Research Article

Technical and Scale Efficiency of Farms Producing Grapes for Wine

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Abstract.
In recent years, farmers have been confronted with numerous challenges namely, climatechange and the subsequent requirements to comply with environmental standards, continuoustechnological change, and the need to adapt it, adjust, and remain competitive. The COVID-19 pandemic and the economic hardship it brought about, followed by the current energy crisis,make it imperative to address issues of competitiveness and efficiency of farm units. Theseunfavorable developments particularly affect mountainous and disadvantaged rural areassuch as the Region of Western Macedonia in Greece. Furthermore, the decarbonizationprocess that this region is undergoing, leads to a period of uncertainty, especially in relationto employment. The cultivation of vineyards and wine production are dominant economicactivities with Xinomavro being the main grape for wine variety. The efficiency of grape-producing farms are considered important for the whole wine supply chain. The objective of this paper is to estimate the technical and scale efficiency of wine-related agricultural firms in the region of Western Macedonia, by applying the DEA methodology. An output-oriented empirical model was applied for the estimation of technical and scale efficiency of farms producing grapes for wine.

Keywords: technical efficiency, scale efficiency, wine grape cultivation, Western Macedonia, wineries

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1. Introduction

Grape production occupies an important position in global markets due to the continuous increase in the gross value of grape production, which from 1991 to 2020 showed a percentage increase of 277.38% [1]. In Europe in 2021 leading positions in grape production were held by Italy, followed by Spain and then France. Greece appeared sixth in the order with 739.66 tonnes of production after Romania and Portugal [2]. The number of farms for the year 2020 in the whole country is 193,252 and of these 7,995 belong to the Region of Western Macedonia, i.e. 4.13% [3]. In this region the most important wine grape variety is Xinomavro followed by other varieties such as Sauvignon Blanc, Syrah and Merlo.

The largest share of the Gross Value Added of the Region of Western Macedonia at country level is held by Mining, Quarries, Electricity Supply, Water Supply 5.79% followed by Agriculture, Forestry and Fisheries with 4.49% respectively [4]. In the agricultural sector, viticulture is the main activity in the region of Western Macedonia, with wineries and agricultural cooperatives playing an important role in its further development. At the same time, agrotourism-wine tourism is a sector that has been developing in recent years, participating in initiatives such as the Wine Roads. Alternative tourism and in particular wine tourism may increase with the participation of more and more young people especially after the prolonged pandemic and all its consequences. The prospect for increased employment opportunities for experienced and skilled staff in grape cultivation as well as in wine production may be promising in the future.

The second section of the paper presents the statistics of the area of vineyards in the Region of Western Macedonia and in the whole country (Greece), as well as the literature review on the profitability of viticulture. The third section includes the research methodology and the calculation of technical efficiency and scale efficiency of the wine growers in the Region of Western Macedonia. Finally, the conclusions from the application of DEA and its important role in understanding the input diversification of viticulturists in the Region of Western Macedonia for more efficient production are presented.

2. Literature Review

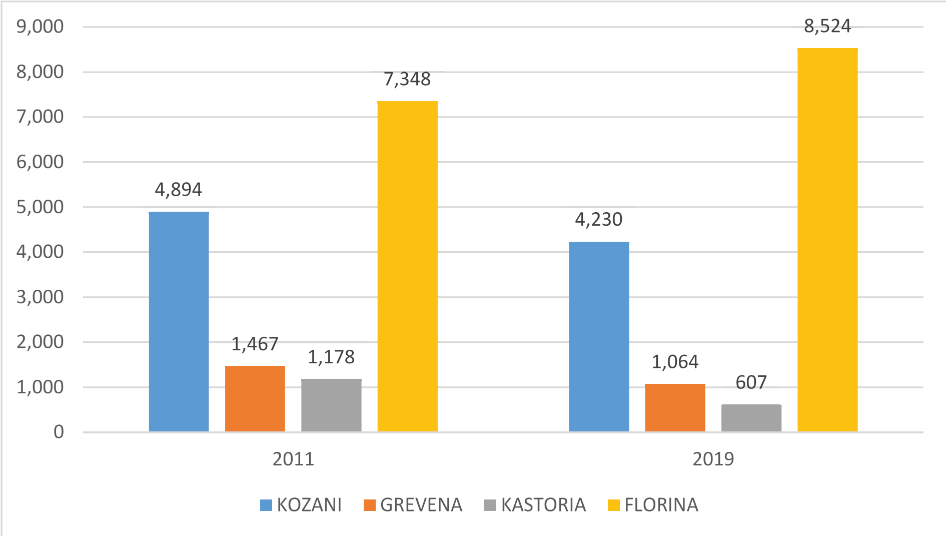
The cultivation of grapes for wine is an important activity both for the Region of Western Macedonia and for the whole of the country. The table below describes the distribution of the area used in stremmas (str) of vineyards (grapes and raisins) in the years 2000, 2009 and 2016 for Greece and for the Region of Western Macedonia. In Greece in 2000 there were 976000 str with vineyards, whereas in 2009, this figure fell to 863000 str. and in 2016 shank further by a 127000 str. While, in the Region of Western Macedonia the area with vineyards kept increasing over the same period starting [5].

