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Efficiency analysis of Italian wine producers

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Abstract

An analysis of the efficiency of wine and grapevine producers in Italy was performed. Data for 2005 and 2010 from the Farm Accountancy Data Network were used; this network records the balance sheets of a representative sample of farms. The data were analyzed using data envelopment analysis, which is a method for estimating the comparative efficiency of a group of farms. We investigated the determinants of the estimated levels of efficiency through an econometric model, aiming to understand which farm and area characteristics affect the differences in efficiency levels. The results indicate that between 2005 and 2010, a reduction in grape prices led to an increase in the efficiency of companies producing wine compared with a significant reduction among companies that are dedicated exclusively to the production of grapes.

Keywords: Data envelopment analysis; Tobit model; Italian wine and grapevine production

1. Introduction

European Union policy has long recognized that the competitiveness of the wine production chain is largely based on the grape production stage. With the 1999 CAP (Common Agricultural Policy) reform, the wine sector had a specific financial endowment at its disposal. The aim of the reform was to convert and restructure vineyards to encourage the validation of grape varieties and growing techniques with support from structural policies (EC, 2012; Pappalardo et al., 2013).

Validation of the sector was an undoubtedly effective policy, and within ten years (2006–2015), viticulture in Italy evolved significantly towards higher quality production and levels of mechanization in the vineyards (Cembalo et al., 2014; Di Vita et al., 2015; Caracciolo et al., 2016), making the Italian wine sector one, if not the first, of the major producers in the world (Corsi et al., 2004; Anderson, and Nelgen, 2011; Sellers, and Alampi-Sottini, 2016).

There are, however, serious challenges ahead. Recent years have seen considerable recovery of the competitive capacity of the Italian wine production chain on the international market (Lombardi et al., 2016; Mariani et al., 2012; Pomarici, 2016). However, competitors in both the old and new worlds are improving their strategies for greater efficiency and quality production (Dal Bianco et al., 2013, Osorio et al., 2015), and Italy's wine sector is now being called on to make further progress (Galati et al., 2014).

Recent surveys on the profitability of European viticulture for wine production, conducted using the Farm Accountancy Data Network (FADN), have revealed a general picture that is undoubtedly positive both in absolute terms and in comparison with other agricultural activities (Pappalardo et al., 2013). However, diversification of production conditions requires a corresponding detailed examination of Italian production diversity to highlight the efficiency conditions in various viticultural contexts, with a view towards understanding the sector's current degree of stability and production potential (Caracciolo et al., 2013). To answer to this question, the current study empirically investigates the determinants of the efficiency of wine and grapevine producers in Italy, with the aim of understanding which farm and area characteristics

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affect the differences in efficiency levels and if changes over recent years affected their performance.

Our results will contribute to defining a framework for Italian viticulture, considering its great importance in the context of world wine production (Schimmenti et al., 2016; Corsi et al., 2017), with an in-depth analysis of the current efficiency conditions and the goal of outlining operational suggestions in the context of the new Common Agricultural Policy (CAP) agenda. The investigation was conducted using the FADN database (for 2005 and 2010). FADN records information from the balance sheets of a sample of statistically representative farms. The data drawn from the FADN database were analyzed using an efficiency model. In this study, efficiency was assessed using Data Envelopment Analysis (DEA) (Coelli, 1995; Liu et al., 2013; Maietta, 2007). The analysis was applied to firms with TF (types of farming) grapevines for quality wine (with PDO/PGI or variety indication as regulated by EU Reg. 1308/2013 and Reg. 607/2011) and grapevines for wine without PDO/PGI or variety indication, separating vine growers from wine production firms; in fact, business practices are generally very different depending on the business activity (Remaud and Couderc, 2006).

Our empirical analysis may be subdivided into two phases. The first phase involved the computation of an efficiency parameter as dictated by the DEA. The second phase aimed to specify an econometric model (Tobit) that allows the efficiency levels of firms to be determined and interpreted. Moreover, the use of this model may help determine which area-specific or firm-specific characteristics affect differences in observed efficiencies. The results are thus useful for building a useful body of knowledge for public and private operators to guide possible reforms of EU interventions in the sector.

2. Methodology

In all advanced economies and in the presence of production facilities that are strongly interconnected, the efficiency of an industry does not affect only itself. Through various steps, efficiency is transmitted to other sectors, with systemic effects called *spillovers*.

Specifically, under certain favorable conditions, these *spillovers* may occur together and may be reflected both directly and indirectly in the economic system, for example, by encouraging the introduction of innovative techniques that influence cost dynamics and enhance total factor productivity growth. Furthermore, differences in efficiency explain the variation in productivity observed across countries more than differences in technology do.

