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Determinants of Technical Efficiency and Production Costs in Small-Scale Apple Farms in Albania

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Abstract The aim of this research is to identify the factors that influence the technical efficiency of total production costs in apple farms, addressing some of the complexities posed by small-scale farming, within the regional and national context. The data of the study were collected from 150 randomly selected apple farms in Korca district, one of the major apples growing regions in Albania. The methodology approach consists of an econometric modelling of the factors that affect farm efficiency, capitalizing on the utility of the Stochastic Frontier Analysis (SFA), as a tool for gauging the spectrum of technical efficiency levels exhibited by apple farms. The findings reveal the substantial impact exerted by various factors such as farm size, irrigation, the deployment of capital stock, and the quantity of pesticides and fertilizers upon the technical efficiency of the total production costs. Farmers involved in apple production can improve the efficiency level by improving the irrigation techniques, and optimizing the quantity of fertilizers and capital stock. Also, apple producers in Albania may overcome yield instabilities by extending the area planted with apples.

Keywords Agricultural Farms, Total Costs, Technical Efficiency, Econometric Modeling

1. Introduction

Agriculture is considered one of the most important sectors in Albania. Its contribution to the national GDP accounts for 17,66%, while it employs 43% of the total workforce [1]. Although, it should be determined that due to the high level of informality the sector encounters, the value of the agricultural production is higher, while around 86% of the agricultural farms are considered as small-scale farms. Despite the positive trends shown during the last decades, in terms of farm consolidation, the competitiveness of the agricultural sector is negatively affected by the small size of the farms.

Agricultural economy, in the region of Korça provides 29-30% of the total production, while, it is foreseen that this share will remain unchanged even in the upcoming years. This region is the most important in terms of apple production in Albania, due to the climatic conditions, making it suitable for the cultivation of fruit orchards. Apple production occupies the first place in family consumption among all other fruits (around 37%), while the production of fruit trees in 2022 was 295,428 tons, 2.86% higher compared to 2021. Korça region accounts for 62.97% of the total apple production at the national level [2].

Cachia, and Franck [3] define the dependence of agricultural productivity on the type and quality of the inputs used during the production process and also the combination between them, justifying the existence of differentiated productivity targets. Consequently, the inefficient level of used production inputs can create scarcity among apple farms. In this context, the results of the study generate insights and are related to the efficiency gap of small-scale apple producers in Albania.

Among these factors, Minga et al [4] analyze the impact of different factors such as: education, age, the amount of fertilizer used, the surface of apple and irrigation, arguing that these variables have influenced the increase of apple production.

During the transition period, the state has supported the development of the agricultural sector through various programs and policies. Thus, up to 2007, the agricultural support policies were mainly focused on investments aiming to rehabilitate irrigation and drainage, increasing food security and agricultural services. Later on, the implementation of support measures in the form of direct payments was applied, aiming to increase competitiveness and support farm incomes of farmers involved in fruit production. In addition to addressing basic data requirements, there is a need to better define and measure concepts related to productivity, such as technical and economic efficiency.

Thereby, Marku et al [5] point out that farmer's subsidies in the form of direct payments have an important impact on the area cultivated with orchards and productivity. Coelli et al [6] in their study determine that the performance is not only limited to the financial dimension but is also evaluated by the capacity of a production unit to "better" produce, using the available factors of production. Parallelly, Djimasra [7], describes it as the ability of a firm to produce efficiently with the limited available resources.

Previous studies, carried out by various researchers, point out that the income generated from on-farm and off-farm operations, has a moderate influence on the area cultivated with fruit orchards. In addition, the productivity of orchards is influenced by the cultivated area and yields, improvements on the varietal structure, labor, and technology. Meanwhile, another component that affects incomes and well-being of farmers communities is the efficient use of resources, implying a significant impact on the technical efficiency of agricultural farms. In this context, Amores et al [8], conducted an efficiency analysis in the olive sector, defining that the efficiency is positively related to the size of the farm and as a consequence it can be improved by improving the irrigation system as well as the planting of new orchards.

According to Ghali et al [9], technical efficiency is defined as the firm's ability to utilize resources optimally, referring to the farm's ability to avoid the misuse of available resources, while, Saucier et al [10], comprise the variables of production and yield in the concept of efficiency, illustrating the relationship between input and output resources, and their best use in terms of productivity.