Table 1: Areas in Stremmas (str).

Year	2000	2009	2016
Country Total	976000	863000	736000
Region of Western Macedonia	19000	22000	29000

Source: www.statistics.gr

The following graphs compare the production of grapes for wine in tons per Regional Unit (Kozani, Grevena, Kastoria, Florina) of the Region of Western Macedonia in 2011 and 2019. What is important to analyse is that while in the Regional Units of Kozani, Grevena and Kastoria there is a decrease in the production of grapes for wine in recent years, in the Regional Unit of Florina the production in tones of grapes for wine has increased by 1,176 tones and from 7,348 tons in 2011 to 8,524 tons in 2019. [6]



Source: www.statistics.gr

Figure 1: Production of Grapes for Wine 2011 and 2019 (Tons).

According to the Hellenic Statistical Authority, in 2016 the number of farms cultivating quality wines in the country as a whole was 24,077, other wines 57,297 and table grapes 13,547. While, in the Region of Western Macedonia the holdings dedicated to quality wines were 907, other wines 3,042 and table grapes 450, i.e. the percentage participation of the Region of Western Macedonia in the total number of holdings is 21.07%, 70.68% and 10.45% respectively. [7]

Consumer interest in wine - particularly popular nowadays - and the response of the Region of Western Macedonia to its increased demand, led to an increase in the production of grapes for wines. The primary sector follows a policy of seeking qualified and experienced personnel, resulting in the creation of new jobs. The unemployment rate of the Region of Western Macedonia in 2016 is decreasing and reaches 19.7%. [8] According to the Strategic Planning of the Region of Western Macedonia 2015-2019, an important priority was the conservation of energy capital based on the environmental standards of the region. [9]

The combination of the economic crisis and the pandemic with all the above has brought to the fore the need for survival of each agricultural enterprise. Gordana Manevska - Tasevska argued that the variety of grapes and the size of the farm influenced the efficiency of the vinegrowers. However, the investments of producers in the wine sector lead to the selection of local and table grape varieties [10]. A study in India on more effective grape value chain management compared producers in three regions. The results showed that in all three regions the winegrowers were more efficient at the production stage than at the marketing stage and suggested ways to improve the marketing of the product [11].

The grape producers who budgeted and followed the production process based on accounting realized that they could achieve higher profitability and strengthen the wine industry. However, inappropriate, irrational planning with regard to the production process leads to low efficiency [12]. A South African study shows the time trend in scale efficiency, technical efficiency and overall productivity over the period 2005-2015. The average total return ranges from a low of 0.69 to a high of 0.96. Four of the eleven years show low overall profitability and this is due to the fact that in these years had poor weather conditions and apparently lower income from grape production. Small grape growers specialise in the production process and manage it better and more rigorously than large producers due to the size of the holding [13].

In northern Portugal, a study on the productive efficiency of vine growers showed that the grape variety and the specific characteristics of the region are decisive factors influencing the efficiency of the holding [14]. According to Santos, Rodriguez and Marta-Costa, large vine growers produce more grapes of a particular variety because of its higher price and also make extensive use of hired labour, resulting in higher production costs than small growers. The results show low average efficiency and to improve it they will have to reduce inputs in such a way as to achieve a desired level of outputs given the technology [15]. Also, the corresponding reduction of inputs - materials contributes to an increase in environmental gains - benefits resulting in a better ecological performance of viticulture [16].