For this reason, it is important to know how to measure the efficiency of microeconomic units and both intrasectoral and intersectoral productivity. This knowledge allows the identification of both the determinants of the highest-performing individual and aggregate productivity growth over time (Sengupta, 2000).

The interpretation of differential efficiency is highly developed in the agricultural and financial fields but is not resolved in other sectors (Maietta, 2007). Many assessments of business efficiency have targeted the identification of the determinants of direct political action, particularly in agriculture (Zhu and Lansink, 2010).

In terms of modeling, the literature includes various techniques for analyzing efficiency (Coelli, 1995). Available methodologies can be divided in two main types of research according to whether a parametric or a non-parametric approach is followed. The former includes a wide range of stochastic frontier models (SFMs) first introduced by Aigner et al. (1977) and by Meeusen and van den Broeck (1977), characterized by an econometric estimate of parameters defining specific functional forms. The latter approach exploits mathematical programming techniques without any assumption on the data distribution, and this approach is widely known as data envelopment analysis. This paper uses DEA. The foundations of DEA were described by Farrell (1957), who introduced the concept of the piecewise linear production function but failed to establish a system of linear programming to explain the graphically obtained performance index.

Farrell also broke down the efficiency of a production unit into two components: technical efficiency and allocative efficiency. The first component reflects the production unit's ability to obtain the maximum output from a given (and limited) set of inputs. Allocative efficiency, however, reflects the unit's ability to use these inputs in optimal proportions given their respective market prices.

DEA was developed by Charnes et al. (1978) based on the studies of Farrell (1957), and since then, it has evolved significantly as a result of different contributions (Maietta, 2007) that led to the method currently in use. Since the 1990s, we have witnessed the continued improvement of technology and the recognition of DEA as a versatile method for analyzing data. In addition, in conjunction with the development of software applications, we are witnessing an increase in the application of DEA to empirical studies that are increasingly complex and large-scale.[1]

The largest advantage of this type of analysis is that it allows a global approach to be applied to a company, considering all the inputs and outputs simultaneously (Coelli, 1995) rather than considering them in terms such as yield by unit input.

Considering a company's performance in economic efficiency, both technical and allocative, and input-output terms, we can examine the individual components of profit maximization. A company that has suitable allocative efficiency in input uses the least expensive combination of inputs, while a company that has suitable allocative efficiency in output maximizes income.

The value of DEA in scientific research lies in its ability to assess efficiency relative to an individual or to the performance of a decision-making unit in a well-defined interest group. At the operational level, we are able to generate an efficiency frontier through DEA composed of the highest performing companies in the sample, positioning the other firms along a range between the calculated maximum efficiency and zero.

[1]Regarding the applications of DEA, Liu et al. (2013) published the results of a study on the applications made possible by DEA to date using the Web of Science database from 1978 to 2010. The investigation showed that the five research areas for which DEA has been most widely used are credit and finance, health, agriculture, transport, and education.

Thus, this approach generates a ranking of firm performance based on an estimated efficiency parameter theta (θ), defined between "0" and "1", where the value "1" is taken from the most efficient companies in the group. Among the disadvantages of DEA, due to its non-stochastic nature, the results can be largely affected by data errors (including the presence of outliers), and research hypotheses cannot be tested statistically. Furthermore, DEA results must always be interpreted relative to other observed DMUs (decision making units or farms) within the sample, and thus, DMUs cannot be assessed in terms of a theoretically defined benchmark level (Barth, 2007).

DEA has been previously used in the wine sector to perform efficiency analyses at the firm level. Most of the studies were carried out in traditional production countries, such as Spain and Italy. For example, Vázquez-Rowe et al. (2012), analyzing a set of 40 vineyards from a specific Spanish DO appellation, showed that DEA can be used jointly with a life cycle analysis to assess both the operational and environmental performance of vine growing. Aparicio et al. (2013), assessing Spanish designation of origin (DO) wines through DEA, identified the Cava sparkling wine denomination as one of the most technically efficient productions. Sellers-Rubio et al. (2016) investigated the efficiency of both Spanish and Italian wineries between 2005 and 2013 and identified a decrease in the annual productivity of the wineries for both countries for the period analyzed. Maietta and Sena (2008), using a panel of conventional and cooperative Italian wineries between 1996 and 2001, showed that cooperative firms were more efficient than conventional firms and that the level of technical efficiency was not correlated to the market share. Sellers and Alampi-Sottini (2016) showed that winery size had a positive influence on the economic performance of wineries within a sample of 723 Italian wineries (limited companies and cooperatives) in 2013.