The technical efficiency is mainly used to compare the level of gross output with the level of inputs (land, labor, variable costs, and capital). Except for the factors of production, Karimov [11], analyzes even age and education as other potential factors influencing efficiency, as well as on-farm diversification activities. Various authors [12,13], argue that the impact of economic diversification's activities on the level of technical efficiency is justified by the increasing interest that institutional bodies and scholars are assigning to such activities that are seen as drivers of economic sustainability for farmers.

Farrel [14], determines that the concept of technical efficiency is measured by the best practices in the sector. In other words, it measures how a firm utilizes the inputs used in the production process. He provided a theoretical rationale based on the microeconomic concept of the Marginal Rate of Substitution (MRS), defining the concept of economic efficiency and dividing it into two terms: technical efficiency and allocative efficiency. In the economic literature, the term efficiency refers to three forms of productivity: technical, allocative and economic.

Osmani et al [15], assessed the perception of farmers on their willingness to invest in small-apple farms, identifying a set of constraints that influence their decision. Accordingly, they defined that major factors with a positive effect on technical efficiency are the access to advisory services, average plots size, and the number of apple plots. Education and proportion of orchards under modern technology have negative effects, while age, and farmer's experience are not significant. Measures to support planting of apples should take into account the size of plots.

For more than half a century, various authors have continuously explained the concept of efficiency. Koopmans [16], proposed a measurement of the efficiency concept, related to production analysis, while, Debreu [17], measured efficiency empirically, through utilization of resource coefficients (output-input ratio measurements), in order to describe the maximum of an equivalent-proportional reduction of all inputs that allow the production process.

Timmer [18], developed a measure of technical efficiency using the marginal production function, comprising forty-eight US states, estimating the potential marginal output that a farm could produce if it were at the production frontier.

Technical efficiency models are widely used in farming system analysis to study the technical performances of farms [19,20]. These models determine first the technical efficiency of farms and then the factors that influence the efficiency.

Maietta [21] defines the estimation of technical efficiency of the farms as important for understanding if the farmer's is "doing things right". Its estimation allows to better understand if farms are properly using their available inputs, as well as the possible income gains that derive from the efficient use of resources. Thus, it provides a measure of how the decision making of the farms supports its sustainability [22,23].

While the technical efficiency measures the capacity of transforming resources, by measuring the level of the observed production process to a standard of optimality, the "Efficient production frontier" is defined as a productivity measure of the technological ground, through which such transformation is possible [24,25].

According to Bégin [26], "studying technical efficiency is of great interest for companies and governments", providing the possibility to address policies towards using more effectively the factors of production". In our case, the results of this study provide valuable feedback for farmers, policy makers and stakeholders to better address their policies in order to improve the technical efficiency of farms and diminish costs of production.

The study aims to evaluate the determinants of technical efficiency associated with the cost of apple production in the region of Korca. The specific research objectives consist of:

- Identification of factors that affect the technical efficiency of apple production costs.
- Evaluating technical efficiency of small-scale apple farms, focusing on the optimal use of resources and the minimization of production costs.
- Providing knowledge and recommendations to farmers and policy makers for improving technical efficiency of production costs.

The next session discussed the methodology approach used in the study in order to define the significance of the factors that influence technical efficiency of the production costs in apple farms.

2. Materials and Methods

Part of the research is on agriculture farms that have as a primary activity the production of apples (referred as population), pursuing their activity in the most well-known administrative units of Korca region.

The sample consisted of 150 respondents, selected from a population of 566 farms. The applied reliability level is 93%. The factors analyzed in this study as determinants of the total cost of production consist of the following:

- Production
- Incomes
- Working days
- Quantity of pesticides
- Quantity of fertilizers
- Farm area
- Irrigation
- Interaction type with irrigation
- Capital stock
- Irrigation type

The methodology approach applied consists of econometric modelling of the factors that mainly affect farm efficiency. The research hypothesis consists of the following:

H1: There is no significant difference in the levels of technical efficiency between apple farms.

H2: There is a significant difference in the levels of technical efficiency between apple farms.

H3: Identified factors such as the cultivated area, technology, capital, and quantity of fertilizers have no significant impact in the technical efficiency of the production costs.

H4: Identified factors such as the cultivated area, technology, capital, and quantity of fertilizers have a significant impact on the technical efficiency of the production costs.

The type of research used in this study is a combination of quantitative and qualitative research. Mixed research does not simply consist in the collection and analysis of two different categories of data (qualitative and quantitative), but involves their continuous use, thus increasing the power of a study compared to studies that use only one type of research [27].

