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Analysis of determinants of efficiency in grape farming – the case of Kosovo

This study analyses the performance of vineyards in Kosovo in terms of their technical, allocative, and economic efficiency. It uses two methods to measure efficiency: Data Envelopment Analysis (DEA) and Tobit regression. The data comes from a survey of 165 wine producers through face-to-face interviews in three regions of Kosovo – Rahovec, Suharake and Prizren – between the years 2016 and 2018, each yielding the average of inputs, outputs and prices for the three years. In order to determine the key variables for grape growing efficiency, it was necessary to consider the combined effects of the interactions between inputs, as this has an impact on overall final production. The results show great potential for improving the efficiency of viticulture. The average technical efficiency (TE) is 0.68, the average allocative efficiency (AE) is 0.77 and the average economic efficiency (EE) is 0.52. In general, TE, AE and EE were influenced by the selected variables, suggesting that the selected variables played quite an important role in enabling farmers not to use too many inputs in the production of grapes and instead to use them in appropriate proportions. It also shows how grape growers can improve their productive efficiency by adopting certain practices and identifying the key factors in their system.

Keywords: farms, grapes, DEA, Tobit regression, efficiency, Kosovo.

JEL classification: Q12

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Introduction

Agriculture is one of the most important sectors of the Kosovar economy. It contributes about 13% of GDP and accounts for 5.6% of employment. It is the main source of income in rural areas, where an estimated 60% of the population lives (KAS, 2018).

Kosovo has a long history of grape cultivation and wine production. The total area of vineyards in Kosovo in 2019 was 3,367 hectares, of which 74% were planted with wine grapes and 26% with table grapes, and the total grape production in 2019 was estimated at 19,318 tonnes. The total number of vineyards in 2018 was 7,963, while the total number of farms was 4,571. The average area of vineyards under cultivation over the period 2010-2019 was 3,204 hectares. In 2014, the total consumption of table grapes per capita in Kosovo was 5.2 kg (MAFRD, 2015; 2018).

Unemployment is a major problem in Kosovo, where an estimated 25.7% of the population is unemployed (KAS, 2019). One solution to this problem is the development of agriculture in general and viticulture in particular. The correlation between the number of productive hectares and employment is conducive to alleviating the unemployment problem, as about 37 jobs are created for every 100 hectares added (MAFRD, 2015).

Grapes are grown in different zones of Kosovo, but the regions of Rahovec, Suhareka and Prizren are dominant in all respects, whether one considers area under cultivation, production, number of vintners or number of farmers. In Kosovo, more than 60 varieties are cultivated and grown for various purposes. These can be divided into varieties of wine grapes and varieties of table grapes. Productivity can be divided into two components: efficiency change and technical change. Efficiency change reflects the ability of a firm to achieve maximum output, while technical change reflects the movement of the efficiency frontier due to technological change.

Measuring the efficiency of enterprises is very important because it can help researchers, policy makers and producers to make decisions. Hitherto, there has been insufficient economic research on wine production in Kosovo. Therefore, this study conducts an empirical analysis of wine production performance in terms of technical efficiency (TE), allocative efficiency (AE) and economic efficiency (EE); it also analyses specific aspects of farm performance using measures of farm efficiency. Our findings will help define a framework for Kosovo viticulture, given its great importance in the context of domestic production, providing an in-depth analysis of the current efficiency conditions with a view to outlining operational proposals in the context of the new agricultural policy agenda.

Literature review

The role of agriculture in economic development is undeniable, hence the need to focus on enhancing the development of the agricultural sector. Research is therefore needed to determine the contribution of various factors to agricultural performance.

The value of data envelopment analysis (DEA) in scientific research lies in its ability to assess efficiency in comparison to an individual or to the performance of a decision-making unit in a well-defined group of interests. DEA was developed by Charnes *et al.* (1978) based on the studies of Farrell (1957) and has since evolved considerably due to various enhancements that have ultimately resulted in the method used in this study. The main advantage of DEA analysis is that it allows researchers to take a global approach to a farm, taking all inputs and outputs into account at the same time (Coelli, 1995), instead of considering them in terms of yield per unit of input. By looking at a farm's performance in terms of economic efficiency - both technical and allocative - and input-output, we can examine the individual components of profit maximisation.