The need for a large amount of input, output, revenue and corporate income information has prompted the use of the official statistical information network, the Farm Accountancy Data Network. The FADN is an instrument for evaluating the income of agricultural holdings. This network consists of an annual survey carried out by the member states of the European Union, and this is the only source of microeconomic data that is coordinated, i.e., the bookkeeping principles are the same in all countries. The methodology applied aims to provide representative data along three dimensions: the region, economic size and type of farming. The aim of the network is to gather accounting data from farms to determine incomes and conduct business analyses of agricultural holdings with the aim of evaluating, ex-ante and ex-post, the impacts of the Common Agricultural Policy (European Commission website).

The analysis included firms with TF (*types of farming*) grapevines for quality wine and TF grapevines for common wine, separating vine growers from wine production firms. The reference years 2005 and 2010 were used to evaluate, through comparative statistics, the possible effects of the global economic crisis on this sector.

Our empirical analysis is subdivided into two phases. The first phase involved the computation of an efficiency parameter (θ, theta), as dictated by DEA: solving the constrained optimization problem returned a classification of farms for each combination (grape production and wine production for 2005 and 2010) based on the relative efficiency of farms with respect to the estimated nonparametric frontier. The second phase aimed to specify an econometric model that allows the observed efficiency levels of firms to be determined and interpreted. Moreover, this model may help ascertain which area-specific or firm-specific characteristics affect the differences in observed efficiency.

Thus, the first phase consisted of a multi-input DEA with variable returns to scale. More formally, for each *j*-th observed farm/firm, let x_j and y_j be input and output vectors forming the input (X) and output (Y) matrices, respectively. Let λ be a non-negative vector that forms the linear combinations of J farm/firm. The output-oriented DEA model aims to maximize the proportional increase in output while remaining within the production possibility set.

$$max\ \eta \quad (1)$$

$$subject\ to\ x_j - X\lambda \geq 0; \eta y_j - Y\lambda \leq 0; \lambda \geq 0 \quad (2)$$

The indicators used to estimate the efficiency index theta can be summarized as follows. Company output was measured through gross marketable output (GSP). The inputs that determine the performance of the farm (i.e., GSP) were the following: 1. the value of the land capital, 2. the value of labor, and 3. the value of the working capital. For labor, the computation was performed using not only the explicit cost of the labor reported in working capital reported by FADN but also an estimated value of implicit family work. The estimate combined hours of family work and labor costs (the net of social security contributions) according to the national contract for agricultural workers (EUR 8.40 for 2005 and EUR 9.60 for 2010).

The results of the first phase are illustrated by subgroups based on

- business productivity (GSP per hectare);
- net farm income (net income (NI) per hectare);
- for wine producers, average GSP and NI per farm;
- average production costs (per unit of output), with the cost of labor and capital distinguished per farm;
- stratification by geographic area (north, central and south), size class of the farm (< 5 ha, 5–10 ha, 10–20 ha, 20–50 ha, ≥ 50 ha), and efficiency class (theta < 0.25, 0.25 to 0.50, 0.50–0.75, 0.75 to 1.00); and
- the average level of efficiency for each size class in the sample (mean and median values of theta).

The samples (for 2005 and 2010) include different farms, but they are equally representative of the population of farms since both samples share the same stratification method. Considering that θ is a relative index within each group, comparisons between years relied on the mean and median values obtained within each sample, ensuring that they were correctly layered.

Regarding the second phase, the econometric analysis, a Tobit model was implemented given the censoring nature of theta, as suggested by Casu and Molyneux (2003) and Ray (2004), among others. The aim of this approach was to investigate the determinants that can explain and interpret the observed levels of efficiency among producers and to understand which characteristics of the area or farm affect the observed efficiency differences.

Statistically, we can express the Tobit model as

$$\theta_j = \alpha + X_j\vec{\beta} + \varepsilon_j j = 1, \quad 2, \ldots, N \tag{3}$$

where θ_j is the efficiency ratio obtained by the DEA for the j-*th* company, α is the estimated coefficient of the intercept, X_j is a matrix composed of as many vectors as explanatory variables of the model, β is a vector of estimated coefficients, and ε_j is the stochastic error. Explanatory variables, in this specific case, are related to farm/firm size (economical and physical), human capital (farmer gender and age), mechanization (horsepower), type of farmer (family farmers *vs* professional farmers), presence of designation of origin and/or other certifications, localization (altimetry and geographic area: North, Central, and South Italy), and market price.