With reference to the objective of the research, the sample of the population used in this study is intentional. Cooper et al [28], define that the researcher chooses the sample in accordance with the objective of the study.

Efficiency assessment can be attained by applying several methods. In this study, the Stochastic Frontier Analysis (SFA) method is used, focusing on the use of the translog or the Cobb-Douglas model. Greene [29], defines two main functions of evaluation models: simple functional forms, of the Cobb-Douglas type, and flexible functional forms of the translog type. The trans-logarithmic production function is flexible and provides an easier estimation of the production technology and technical efficiency levels. Comparing the elasticities obtained from the derivatives of the translog function with the ones that derive from the Cobb-Douglas, more details in terms of flexibility are provided.

Cobb-Douglas production function is based on limited assumptions. In particular, it considers constant factor elasticities while they depend on the factor level for a trans logarithm production function [30]. The translog function allows them to change from period to period. Consequently, the functional form of the translog model imposes fewer restrictions on the structure of production, on the levels of elasticity of substitution and on the products of scale, allowing the application of econometric analysis.

According to Battese et al [31], the Stochastic Production Frontier, is proposed in a general functional form as defined below:

$$y = f(xi, \beta) \exp(\varepsilon i) \quad (1)$$

Where,

y: output

x: vector of used inputs

β – vector of unknown parameters

ε – error term

Thus,

$$\varepsilon = \mathrm{v} - \mathrm{u} \quad (2)$$

v - a random component assumed to follow a normal density (0. σ2 v)

u - a random non-negative component, representing technical inefficiency

The inefficiency term of u can be calculated indirectly by assuming different forms of its distributions. One of the most common forms of calculation is by using the semi-normal distribution. Accordingly, it is estimated that:

$$u \sim N(0, \sigma_u^2) \quad (3)$$

$$v \sim |N(0, \sigma_v^2)|$$

The u value is calculated using the Jondrow formula (1982):

$$\hat{u}_i = \frac{S\delta}{1+\delta^2}\left[\frac{\Phi(\omega)}{1-\varphi(\omega)} - \omega\right] \quad (4)$$

$$\omega = e\delta \,/\, SS = SQRT(Su^2 + Sv^2) \quad (5)$$

$$\delta = Su/Sv \quad (6)$$

φ defines the density and ϕ is the Cumulative Distribution Function (function of the normal standard distribution. Technical Efficiency of production (TE) is defined as:

$$TE_i = exp(-u\mathrm{i}) \quad (7)$$

$$TEi = [\frac{\phi\left(\frac{wi}{S} - S\right)}{\phi\left(\frac{wi}{S}\right)}] * esp \ \left(\frac{S^2}{2} - wi\right) \quad (8)$$

$$\omega = -\mathrm{e}\frac{S_u^2}{S^2} \qquad S^2 = \frac{S_u^2 S_v^2}{S^2} \qquad S^2 = S_u^2 + S_v^2 \quad (9)$$

The Technical Efficiency (TE) for the defined sample is calculated as follows:

$$TE = 2\Phi(-S)^* \, exp\left(\frac{S_u^2}{2}\right) \quad (10)$$

The main models used for the estimation of the efficiency are: Cobb-Douglas in logarithmic form, translog and quadratic models. In this study, the Cobb-Douglas model in log form is used, as defined below:

$$ln\,\mathrm{Y} = a_0 + \sum_{i-1}^{k} a_i \, ln\, X_i + v - u \quad (11)$$

Where:
Y – output
Xi – used inputs

3. Results

In order to calculate the technical efficiency, the estimation of the model along with the other parameters (Su, Sv) is performed, using a maximum likelihood estimation procedure (MLE).

The analysis of the production costs in apple farms is an important instrument that precedes the analysis of technical efficiency, providing a more complete argument. This analysis is necessary because the applied SFA method for efficiency assessment requires preliminary estimations of the multifactorial model parameters. Table 1 summarizes the estimated economic models of the production costs. All the models and factors are defined as significant, while the model categories are linear and logarithmic. From the linear model it is obtained information about the natural terms of the cost's variability compared to the changes of the identified costs of production.