For recent reviews of these studies, see Battese and Coelli (1995), who constitute the main empirical reference on the determinants of technical efficiency in agriculture. Townsend *et al.* (1998) studied productivity and farm size, using relationships between winegrowers to advocate for rural development, while Guesmi *et al.* (2012) compared the production efficiency values of organic and conventional grape farms in Catalonia. Sellers-Rubio *et al.* (2016) studied the efficiency of Italian and Spanish wineries over a nine-year period and found that the annual production of wineries in both countries declined over this period. Urso *et al.* (2018) analysed the efficiency of wine and vine producers in Italy and indicated that a reduction in grape prices led to an increase in the efficiency of wine-producing companies.

An analysis of agricultural production performance is an examination of efficiency, and efficiency is an indicator used in EU rural policy: highly efficient farms are considered more viable. The few exceptions include Gul (2005), who measured the efficiency and productivity of apple production in Antalya, Turkey; Plénet *et al.* (2009), who measured the efficiency of peach and nectarine production in France; and Ymeri *et al.* (2017), who studied the impact of farm size on the economic efficiency of poultry farms in Kosovo. Abate (2014) assessed the impact of agricultural cooperatives on the technical efficiency of smallholder farmers by comparing the average difference in technical efficiency between cooperative members and similar independent farmers. Bravo-Ureta *et al.* (2012), Kaleb and Workneh (2016), Kumbhakar (2009) and Mwalupaso *et al.* (2019), Kovacs and Szucs (2020) as well as Mitsopoulos *et al.* (2021) have also analysed the technical efficiency of agricultural production. To summarise, there are many studies on the efficiency of grapes, olives, citrus fruits, and apples, but this is the first study to analyse the efficiency of viticulture in Kosovo.

Data and method

In order to analyse and measure performance in viticulture, a formal and theory-based methodology was required, using appropriate data sets for comparison. This study was conducted in two steps: in the first step, a data envelopment analysis (DEA) and in the second step, a Tobit regression analysis was conducted. The use of this model can help to determine which area-specific or farm-related characteristics influence the differences in observed efficiencies. The results are therefore useful in building up a useful body of knowledge for private and public actors to guide possible reforms of EU interventions in the sector.

Measuring the efficiency of agricultural production is of particular importance, as it is an important source of information for decision-making as well as for the formulation of appropriate agricultural policies. Inefficient production results from the inefficient use of scarce resources (Dessale, 2019). To measure efficiency, a non-parametric approach was adopted using the DEA technique developed by Charnes, *et al.* (1978), Bournaris *et al.* (2019), Cook and Seiford (2009) and Zhou (2018). DEAP (v2.1) software was used for the calculations of DEA (Coelli, 1996). DEA is a mathematical linear programming technique that uses a frontier approach where the frontier function is a 'best practice' technique against which the efficiency of producers within the sample can be measured. The model allows individual and multiple efficiency analyses to be conducted for more than one producer and permits many inputs and outputs to be analysed using different units of measurement.

The production technique explains an output or input perspective. EE can be decomposed into TE, which measures the ability of the farm to produce more output with the same inputs or to produce the same output with fewer inputs, and AE, which measures the minimisation of input costs as calculated by the quantity of inputs and their unit prices. The combination of these two measures gives EE.

In DEA, "0" and "1" are used to represent efficiency values, with "1" corresponding to full efficiency. The choice of economic scale depends on the characteristics of production. When production is influenced by external factors, the variable returns to scale (VRS) assumption applies, and when enterprises operate at optimal size, the constant returns to scale (CRS) assumption is preferred. In the case of grape growing, it cannot be assumed that all growers operate at optimal scale, as grapes are very sensitive to external factors such as climatic and demographic influences, diseases, pests, and the ability of growers to carry out all necessary operations in the right way and at the right time.

Consequently, a DEA model of VRS was applied, where the technical input-based efficiency for each farm was obtained by solving a linear equation assuming VRS:

$$\begin{aligned} & minimize_{\beta_i\lambda}\ \beta i \\ & \quad -y_i + Y\lambda \geq 0 \\ & \quad \beta X_i - X\lambda \geq 0 \\ & \quad M1\lambda = 1 \\ & \quad \gamma \geq 0 \\ & \quad \beta_i \in (0,1) \end{aligned} \tag{1}$$

where*:*

βi is a scalar that also measures the technical efficiency for farm i; X and Y are matrices of the inputs and outputs of all farms in the observation M; $Y\lambda$ and $X\lambda$ are the efficient projections on the frontier, and $M1\lambda = 1$ is a constraint for measuring VRS.