3. Results

3.1. Efficiency analysis

The net income of the vineyards that belong to the FADN is captured through the average data for 2005 and 2010. In 2005, 623 farms were producing grapes, while 401 produced wine. In 2010, FADN recorded 842 farms producing grapes and 435 producing wine. In 2005, the farms with the highest efficiency index value were in southern Italy (Tables 1 and 2). This result could be attributed to a larger average farm size. Sample stratification highlights the presence of a much higher share of farms engaged in quality production in the north than in the rest of Italy. Indeed, dividing the sample into five classes of UAA (utilized agricultural area), the average efficiency improves with increasing UAA, and at the same time, there is a decrease in the net income per hectare for grapes grown for high-quality wine production, which constitutes the bulk of the sample. With reference to wine production (Table 3), companies located in Central Italy exhibit higher efficiency levels, with the exception of common wine production, for which efficiency values are largely the same across all three geographical districts. The median value of θ, however, is higher for Central Italy, indicating a distribution of θ that is not centered on the average value.

Indeed, by dividing the sample into five classes of UAA, the average efficiency improves with increasing UAA (Table 4). The differences in the level of efficiency are particularly marked in the case of large companies. Specifically, in the case of wine production without PDO/PGI or variety indications, the average value of θ is more than doubled for large companies compared to the other classes.

Additionally, the 2010 sample of grape producers, as in 2005, shows a markedly higher efficiency index among companies located in southern Italy compared to those situated in the north and, in this case, compared to companies situated in Central Italy (Table 5).

Dividing the sample into UAA classes, we observe the same trends as in 2005, an improvement in the average level of efficiency with increasing UAA and a decrease in the net income per hectare (Table 6). In this specific case, the decrease in NI/ha is much more evident than in the 2005 sample.

Companies in the highest class of UAA have, in terms of quality production, yields per hectare that are 35% higher than the average of the smaller UAA class. In the case of production for common wine, the differences are very slight. The analysis of data for companies producing wine in 2010 is reported in Table 7. The average values of θ, in this case, do not show a significant difference by geographical area, with a slight predominance of average values achieved by companies in southern Italy. However, it should be noted that the average data for the companies in southern Italy reflect a small number of observations. The results, subdividing the sample based on UAA class, are reported in Table 8. In addition, the mean efficiency (θ) is higher with increasing size classes.

Table 1
Descriptive statistics and average values of θ of grape production in 2005 by district. *Source: elaboration based on FADN-RICA 2005 database*

Description	Area	Frequency	Distribution [%]	Average θ	Median θ
a) Quality production	North	302	73.84	0.340	0.292
	Center	49	11.98	0.350	0.319
	South and Islands	58	14.18	0.420	0.361
	Italy	*409*	*100.00*	*0.355*	*0.303*
b) Common production	North	56	26.17	0.299	0.284
	Center	24	11.21	0.354	0.305
	South and Islands	134	62.62	0.338	0.286
	Italy	*214*	*100.00*	*0.329*	*0.287*
c) Total production	North	358	57.46	0.336	0.291
	Center	73	11.72	0.353	0.309
	South and Islands	192	30.82	0.363	0.301
	Italy	*623*	*100.00*	*0.346*	*0.297*

3.1.1. Cross temporal analysis (2005–2010)

Although it is not possible to compare the efficiency ratios calculated for 2005 and 2010 directly, we compared the aggregate average levels of θ for products (grapes and wine) for these two years. In this case, we have computed the index of the average θ for the categories that are considered significant and most representative of the trends detectable in the transition from 2005 to 2010.[2]

[2]One of the reviewers noted that another approach could have been performed using pooled data instead of separate comparisons. We agree that is an attractive option, but the use of pooled data using the FADN database can be computationally onerous and cumbersome without adding relevant

Table 2
Descriptive statistics and average values of θ of grape production in 2005 by UAA class [€]. *Source: elaboration based on FADN-RICA 2005 database*

Description	Class UAA [ha]	Obs. [n.]	GSP/ha [€]	NI/ha [€]	Average θ	Capital [€]	Labor[a] [€]	Land [€]
a) Quality production	< 5 ha	176	7715	3255	0.324	42,390	15,634	199,507
	5–10 ha	110	5799	2527	0.340	69,699	20,974	379,007
	10–20 ha	63	5320	2359	0.403	123,052	31,023	529,012
	20–50 ha	44	4911	2208	0.398	208,916	41,655	1,347,645
	> 50 ha	16	3785	1597	0.498	346,985	66,007	3,991,255
	average value	*409*	*6375*	*2744*	*0.355*	*91,990*	*24,211*	*570,387*
b) Common production	< 5 ha	78	4625	1289	0.311	32,059	11,931	108,059
	5–10 ha	70	3438	893	0.315	44,830	16,809	186,625
	10–20 ha	38	3178	987	0.337	54,499	17,703	370,039
	20–50 ha	21	3755	1329	0.359	154,016	37,675	837,167
	> 50 ha	7	4043	2200	0.568	266,304	82,672	2,878,229
	average value	*214*	*3875*	*1140*	*0.330*	*59,851*	*19,392*	*342,439*