Table 1. Models of the factors that influence total production costs

No	Models
1	$TC = 13.2(***) - 0.321(***)(CC) + 0.346(***)(WD) + 0.794(***)QP - 0.11\ (OT) + 0.07\ (ITI) + e$ $R^2 = 0.844$
2	$l\_TC = 8.75(***) + 0.2675(***)\ l\_I + e$ R^2=0.2
3	$l\_\ TC = 22.37(***) - 0.86(***)\ log\ (CC) + 1.426(***)\ log\ (FA) + e$ R^2=0.577
4	$l\_TC = 8.955(***) - 0.084(**)\ l\_CA + 0.034\ (***)\ IAC + 0.079\ (***)\ l\_Q + 0.549\ (***)\ l\_QF + 0.275\ l\_WD\ (***) - 0.027\ (***)\ ITI + e$ R^2=0.952

**TC – Total cost
CC – Capital costs
WD – Working days
ITI – Interaction type with irrigation
FA – Farm size
CA – Cultivated area
QF – Quantity of fertilizers
IAC – Irrigation area cultivated with apples
Q – Production
QP – Quantity of pesticides
OT – Orcharding type
I – Income

In order to assess the efficiency, the linear econometric model of the total cost is estimated, through the Ordinary Method of Least Squares. According to the SFA methodology, the parameters of this model are necessary for estimating the coefficients of the efficiency model by the Maximum Length Method. The linear econometric model of the total costs, in compliance to model 1 is shown in Table 2.

Table 2. The model of the factors that determine total cost and apple production

	Coeficcients	Standard Error	t	Probability value	
Constant	13.2080	0.583254	22.65	2.64e-049	***
Capital costs	-0.321326	0.0441238	-7.282	1.97e-011	***
Working days	0.345698	0.0373116	9.265	2.57e-016	***
Quantity of pesticides	0.793709	0.0541255	14.66	2.31e-030	***
Orcharding Type	-0.123633	0.0353139	-3.501	0.0006	***
Interaction Type with Irrigation	0.0705334	0.0191663	3.680	0.0003	***

*Significance level 0.1; ** Significance level 0.05; *** Significance level 0.001;

Mean dependent var	12.59863	S.D. dependent var	0.268393
Sum squared resid	1.673210	S.E. of regression	0.107794
R-squared	0.844108	Adjusted R-squared	0.838695
F (5, 144)	155.9435	P-value (F)	2.81e-56
Log-likelihood	124.3511	Akaike criterion	-236.7022
Schwarz criterion	-218.6383	Hannan-Quinn	-229.3634

The regression analysis shows that the variables capital costs, working days, quantity of pesticides, orcharding type, and interaction with irrigation significantly influence total costs in apple production. The model explains a substantial proportion of the variability in the dependent variable.

After identifying the main factors that determine the total production costs on apple farms, the coefficients of the model provided above are used as initial estimates of the technical efficiency, by applying the MLE (Maximum Likelihood Estimation). In addition, the evaluation of the efficiency model consists of the following:

Table 3. MLE of technical efficiency of total costs in apple production

	Coefficient	Standard Error	z	Probability value	
b0	11.2357	0.871309	12.90	4.79e-038	***
b1	- 0.182974	0.061404	- 2.980	0.0029	***
b2	0.271483	0.060446	4.491	7.08e-06	***
b3	0.766713	0.085657	8.951	3.53e-019	***
b4	- 0.0570526	0.042746	- 1.335	0.1820	
b5	0.0569977	0.031204	1.827	0.0678	*
Su	0.171973	0.017034	10.10	5.77e-024	***
Sv	0.0286152	0.013992	2.045	0.0408	**

Log-likelihood 170.4288 Akaike criterion - 324.8577

Schwarz criterion - 300.7726 Hannan-Quinn - 315.0727

The MLE results show that certain coefficients (b0, b2, b3, Su, Sv) significantly impact the technical efficiency of total costs on apple production, indicating marginal influences.

Table 4 below displays the main indicators of the technical efficiency related to the costs of production. These indicators provide insights on how the production costs can be efficiently managed on apple farms.

Table 4. Technical efficiency indicators of production costs

Mean	Median	Minimum	Maximum
1.14649	1.09280	0.961990	1.86037
Std. Dev.	C.V.	Skewness	Ex. Kurtosis
0.159036	0.138716	2.35727	6.26092
5% Perc.	95% Perc.	IQ range	Missing obs.
1.01011	1.50413	0.125968	0.000000

According to the summary of the results as provided in the table above, it is observed that the average mean of the technical efficiency related to the production costs is 1.146, indicating that the same production quantity could be achieved with 15% lower costs. The closer the value of the efficiency index is to 1 (or 100%), the more efficient the production costs incurred. From the estimates in Table 4, it is noted that there are farms operating at a high inefficiency level, incurring 86% higher costs, as indicated by the maximum value of the efficiency index, while the variance coefficient 0.138 (relatively low), provides evidence that in general apple farms

Albania is homogeneous in terms of the production costs and efficiency. In addition, the information provided above confirms the H1 hypothesis that there is no significant difference in the levels of technical efficiency between the apple farms that are part of the study.