The values of technical efficiency obtained under VRS and CRS were used to obtain a measure of scale efficiency:

$$SE = \frac{\beta_{CRS}}{\beta_{VRS}} \tag{2}$$

Moreover, the determination of economic efficiency began with the solution of the cost minimisation problem:

$$\begin{aligned} &minimize_{\lambda x_i}\ \upsilon_i x_i^* \\ &\quad - y_i + Y\lambda \geq 0 \\ &\quad x_i^* - X\lambda \geq 0 \\ &\quad M1\lambda = 1 \\ &\quad \gamma \geq 0 \end{aligned} \tag{3}$$

where: υ_i is a vector of input prices; x_i^* is a cost-minimising vector of input quantities, given the prices υ_i and the output level *Yi*; and $M1\lambda = 1$ is a constraint on VRS.

The economic efficiency calculation was:

$$EE = \frac{v_i x_i^*}{v_i x_i} \tag{4}$$

The allocative efficiency calculation was:

$$AE = \frac{EE_i}{\beta_i} \tag{5}$$

Tobit regression was used for the regression analysis (Amemiya, 1974). The Tobit model evaluates the relationship between x_i (a vector of independent variables) and y_i (a non-negative dependent variable). z_i is an error term.

The model can be written as:

$$y_i = \begin{Bmatrix} y_i & if\ y_i < 1 \\ 1 & if\ y_i \geq 1 \end{Bmatrix} \tag{6}$$

$$y_i = \delta_0 + \delta x_i + z_i \tag{7}$$

where:

$z_i \sim M(0, \sigma^2), \quad i = 1, 2$

Data were obtained from interviews with farmers and represented farm characteristics, including inputs, prices, and production characteristics. The sample consisted of 165 grape farms in three regions of Kosovo: Rahovec, Suharake and Prizren. The study used average production data for the years 2016-2018.

Variables and hypotheses

Variables were divided into two groups: DEA variables and farm variables. DEA variables were divided into three categories: output variables, input variables and input prices, which are explained below.

Average revenue (AR) – represents the average revenue value received by a particular farm for all grape production during the period 2016-2018. This is our output variable.

The following variables were treated as our input variables:

Average quantity of fertiliser (AQF) – represents the average quantity of fertiliser applied during the period 2016-2018. This variable was measured in kilograms and normalised per hectare.

Average number of chemicals (ANCh) – indicates how often the plantation was treated with chemicals. The variable was expressed as the number of chemical treatments.

Average hired labour (AHL) – represents the average amount of labour hired, measured as the number of days of labour paid for per hectare.

Average cost for energy and services (ACES) – represents the energy and services paid for on the farm, normalised per hectare.

The following variables were representing our input prices:

Average price of fertilisers (APF) – represents the average price paid by farmers for one kilogram of fertiliser during the analysed period.

Average price for chemical treatment (APCh) – represents the price paid for chemical treatment per hectare.

Average price of labour (APL) – represents the average daily wage paid during the period 2016-2018.

Average price of service (APS) – represents the average price of services paid by farmers, normalised per hectare.

Farm variables were classified into four categories: resource endowment, production, input use, and the economic dimension, which are explained below.

Resource endowment was represented by four variables: farm area, farm irrigation and farm machinery value. *Total farm area (TFA)* was measured as the average utilised area of each farm included in the study during the period 2016-2018, expressed in hectares.

Hypothesis 1: TFA has a negative influence on farm efficiency.

Total irrigated area (TIA) was measured as a proportion of the total utilised area and expressed as a percentage (%). The impact on farm efficiency is explained by Haji and Andersson (2006), who show a positive impact on efficiency outcomes.

Hypothesis 2: TIA has a positive influence on farm efficiency.

Average machinery value (AMV), as reported by each farm. Grape production is labour-intensive, so many machines reduce efficiency because farmers will not be able to make the best use of all machines. Or conversely, advanced machinery increases efficiency. Asset value has a positive effect on efficiency (Haji and Andersson, 2006).

Hypothesis 3: AMV influences efficiency.

Production was represented by farm yield as average grape production on each farm (QY), expressed in kilogrammes and normalised per hectare. The expectation was that higher yield could lead to higher efficiency.

Hypothesis 4: QY has a positive influence on farm efficiency.

Input use was represented by the cost of materials and labour paid by each farmer. *Material cost (MC)* was the average cost paid by each farmer in 2016-2018 for the production materials used, normalised per hectare. *Labour cost (LC)* was the average cost paid for hired labour in 2016-2018.

Hypothesis 5: MC and LC have a negative influence on farm efficiency.