[a]Implicit and explicit costs

Table 3
Descriptive statistics and average values of θ of wine production in 2005 by district. *Source: elaboration based on FADN-RICA 2005 database*

Description	Area	Frequency	Distribution [%]	Average θ	Median θ
a) Quality production	North	220	68.54	0.277	0.205
	Center	73	22.74	0.446	0.443
	South and Islands	28	8.72	0.279	0.230
	Italy	*321*	*100.00*	*0.315*	*0.225*
b) Common production	North	33	41.25	0.229	0.179
	Center	9	11.25	0.223	0.229
	South and Islands	38	47.50	0.247	0.196
	Italy	*80*	*100.00*	*0.237*	*0.187*

Table 4
Descriptive statistics and average values of θ of wine production in 2005 by UAA class [€]. *Source: elaboration based on FADN-RICA 2005 database*

Description	Class UAA [€]	Obs. [n.]	GSP/ha [€]	NI/ha [€]	Average θ	Capital [€]	Labor[a] [€]	Land [€]
a) Quality production	< 5 ha	25	12,949	4859	0.216	88,144	24,184	188,135
	5–10 ha	30	11,093	5701	0.272	121,176	30,326	275,536
	10–20 ha	17	12,161	5919	0.280	232,292	38,955	705,545
	20–50 ha	7	13,266	5147	0.363	443,478	41,836	1,565,368
	> 50 ha	1	15,080	5154	0.625	2,328,012	32,113	6,195,642
	average value	*80*	*12,590*	*5410*	*0.315*	*459,900*	*32,509*	*1,266,811*
b) Common production	< 5 ha	81	6644	3062	0.247	37,957	17,171	110,781
	5–10 ha	81	5606	1959	0.179	89,893	19,729	281,473
	10–20 ha	81	5998	1697	0.251	149,430	39,213	397,863
	20–50 ha	37	8907	2750	0.333	207,352	37,284	874,320
	> 50 ha	41	4158	2750	0.822	107,406	12,096	1,989,791
	average value	*321*	*6285*	*2327*	*0.237*	*96,812*	*24,511*	*326,092*

[a]Implicit and explicit costs

Regarding grape production, it is possible to observe a marked reduction in the average θ values (Table 9). The data show a “collapse” in the average level of business efficiency for the sample in just 5 years. The most marked difference occurs in the over 50 ha UAA class (-0.264). Looking at the data divided into quality and common wine production (b and c of Table 9), the trend does not change, but the efficiency reduction is less marked overall for the production of grapes for common wine (except for UAA class > 50 ha).

In the UAA class of greater than 50 ha, we obtain more marked variation, with changes in average values from 0.568 in 2005 to 0.240 in 2010. This reduction could be attributed to

(*footnote continued*)
information. However, we believe that the suggestion of the reviewer is a reliable option for future research.

higher average production costs and to the level of the net income of companies.

The same comparison method was developed to compare the data for the 2010 and 2005 samples of companies producing wine (Table 10). In this case, there was an increase in the average level of efficiency with the exception of the size class over 50 ha. In addition, there was an increase in the average costs of production factors, but unlike the production of grapes, there has also been an increase in net income, which resulted in less marked differences in the efficiency indexes over the same period.

3.2. Determinants of efficiency – grapes

The results of the Tobit model for grape producers are shown in Table 11. To simplify the description of the results, only the statistically significant variables are presented. We can infer several aspects from these estimates. The first is that there is a group of variables that are significant in both 2005 and 2010.

The second is that these variables help explain the performance of the grape producers in terms of economic efficiency. Other variables, however, even if subjected to empirical testing in both datasets, have effects on only one of the two analyzed years. The variables present in both years represent a mix of factors, such as economic size, market characteristics and policies. Consistent with the literature, economic size (ESU) has a directly proportional effect on efficiency performance. In the descriptive phase of the results, increasing returns to scale that make larger companies considerably more efficient were observed. The estimated coefficients for HP (horsepower) of mechanical equipment, although statistically significant, are minor compared to those of ESU. This is also the only case with opposite signs in the two years under review: a negative coefficient in 2005 and a positive coefficient in 2010. One interpretation may be that in 2005, the presence of agricultural machinery, which was experiencing a period of depreciating value, accounted significantly for working capital. When this impact is extinguished, or at least mitigated, machinery was found to have a positive effect on business efficiency. The coefficients of the dummy variable associated with location in the

Table 5
Descriptive statistics and average values of θ relative to grape production in 2010 by district. *Source: elaboration based on FADN-RICA 2010 database*

Description	Area	Frequency	Distribution [%]	Average θ	Median θ
a) Quality production	North	406	63.74	0.182	0.126
	Centre	145	22.76	0.240	0.207
	South and Islands	86	13.50	0.282	0.289
	Italy	*637*	*100.00*	*0.213*	*0.167*
b) Common production	North	51	24.88	0.129	0.115
	Centre	42	20.49	0.247	0.232
	South and Islands	112	54.63	0.258	0.208
	Italy	*205*	*100.00*	*0.224*	*0.190*