A survey to analyse the efficiency of wine producers in Italy between 2005 and 2010 showed that the reduction in the price of grapes led to an increase in the efficiency of enterprises engaged exclusively in wine production compared to agricultural enterprises engaged exclusively in grape production [17]. They point out that government policies, through the adoption of various forms of aid, have a positive impact on the average technical efficiency of grape production and the efficiency of viticulture so as to improve the competitiveness of the wine sector in general [18].

3. Research Methodology

An appropriately structured questionnaire was prepared for the research needs. The questionnaire consists of three parts. The first part of the questionnaire records demographic information. The second part records the vine varieties, their planting, the hectares and their yield per hectare. Finally, the third part records inputs such as hours of foreign and family labour, pesticides, fertilisers and other vineyard costs, such as irrigation costs.

The questionnaires were completed using the face-to-face interview method among the wine growers in the area. A total of 107 questionnaires were collected. Of the sample of 107 farms, about 51% grow exclusively vines and the other 49% are also involved in other types of farming, with viticulture as their main activity. The software program R-studio (based on R language) was used for statistical processing of the survey data.

In summary, the calculation of the variables used for the purposes of this study is as follows: The output shall be understood as the quantity produced, measured in terms of total gross receipts, in euro. Five inputs are included in the model, i.e. land in stremmas (1 stremma = 0.1 ha), labour (including family and wage labour) measured in annual hours worked, fertilisers, pesticides measured in euro and other variable costs (irrigation costs, etc.) also measured in euro.

Summary statistics of the variables used for the purposes of this study are given in Table 2.

Measuring efficiency and effectiveness is an essential element both in the economic sector and for policy makers. The element of interest to economic planners is whether efficiency can be increased without the need to spend more resources [19]. The DEA method for measuring efficiency and effectiveness has recently been applied to different production units, with different scopes of activity, taking place in different contexts and in different countries, paving the way for its potential use due to the complexity of multiple inputs and multiple outputs [20].

This method deals with efficiency and effectiveness in areas such as education, health, public and private institutions, etc. The organization under study consists of DMU (Decision Making Unit) entities, which should decide and choose the appropriate conversion of inputs to outputs and evaluate the efficiency of these units. It uses two models in its implementation. The first is CCR (Constant Returns to Scale) and the second is BCC or VRS (Variable Returns to Scale). In the first model output varies with the change in inputs (tripling of all inputs and therefore tripling of outputs), while the VRS model contains variable returns to scale with increasing or decreasing returns to scale.

Table 2: Descriptive Statistics of Input and Output Values.

Inputs					
Land in stremmas (1 stremma = 0.1 ha)		Labor (annual working hours-including family and wage labor)		Fertilizers (measured in euros)	
Group	Frequencies	Group	Frequencies	Group	Frequencies
<20	80	<200	71	<400	80
[20-40)	18	[200-400)	21	[400-800)	15
[40-60)	4	[400-600)	6	[800-1200)	5
[60-80)	3	[600-800)	2	[1200-1600)	4
80≤	2	800≤	7	1600≤	3
Mean:	28.02	Mean:	325.22	Mean:	583.18
Std. Deviation:	16.82	Std. Deviation:	223.02	Std. Deviation:	379.99
Inputs				Output	
Pesticides (measured in euros)		Other variables costs (measured in euros)		Total gross revenue (measured in euros)	
Group	Frequencies	Group	Frequencies	Group	Frequencies
<800	97	<600	73	<8000	75
[800-1600)	5	[600-1200)	20	[8000-16000)	18
[1600-2400)	2	[1200-1800)	4	[16000-24000)	5
[2400-3200)	0	[1800-2400)	6	[24000-32000)	5
3200≤	3	2400≤	4	32000≤	4
Mean:	957.00	Mean:	947.65	Mean:	12,411.20
Std. Deviation:	583.27	Std. Deviation:	630.29	Std. Deviation:	8,274.44