Economic dimension was represented by total production (TO), which was the average value of grape production in each farm. Carvahlo *et al.* (2008) use the value of total production and net income as indicators of the economic size of the farm and have found positive influences.

Hypothesis 6: TO has a positive influence on farm efficiency.

Results and discussion

Table 1 presents a description and summary of the variables used and the characteristics of each variable.

Results show that almost 97% of farms in Kosovo should focus on reducing input use and increasing the size of their farms. Unfortunately, the largest extent of change (59%) was an increase in the use of labour, energy consumption

Table 1: Description and summary statistics of the DEA variables (Average values for the period 2016-2018, n = 165).

Variable	Unit	Mean	Min	Max	Std. Dev.
DEA, efficiency variables					
Average revenue (AR)	€/ha	2,121.24	412.14	6,348.00	1,002.11
Average quantity of fertiliser used (AQF)	kg/ha	224.07	50.00	644.44	111. 36
Average number of chemical treatments (ANCh)	No.	4.17	2.00	8.00	0.7
Average hired labour (AHL)	wages/ha	16.64	0.36	63.93	8.77
Average cost for energy and services (ACES)	€/ha	271.25	117.98	1,704.03	139.58
Average price of fertilisers (APF)	€/kg	0.41	0.31	0.67	0.09
Average price of one chemical treatment (APCh)	€/ha	64.93	23.18	130.58	18.81
Average price of labour (APL)	€/wage	9.78	8.52	12.64	0.74
Average price of service (APS)	€/ha	43	26.57	169.43	12.9
Farm variables					
Resource endowment					
Total farm area (TFA)	ha	1.86	0.25	8	1.26
Total irrigated area (TIA)	%	64	0	97	0.33
Average machinery value (CMV)	€	5,264.47	0	45,309.69	4,773.29
Production					
Yield produced at the farm (QY)	kg/ha	12,245.53	3,500.00	28,200.00	3,478.25
Input use					
Cost of materials used (MC)	€/ha	691.15	289.42	1,995.18	196.28
Cost of labour used (LC)	€/ha	183.1	2.9	774	99.78
Economic dimension					
Total output (TO)	€	3,786.11	218.87	26,006.89	3,212.33

Source: Own calculations

Table 2: Frequency distribution and summary statistics for efficiency scores (average values for period 2016-2018, n = 165).

	Efficiency scores (VRS)			Scale efficiency		
Efficiency	**TE**	**AE**	**EE**	**CRS**	**VRS**	**SE**
≥ 0.90 ≤ 1.00	8	22	1	3	8	6
≥ 0.80 < 0.90	15	53	3	2	15	20
≥ 0.70 < 0.80	47	60	7	6	47	40
≥ 0.60 < 0.70	60	22	20	10	60	42
≥ 0.50 < 0.60	29	6	66	24	29	33
≥ 0.40 < 0.50	3	2	59	54	3	15
≥ 0.30 < 0.40	2	-	8	48	2	6
≥ 0.20 < 0.30	1	-	1	14	1	2
≥ 0.10 < 0.20	-	-	-	4	-	1
≥ 0 < 0.10	-	-	-	-	-	-
Mean	0.680	0.772	0.521	0.414	0.680	0.622
Min	0.348	0.417	0.211	0.103	0.348	0.126
Std. dev	0.116	0.101	0.115	0.131	0.116	0.132

Note: maximum value for the efficiency scores is 1.
Source: Own calculations

and services. Fertiliser use (36%) could also be a source of inefficiency. The result of the frequency distribution analysis is shown in Table 2, which provides detailed information on the efficiency parameters.

Table 2 shows that 65% of farms had TE values in the range 0.60-0.80; the lowest TE value was 0.35. TE could be increased by an average of 32% if farmers adjusted input use according to best practice. The average TE value was 0.68, the average AE value was 0.77, and the average EE value was 0.52. Complete TE was recorded on five farms, and complete EE was a feature of only one farm. Analysis of scale efficiency showed that 98% of the farms were operating at increasing scale (IRS), one farm was operating at decreasing scale (DRS) and two farms had full scale (SE).

The average value for AE was 0.77, the lowest value for AE was 0.42 and full AE was only achieved on one farm. This shows that a cost reduction of 33% is possible if farmers get better inputs at better prices. In addition, 68% of the farms operated within a AE range of 0.70 to 0.90. EE was calculated as a combination of TE and AE and the average value was 0.52, which means that there is a potential for efficiency improvement in the order of 0.48 if all farms become as efficient as the farms adopting best practice.