Table 7
Descriptive statistics and average values of θ of wine production in 2010 by district. *Source: elaboration based on FADN-RICA 2010 database*

Description	Area	Frequency	Distribution [%]	Average θ	Median θ
a) Quality production	North	245	67.12	0.343	0.270
	Center	84	23.01	0.353	0.305
	South and Islands	36	9.86	0.356	0.306
	Italy	*365*	*100.00*	*0.347*	*0.283*
b) Common production	North	44	62.86	0.297	0.220
	Center	15	21.43	0.297	0.293
	South and Islands	11	15.71	0.345	0.301
	Italy	*70*	*100.00*	*0.328*	*0.285*

Table 6
Descriptive statistics and average values of θ of grape production in 2010 by UAA class [€]. *Source: elaboration based on FADN-RICA 2010 database*

Description	Class UAA [€]	Obs. [n.]	GSP/ha [€]	NI/ha [€]	Average θ	Capital [€]	Labor[a] [€]	Land [€]
a) Quality production	< 5 ha	228	9434	4726	0.205	33,914	16,657	237,796
	5–10 ha	173	5823	2347	0.217	77,513	24,423	407,548
	10–20 ha	116	4572	1763	0.228	87,858	26,410	609,051
	20–50 ha	87	3492	1172	0.186	112,301	29,252	1,069,875
	> 50 ha	33	3362	1367	0.259	265,494	19,216	3,492,284
	average value	*637*	*6442*	*2881*	*0.213*	*78,282*	*22,363*	*633,748*
b) Common production	< 5 ha	76	4114	1346	0.221	11,658	17,027	98,084
	5–10 ha	58	3320	1106	0.220	26,880	22,096	196,775
	10–20 ha	42	3163	1171	0.220	51,543	24,084	419,898
	20–50 ha	20	3436	1490	0.246	71,524	23,229	734,606
	> 50 ha	9	3021	1229	0.240	350,451	18,880	2,087,873
	average value	*205*	*3578*	*1251*	*0.224*	*44,851*	*20,593*	*341,395*

[a]Implicit and explicit cost

Table 8
Descriptive statistics and average values of θ of wine production in 2010 by UAA classes [€]. *Source: elaboration based on FADN-RICA 2010 database*

Description	Class UAA [€]	Obs. [n.]	GSP/ha [€]	NI/ha [€]	Average θ	Capital [€]	Labor[a] [€]	Land [€]
a) Quality production	< 5 ha	80	16,750	8748	0.333	106,738	23,209	193,095
	5–10 ha	103	11,725	5374	0.314	147,644	31,468	404,893
	10–20 ha	93	11,903	5191	0.341	280,468	34,633	712,148
	20–50 ha	56	11,297	5387	0.365	507,972	39,753	1,401,292
	> 50 ha	33	14,664	7281	0.468	1,866,348	38,364	5,190,992
	average value	*365*	*13,072*	*6241*	*0.347*	*383,194*	*32,359*	*1,022,347*
b) Common production	< 5 ha	19	7501	3643	0.310	37,497	18,207	108,231
	5–10 ha	15	3457	1576	0.264	21,670	16,689	167,048
	10–20 ha	18	5565	2169	0.318	149,976	25,736	361,576
	20–50 ha	15	9455	4163	0.376	259,929	36,240	1,741,518
	> 50 ha	3	10,175	5246	0.577	2,528,753	24,640	2,702,567
	average value	*70*	*6670*	*3001*	*0.328*	*217,461*	*23,958*	*647,156*

Table 9
Average θ values comparison in grapevine production – 2005 and 2010 by UAA class. *Source: elaboration based on FADN-RICA 2005 and 2010 database*

Description	UAA Classes	Average θ 2010	Average θ 2005	Δ 2010-2005
a) Aggregate	< 5 ha	0.209	0.320	-0.111***
	5–10 ha	0.218	0.330	-0.112***
	10–20 ha	0.226	0.378	-0.152***
	20–50 ha	0.197	0.386	-0.189***
	> 50 ha	0.255	0.519	-0.264***
	average value	0.216	0.347	*-0.131******
b) Quality production	< 5 ha	0.205	0.324	-0.119***
	5–10 ha	0.217	0.340	-0.123***
	10–20 ha	0.228	0.403	-0.175***
	20–50 ha	0.186	0.398	-0.212***
	> 50 ha	0.259	0.498	-0.239***
	average value	0.213	0.355	*-0.142******
c) Common production	< 5 ha	0.221	0.311	-0.090**
	5–10 ha	0.220	0.315	-0.095**
	10–20 ha	0.220	0.337	-0.117***
	20–50 ha	0.246	0.359	-0.113**
	> 50 ha	0.240	0.568	-0.328***
	average value	0.224	0.330	*-0.106*****

t-test (mean comparison test) * Significant at p-value < .10;
**Significant at p-value < .05;
***Significant at p-value < .01