The CCR model has two versions. The first version aims to minimize inputs by producing the same levels of outputs and is what is called input oriented while the second model is called output oriented where it tries to maximize outputs without using more inputs. The comparisons of the scores of the two models above are interesting to study. That is, whether the sources of inefficiency of a DMU come from inefficient operation or from adverse conditions due to scale efficiencies [21]. The process of measuring the performance of a DMU is done by scoring the DMU under consideration with 1 point if and only if it is efficient and effective [22]. The proposed measure of efficiency is obtained by dividing the weighted outputs by the weighted inputs and shows a result of less than or equal to unity. The efficiency measure revolves around the technology used by the entities under consideration and the utilisation of resources in whatever combinations exist and are feasible [23].

On the production side, it is efficient if it performs at maximum efficiency using given quantities of inputs with a given production technology. Speaking of a production with multiple inputs, the measurement of efficiency presupposes the existence of a production limit. That is, technical efficiency measures the efficiency of a farm compared to the best farm in the sample while scale efficiency captures whether the producer selects the right scale of inputs for his chosen level of production [24].

Furthermore, the non-parametric DEA method has been applied to estimate the efficiency of wineries, in particular in a comparison between Italian and Spanish wineries. The results of the survey showed that wineries could achieve the same amount of production by using fewer inputs. In the period 2005-2013, technological progress had a positive impact on productivity growth, but the profitability of wineries decreased. This inefficiency may be due to the fact that producers are not aware of important aspects in grape production. In other words, they must make better use of production factors, adopt new technologies and improve production while maintaining quality [25].

In this research an output oriented approach is used to assess farm performance of the wine grape growers in the Region of Western Macedonia, through the following linear programming problem. The radial Farrell-type output-oriented technical efficiency measure is given by solving for each farm in the sample the following linear programming problem:

$$F_O^k\left(x^k\ ,\ y^k\right) = \max_{\varphi,\lambda}\left\{\varphi : \sum_{k=1}^{K}\lambda_k\ \ x_n\ \ \leq x_n^k\ \ \forall n,\ \sum_{k=1}^{K}\lambda_k\ y^k \geq \varphi y^k, \lambda_k\ \geq 0 \forall k\right.$$

Where x and y refers respectively to input and output quantities, are the intensity variables, are (1xK) row vectors of the sample input matrix X with elements the quantities of a particular input that are used by the K firms in the sample, and n=1,...,N is the number of inputs. The restrictions on the intensity variables are related to the structure of returns to scale. The above formulation implicitly assumes constant returns to scale for the whole range of input values and results in what is called the benchmarking technology [26].

An alternative specification that restricts the sum of the intensity variables to be equal to one corresponds to a variable returns to scale technology which is referred to as the frontier technology. In this case, output-oriented technical efficiency is estimated by solving for each farm in the sample the following linear programming problem:

$$E_O^k\left(x^k\ ,\ y^k\right) = \max_{\varphi,\lambda}\left\{\varphi : \sum_{k=1}^{K}\lambda_k\ \ x_n\ \ \leq x_n^k\ \ \forall n,\ \sum_{k=1}^{K}\lambda_k\ y^k \geq \varphi y^k, \sum_{k=1}^{K}\lambda_k = 1,\ \lambda_k \geq 0 \forall k\right.$$

In addition, one can estimate scale elasticity using the benchmarking and the frontier based technical efficiency scores, namely:

$$S_O^k\left(x^k\ ,\ y^k\right) = \frac{F_O^k\left(x^k, y^k\right)}{E_O^k\left(x^k, y^k\right)}$$

4. Results - Discussion

Pearson's coefficient is a linear correlation coefficient, denoted by r, takes values from -1 to 1 ($-1 \leq r \leq 1$) and is used in quantitative variables. Depending on the values it takes, the degree of correlation is indicated. Also, low power coefficients express trend and high power coefficients express certainty.

From -1 to -0.5 is considered to be a high negative correlation coefficient and from -0.5 to -0.2 a low negative correlation coefficient. From -0.2 to 0.2: we consider the correlation coefficient to be zero. From 0.2 to 0.5: considered to be a low positive correlation coefficientFrom 0.5 to 1: considered to be a high positive correlation coefficient [27], [28].

