predominantly family-based.

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