Table 10
Average θ values comparison in wine production – 2005 and 2010 by UAA class. *Source: elaboration based on FADN-RICA 2005 and 2010 database*

Description	UAA Classes	Average θ 2010	Average θ 2005	Δ 2010-2005
a) Aggregate	< 5 ha	0.328	0.223	0.105***
	5–10 ha	0.308	0.247	0.061**
	10–20 ha	0.337	0.275	0.062**
	20–50 ha	0.367	0.358	0.009*
	> 50 ha	0.477	0.630	-0.153***
	average value	0.343	0.300	0.043**
b) Quality production	< 5 ha	0.333	0.216	0.117***
	5–10 ha	0.314	0.272	0.042**
	10–20 ha	0.341	0.280	0.061**
	20–50 ha	0.365	0.363	0.002*
	> 50 ha	0.468	0.625	-0.157***
	average value	0.347	0.315	0.032*
c) Common production	< 5 ha	0.310	0.247	0.063**
	5–10 ha	0.264	0.179	0.085**
	10–20 ha	0.318	0.251	0.067**
	20–50 ha	0.376	0.333	0.043*
	> 50 ha	0.577	0.822	-0.245***
	average value	0.328	0.237	0.091*

t-test (mean comparison test)
*Significant at p-value < .10;
**Significant at p-value < .05;
***Significant at p-value < .01

north in the sample are negative for both years. As expected, the estimated coefficients of price and yield are positive and statistically significant in the basic components of GSP with respect to the DEA construction of the frontier of nonparametric maximum efficiency. If we analyze the variables that affect the efficiency index in only 2005, the presence of irrigation on the farm appears to have a negative effect on θ. The variable Inves_2000 is also a binary variable that takes the value 1 if the company has invested since 2000. For the coefficient related to the certifications other than those of origin, it has an effect directly proportional to efficiency performance. The last coefficients described are those related to the year 2010. Regarding the location of businesses, those in the areas of southern Italy appear to be the most efficient. Finally, the physical size of the farm remains of certain importance, although it is negative in 2010.

Table 11
Tobit model results for grapes producers, 2005 and 2010. *Source: elaboration based on FADN-RICA 2005 and 2010 database*

Variables	Grapes	
	2005	2010
Model		
Constant	0.0604*	0.0981***
ESU (Economic Size €)	0.0575***	0.0158***
HP mechanization (no.)	-0.0002**	0.0003**
North (1 if in North-Italy)	-0.0898***	-0.1704***
Prices (€)	0.0025***	0.0015***
Yield (quintal per ha)	0.0003***	0.0005***
Inves_2000 (1 if invest. from 2000)	-0.1087***	
Other certifications (1 if other cert.)	0.0548**	
Irrigation (1 if irrigated)	-0.0669***	
UAA (log UAA in ha)		-0.0183**
Central (1 if in Central-Italy)		-0.0532***
Sigma		
Constant	0.1655***	0.1441***

Only statistically significant variables: * = 10%; ** = 5%; *** = 1%

Table 12
Tobit model results for wine producers, 2005 and 2010. *Source: elaboration based on FADN data*

Variables	Wine	
	2005	2010
Model		
Constant	0.1929***	0.0914**
ESU (Economic Size)	0.1211***	0.0242**
Altimetry	-0.0436**	
Age of the farmer (years)	-0.0588***	
Inves_2000 (1 if invest. from 2000)	-0.1198***	
Gender (1 if male)	0.0441**	
Conduction (1 if family farm)	0.1508***	
HP mechanization (horsepower)	-0.0003***	
Designations of Origin (1 if present)	0.1771***	
UAA (utilized agricultural area)		0.0112*
South (1 if in South-Italy)		0.1023***
Prices		0.0007***
Sigma		
Constant	0.1783***	

Only statistically significant variables: * = 10%; ** = 5%; *** = 1%

3.3. Determinants of efficiency – wine

For the wine producers, we only show the results of the statistically significant variables in the Tobit model (Table 12). The ESU for the processing companies is the only key variable to explain efficiency performance in 2010. Again, there is a strong possibility of increasing returns to scale. The sample in 2005 was made up of 40% male respondents, while in 2010, the percentage was 83%. The variable "gender" is statistically significant only in 2005.