López, etc. (2016) propose that in the incidence of only positive correlations between characteristics, the inputs and outputs included in the model should be highly correlated. In DEA, this indicates a CRS relationship where all DMUs are near the efficient frontier. Inputs that are not correlated with outputs or outputs that are not correlated with inputs do not appear to affect significantly efficiency scores and therefore they may not contribute much to a model [29].

Table 2 presents the results of the Pearson correlation coefficient for finding the correlations between the input and output variables. The test was implemented in the software program R-Studio (based on R language). There is a relatively high positive correlation between the variable labour and the variables land, pesticides and gross production revenue. The positive high correlation between the variables means that an increase in one variable leads to an increase in the other. There is also a relatively high positive correlation between the variable 'land' and the variable 'gross revenue', since the total acres of vineyards are also included in the calculation of gross revenue. This means that a decrease in land will also lead to a decrease in gross revenue due to the high positive correlation between the two variables.

In table 3 the technical efficiency estimates of the farms in the sample are presented, in the case of constant returns to scale, of variable returns to scale, as well as the estimates of scale efficiency.

Table 3: Results of the Pearson Correlation.

Inputs	Land	Labour	Fertilisers	Pesticides	Other expenditure	Gross revenue (Output)
Land	1.0000	0.820	0.670	0.732	0.284	0.930
Labour	0.820	1.0000	0.380	0.827	0.238	0.813
Fertilisers	0.670	0.380	1.0000	0.502	0.275	0.640
Pesticides	0.732	0.827	0.502	1.0000	0.240	0.709
Other expenditure	0.284	0.238	0.275	0.240	1.0000	0.284
Gross revenue (Output)	0.930	0.813	0.640	0.709	0.284	1.0000

Each of the numbers calculated by the programming language corresponds to the technical efficiency of each of the 107 farms. Technical efficiency takes values between zero (for a completely inefficient decision unit) and unity (for a completely efficient decision unit). Whereas, interpretatively, a decision unit showing a technical efficiency of 0.58 means that it in order to become fully efficient it would have to reduce its input use by 41.7% for a given production technology and with no impact on its output.

Table 4: CRS, VRS of Technical Efficiency and Scale Efficiency.

Technical efficiency (CRS)			Technical efficiency (VRS)			Scale efficiency		
Efficiency Score	Number of farms in range	Percent (%)	Efficiency Score	Number of farms in range	Percent (%)	Efficiency Score	Number of farms in range	Percent (%)
>10	1	0.93	>10			>10	1	0.93
10-20	1	0.93	10-20	1	0.93	10-20	0	0
20-30	8	7.48	20-30	1	0.93	20-30	1	0.93
30-40	17	15.89	30-40	10	9.35	30-40	4	3.74
40-50	15	14.02	40-50	16	14.95	40-50	1	0.94
50-60	16	14.95	50-60	15	14.02	50-60	7	6.54
60-70	18	16.82	60-70	14	13.08	60-70	12	11.21
70-80	11	10.28	70-80	8	7.48	70-80	8	7.48
80-90	2	1.87	80-90	7	6.54	80-90	16	14.95
90-100	6	5.61	90-100	2	1.87	90-100	46	42.99
100	12	11.21	100	33	30.84	100	12	11.21
No of eff. units	12	11.21	No of eff. units	33	30.84	No of eff. units	12	11.21
1st Quartile	0.4039		1st Quartile	0.4861				
Median	0.5701		Median	0.6731		Median	0.917504	
Mean	0.5903		Mean	0.7082		Mean	0.833935	
3nd Quartile	0.7329		3nd Quartile	1.000				
Max	1.000		Max	1.000		Max	1.000	

The table 3 shows the orientation of vine growers towards input savings with constant returns to scale technology and variable returns to scale technology. The average technical efficiency under constant returns to scale (CRS) and variable returns to scale (VRS) is 0.59 and 0.70 respectively. This result suggests that, on average, the grape farms in the sample could have achieved the same level of production using 30% less inputs in total. The average scale efficiency of the sample is 0.83, which means that most of the deviation from the efficient frontier is due to inefficient use of inputs and, to a lesser extent, to farms not operating at optimal size.