Moreover, Tobit regression analysis was used to determine the relationship between the DEA efficiency variables and the farm variables, where TE, AE and EE were dependent variables, and the farm characteristics were explanatory variables. The results are presented in Table 3.

The results presented in Table 3 show the differences between the coefficients TE, AE and EE resulting from the selected variables of the grape farms. Evidently, most of the selected variables have a significant influence on TE, AE, and EE. The results show that TFA has a significant negative influence on farm efficiency, which confirms hypothesis 1. In addition, TFA has an influence on TE, AE, and EE. TIA is significantly negatively associated with TE and EE, while AMV was not found to have a statistically significant relationship with farm efficiency.

The significant positive influences of operating efficiency (QY) and total output (TO) on operating efficiency were confirmed, but TO has an influence on TE, AE, and EE, while QY only contributes to the variation of AE and EE. It was hypothesised that MC and LC have a negative influence on operating efficiency and negative influences were expected. This hypothesis was only partially confirmed, as these two variables were found to have a negative influence on farm efficiency in general, but a positive influence was found for AE specifically.

In general, TE, AE and EE were found to be influenced by the selected variables. This shows that the selected variables are quite important and that farmers should not use too many inputs in the production of grapes and should use these inputs in appropriate proportions.

Conclusions

The aim of this study was to provide an empirical analysis of the performance of grape production in farms in Kosovo, assessed in terms of technical, allocative, and economic efficiency, and to relate production to efficiency scores. An analysis of efficiency using a DEA model allowed us to examine the determinants of efficiency of grape producers in Kosovo.

We conclude that most of the variables used in this study have a statistically significant impact on farm efficiency, increasing TE by 32%, AE by 23% and EE by 48%. The scale efficiency analysis showed that TE was on average 41% below CRS and 68% below VRS. In addition, 98% of the farms were operating under IRS, one farm was operating under DRS and two farms had full scale efficiency.

The results confirm that farm efficiency improves significantly when farmers manage to apply optimal combinations of inputs. They show how grape growers can improve their productive efficiency by adopting certain practices and identifying the key factors of their system. In this context,

Table 3: Tobit regression between the DEA efficiency variables and the farm variables (average values for the period 2016-2018, n = 165).

Variable	TE	AE	EE
Resource endowment			
Total farm area (TFA)	-0.0013**	-0.0033***	-0.0034***
Total irrigated area (TIA)	-0.0211**	0.0033	-0.0254*
Average machinery value (AMV)	2.20E-08	-2.32E-08	-1.28E-08
Production			
Yield produced at the farm (QY)	0.0001	0.0001***	0.0001***
Inputs use			
Cost of materials used (MC)	-0.0001***	0.0001*	-0.0001***
Cost of labour used (LC)	-0.0002**	0.0001*	-0.0001
Economic criterion			
Total output (TO)	2.12E-07***	2.08E-07***	3.50E-07***
Constant	0.8111***	0.5278***	0. 5146***
Log likelihood	200.1350	224.59312	215.2133
Pseudo R2	-0.2229	-0.2100	-0.2270
Sigma	0.1023	0.0547	0.0603

Note:* Statistical significance level at 10%, ** statistical significance level at 5%,*** statistical significance level at 1%.
Source: Own calculations

agricultural growth should only be supported if it is accompanied by measures to strengthen management capacities. Farmers need to focus on irrigating the entire area, using fewer tenants, using and paying for fewer inputs, and replacing older grape varieties with new ones to achieve higher value per hectare. Also, the new Rural Development Regulation should put more emphasis on specific measures for small and medium-sized farms that need a restructured production environment.

Conditions can be further improved by educating and training farmers in the proper use of inputs and for certain skilled activities. Strengthening extension capacities and cooperation are appropriate means to deliver these services. This requirement is also found in the EU agricultural policy, which sees investment in human capital and skills as crucial for the development of growth and employment opportunities in rural areas.

Based on the findings of the study, our suggestions for strategy and policy development can be put forward:

- Policy makers need to focus on increasing the production rate of productive farmers by providing them with easier access to financial and credit services. Productive farmers who have more working capital can operate on a larger scale and offer diversified products.
- Policy makers need to take effective measures to reduce input costs.
- Policy makers need to build communication platforms for farmers and other supply chain members to create long-term and closer relationships between them.

This paper has some limitations. The focus is only on Kosovo. Further cross-country research could be useful to confirm our findings in other areas, and more research needs to be done, including on our case (i.e. the role of price in influencing productivity), to provide more evidence on this topic.

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