For the results in terms of significant variables, companies located in southern Italy seem more efficient only in 2010. The age of the farmer was a significant variable for only 2005, even in the case of companies with younger farmers.

4. Conclusions

An analysis of efficiency using a DEA model allowed us to investigate the determinants of the efficiency of wine and grapevine producers in Italy. The results demonstrate the level of efficiency by company and area characteristics. The changes in efficiency performance between two specific years were also studied: immediately before and after the beginning of the global economic crises.

An association was highlighted between company size and efficiency, which is characterized by an increasing trend in the relevant index in large companies and by the tendency to reach higher levels of efficiency in companies that process grapes rather than those that sell only grapes and in those oriented towards quality production rather than common production. This study not only highlights the relations between efficiency and firm and context characteristics but also allows a more thorough investigation of the issue of optimum utilization of the factors of production. One of the most interesting results is that the critical economic size for the optimization of the use of the production inputs is different for the production of grapes and wine and is determined according to production specialization. The analysis of the 2010 data confirmed the importance of the size for grape and wine production, but it also highlighted other elements that indicate varying performance and efficiency. In the production of grapes, overall efficiency appears linked to both physical and commercial aspects, as the coefficients relating to manufacturing yields and those relating to prices are significant. In wine production, commercial aspects, in addition to the selling prices of wine, are discriminating elements. The DEA did not identify other significant specific factors, showing that the production of grapes and wine occurs under very different conditions in terms of the subjective characteristics of entrepreneurs, structures, and corporate behaviors. This outcome is also explained by the specific features of the winegrowing industry and its roots in the tradition of national agricultural (Scardera and Tosco, 2014).

The scenario described above presents a large variety of structural situations that we highlight, for example, the low performance of most small production units, which was offset by the economic viability and competitiveness of medium to large units. Furthermore, considerable differences emerged between common production and quality production and between farms that sell only grapes and those that produce wine.

The data described a situation in which, excluding the cases of companies with fully integrated supply chains (such as companies producing both grapes and wine), there are significant imbalances in the distribution of value along the chain, which in this case, favor the downstream stages to the detriment of the primary agricultural phase. This scenario is rather serious in common wine production. From this, one might assume that the successful performance of Italian wine on the international market, particularly with regard to cheaper wines, comes in part from the under-remuneration of grapes and wine that allows operators at the end of the market chain to offer products at very competitive prices while maintaining adequate margins. It is evident that the continuation of this situation over the mid to long term will lead to further reductions in the area under vines, with negative consequences on the economy of strictly agricultural production areas. In addition, operators who have the final advantage of low procurement costs, observing a decrease in the production base of commodities (grapes and wine), may lose competitiveness compared to international competitors.

Ultimately, large imbalances in the value distribution within the wine industry produce instability in the structure of the supply chain itself. These imbalances also foreshadow doubts about the ability of the wine sector to continue to perform its many functions: the main macroeconomic function, directly and indirectly generating an income that supports professional staff; the environmental function; and the social stabilization function through the integration of family income. Viticulture in Italy is very advanced overall thanks to the intensity of the restructuring of vineyards stimulated directly and indirectly by the Common Market Organization (CMO) wine since 2000 and supported by rural development policy measures encouraging the mechanization of the vineyards and cellar facilities (Foti et al., 2011). These policies should incorporate differentiated interventions based on analyses of the wine market, including its domestic and international components. From these analyses, it is possible to derive the information needed to adapt the sector to the opportunities and needs of the market while exploiting all existing components. Considering the new rural development regulation, there should be more emphasis placed on specific measures for small and medium farms that need a restructured production environment. In fact, given the relevance of farm dimensions in the sector, combined with their structural weaknesses, specific measures could be particularly useful. A possible program could combine a more flexible and easy way to apply and, at the same time, be integrated into a wider vision of development that considers not only the single farm but a farm within a territory.

In conclusion, the presented comparison relies on the data collected at different times with different methodologies, which is a limitation of this work, as it requires considerable effort to homogenize the data. Moreover, even if the two-stage DEA approach is widely used for characterizing the observed heterogeneity in the efficiency scores, several authors identified the existence of biases and low precision in the second stage estimates (econometric model), especially when the explanatory variables of the second steps are correlated with the inputs used for calculating the efficiency scores (Simar and Wilson, 2007; Barnum and Gleason, 2008). Looking ahead, the econometric estimates may be improved by accounting for this source of bias, and the resulting comparisons may be extended over time and space to other countries (both EU and non-EU) to generalize the drivers of the economic performance of wine producers. Lastly, one of the anonymous reviewer of this manuscript noted the relevance of the spillover effect. The methodological approach of this paper does not attempt to verify and quantify this effect. However, due to its relevance, we believe this could be a subject for further research in this field.

Conflict of interest

None declared.

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