Technical efficiency scores vary with 33 farms being technically efficient based on variable returns to scale (VRS). There are 12 farms with optimal scale performance. The vast majority of farms in the sample achieved technical efficiency scores in the 50-80% range and scale efficiency scores in the 70-100% range. In addition, 27 farms in the sample faced serious problems of technical inefficiency, while almost 11% were fully efficient farms in the use of existing technology.

In the case of the constant returns to scale technology, the number of fully efficient farms out of the total of 107 is 12 and they are the ones that have defined the production frontier formed by the DEA methodology, while the remaining 95 growers are below it. The average technical efficiency of the sample is of the order of 0.59.

Also, the above table categorizes the values of technical efficiency from the lowest value (0.1) to the highest (1.0), thus creating a range (with a step of 0.1) and at the same time returns the number of farms that fall within this range and what percentage of the total number of farms this range corresponds to. More specifically, in the 60-70 category, 18 of the sample vine growers fall into the 60-70 category, which corresponds to 16.82% of the sample. While, in category E=1, there are 12 holdings in the sample, representing 5.61% of the sample.

Table 2 presents the distribution of the values of technical efficiency in the sample such that in the first quartile, i.e the 25% of the wine growers have efficiency $E \leq 0.40$, median value which is E=0.57 and mean E=0.59. In the third quartile, the 75% of farms have technical efficiency $E \leq 0.73$ as well as the maximum value obtained by the technical efficiency of the units under consideration.

In the case of variable returns to scale technology, the number of fully efficient farms out of the total 107, is 33, with a percentage of 30.84%, while the remaining 74 vine growers are below this production frontier. The average technical efficiency of the sample is of the order of 0.71.

In addition, the data are categorized by the values of technical efficiency from the lowest value to the highest and at the same time the number of wine growers falling within the range and the percentage of the total number of agricultural enterprises within this range is given. More specifically, in the 50-60 category, 15 enterprises in the sample fall into the 50-60 category, which corresponds to 14.02% of the sample. While, in the E=1 category, there are 33 wine growers in the sample, representing 30.84% of the sample.

The distribution of technical efficiency values of the sample is also reflected as the first quartile i.e. 25% of the sample farms has efficiency $E \leq 0.4861$, the median value which is E=0.6731, the mean with E=0.7082, the third quartile, i.e. 75% of the wine growers and the maximum value obtained for the technical efficiency of the units under consideration.

It is also worth noting that scale efficiency is that which refers to the deviation of a technically efficient production unit from the optimal production scale size. In the sample under consideration, the number of completely inefficient farms out of the total 107 is 12 with a percentage of 11.21%, while the remaining 95 farms are below this production frontier. The average scale efficiency is 0.83. In addition, 46 firms in the sample fall in the 90-100 category with a percentage nearly 43%.

In this context, DMUs are entities that use similar inputs in the production process of a product such as grapes. That is, DMUs are assessed for their efficiency relative to other DMUs. According to the results of a study investigating energy use efficiency and CO_2 emissions from grape production in Iran, most producers did not make proper use of inputs to increase their efficiency. This may be due to different levels of education or to the use of different and traditional methods of grape production [30].

It is worth noting that research should focus on the factors affecting the efficiency of wineries that have a positive impact on their profits, productivity and profitability. Wineries need to operate in a more rational way than in the past due to the ever-increasing grape production worldwide and the competition in this sector in order to maintain grape productivity for a long period of time [31].

Furthermore, the non-parametric DEA method has been applied to estimate the efficiency of wineries, in particular in a comparison between Italian and Spanish wineries. The results of the survey showed that wineries could achieve the same amount of production by using fewer inputs. In the period 2005-2013, technological progress had a positive impact on productivity growth, but the profitability of wineries decreased. This inefficiency may be due to the fact that producers are not aware of important aspects in grape production. In other words, they must make better use of production factors, adopt new technologies and improve production while maintaining quality [32].

One of the most interesting results is that the critical economic quantity for optimising the use of production inputs is different for grape and wine production and is determined according to the specificity of production. The analysis of the 2010 data confirmed the importance of size for grape and wine production, but also highlighted other elements indicating performance and efficiency. In grape production, overall profitability seems to be linked to both physical and commercial aspects, as factors related to production yields and those related to prices are important. In wine production, overall profitability appears to be linked to both physical and commercial aspects, as the factors relating to production yields and those relating to prices are important. In wine production, commercial aspects, in addition to the selling price of wine, are discriminating factors. In Italy, an article entitled "Efficiency analysis of Italian wine producers", studies the production conditions of viticulture, which differ from region to region and their efficiency level in 2005 and 2010 respectively. That is, it clarifies the points of the area and farm characteristics that influence efficiency. The efficiency in grape production is directly related to both the physical and commercial aspects of the product, while in wine production the commercial aspects and the selling price of wine differentiate the efficiency. [33]

5. Conclusions

In this paper, estimates of the technical and scale inefficiency of wine-grape growers in the Region of Western Macedonia are obtained using a non-parametric approach. The degree of technical efficiency is calculated relative to the best producing farms in the sample considered and was found to be lower than the degree of scale efficiency and thus a greater proportion of the overall inefficiency can be attributed to farms producing below production limits than to inefficient scale. Also, the calculation of technical efficiency with constant returns to scale presents obvious implementation difficulties. Estimates of technical efficiency under constant returns to scale always appear to be lower because of the way the production frontier is constructed. We also use the model measuring efficiency with variable returns to scale because the model with fixed returns to scale may be driven by the size of DMUs. In the specific case of the agricultural sector, wine-grape growers primarily influence the quantities of their inputs from which they try to produce the largest possible quantities of outputs.

The degree of technical efficiency indicates how well the winegrower uses the inputs for the production of the given product. In particular, there is scope for more efficient use of inputs in viticulture in the Region of Western Macedonia. It is necessary for a relatively small number of producers to achieve an improvement in their technical efficiency either to increase outputs using the same quantities of inputs or to maintain the same level of grape production by reducing the quantity of inputs. Scale efficiency, on the other hand, shows how much a farm uses economies of scale to increase its productivity. A farm that has a scale efficiency of less than unity may be due to the fact that it operates either under increasing scale efficiencies or under decreasing scale efficiencies. If the former is the case, the producer should increase the 'size' of his farm, while if the latter is the case, he should reduce it.

The modern demands of recent years have compelled the agricultural sector to address environmental standards, the energy crisis and climate change. Energy plays a dominant role in grape production and its more efficient consumption leads to the minimisation of environmental risks, the correct use of production factors and finally to the sustainability of farms. According to a study on energy efficiency in grape production, educated producers are more energy efficient than less educated producers [34]. Also, in a study in Iran where the energy efficiency of grape production in fields was measured, eight inputs were calculated with one output, that of grape production. The study of the use of inputs such as labour, machinery, fuel, electricity, water, chemical and organic fertilizers led to the conclusion that if chemical fertilizers, electricity, and fuel were reduced, there would be significant energy savings [35]. In the case of the 2021 survey in Iran, the energy consumed by the vine growers was calculated and distinguished between efficient and inefficient. The conclusion drawn is that using less chemical fertilizers, fuels and electricity results in optimizing the use of this energy [36].

The DEA method helped to understand which characteristics of the farms and specifically of the wine growers in the region of Western Macedonia can be differentiated so that the vine production can be more efficient. The role of combining inputs for efficient production (outputs) is important. In particular, it is a way to help public and private actors to achieve good practices and better support policy for vine growers for more efficient production with less wasteful use of inputs, elements that have become essential in recent times.

Furthermore, the viticulture sector is the ticket for the expansion of the tourism sector and in particular wine tourism. The development of alternative tourism nowadays is particularly well known and brings an increase in the individual incomes of producers, an improvement in the living standards of the region and the whole society, signaling a promising future with new daily challenges at individual, regional and national level.

In conclusion, it is worth emphasizing that DEA is a non-parametric method which does not account for random noise in its application. On the contrary, the SFA parametric method generates a stochastic technology boundary and does account for random noise. When SFA is applied and deviations of the observed input-output from the stochastic frontier occur, it may be not so much due to technical inefficiency as due to random factors such as weather conditions. This is therefore a subject for further research, to estimate the SFA model and to compare the results of these two models in this sample [37].

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