The next step consists of the analysis and identification of potential factors that influence the efficiency of total production costs. The following table presented the estimated results of the model, using the ordinary least squares (OLS) method.

From the analysis of the values provided in Table 5, it is observed that the coefficients are highly significant, with probability values < α (0.001). The R^2 (the coefficient of determination) is 0.65, indicating that 65% of the overall variation in efficiency is determined by the variation of the 5 identified factors. The correlation coefficient $\boldsymbol{R = \sqrt{0.65} = 0.80}$ indicates a strong linear relationship between efficiency of production costs and its factors. The evidence from the regression analysis as shown in the table above confirms the H4 hypothesis that the factors such as irrigation, cultivated area, capital stock, quantity of fertilizers, and labor have a significant impact in the technical efficiency of the total production costs.

Table 5. Model of technical efficiency factors of total production costs

	Coefficient	***Std. Error***	***t-ratio***	***p-value***	
Constant	1.04832	0.0346794	30.2290	<0.00001	***
Irrigation	-0.074297	0.0132793	-5.5950	<0.00001	***
Cultivated area	0.0201335	0.00554897	3.6283	0.00040	***
Capital stock	-1.79282e-08	6.18617e-09	-2.8981	0.00434	***
Quantity of fertilizers	-0.000204063	4.94639e-05	-4.1255	0.00006	***
Working days (labor)	6.07299e-06	4.24585e-07	14.3034	<0.00001	***

*Significance level 0.1; ** Significance level 0.05; *** Significance level 0.00

Mean dependent variable	1.146488	S.D. dependent variable	0.159036
Sum squared res	1.329614	S.E. of regression	0.096091
R-squared	0.647182	Adjusted R-squared	0.634931
F (5, 144)	52.82852	P-value(F)	6.59e-31
Log-likelihood	141.5902	Akaike criterion	-271.1804
Schwarz criterion	-253.1166	Hannan-Quinn	-263.8416

The area planted with apples has a positive effect on technical efficiency. This shows that it is possible to overcome yield instabilities by extending the area planted with apples, and to a lower margin, by increasing the plantation density, which is consistent with other research studies [32].

Due to the small farm size, most of the farmers involved in apple production possess amortized agricultural machinery, incurring high inefficiency levels on the total production costs.

Irrigation and drainage are among the key factors defined for increasing the production per unit area, as well as farmers' incomes generated by the agriculture sector. In this context, the irrigation systems applied in apple farms have a substantial role in the efficiency of production costs. According to the responses to the survey, only 20% of the farmers have invested in improving the irrigation system, providing evidence that apple farms in the studied area have a high level of inefficiency of total production costs. This is confirmed by the values of the irrigation coefficient (-0.074), displayed in Table 5.

4. Discussions

The importance of this study can be seen in several aspects. First, the efficiency measures at the farm level in a particular region are studied. Second, the study considers the technical efficiency of production costs, and also defines the main determinants of technical efficiency at the farm level.

The main purpose of this study is to analyze the factors that influence the technical efficiency of total production costs of small-scale farms, an aspect that has been recently part of many debates related to the agriculture sector.

The interpretation of the econometric estimates by using the Stochastic Frontier Analysis allows us to process a remarkable quantity of data sets and get the most important aspects of the study. As a consequence, we can identify the limitations faced by apple farms in the study area and their future potential development.

The estimates of the models revealed a remarkable level of production costs inefficiency in apple farmers, due to the small farm size, deployment of the work-force and low level of mechanization, providing evidence that the efficiency level may increase by increasing the size of the farms, and improving technology and techniques of production. This is in line with the findings of other studies C.O. de Freitas, E. Cardoso Teixeira, M.J. Braga [33], Nathan D. DeLay, Nathanael M. Thompson [34].

In the future, the focus of the study on technical efficiency could be complemented with analyses of other dimensions such as environmental sustainability and social impacts.

5. Conclusions

The econometric models utilized in the analysis indicate a strong significance and exhibit a good fit to the data, as the identified factors in shaping both production costs and technical efficiency related to them. Among the sample farms there is a high variability in terms of the efficiency level related to the cost of production, confirmed by the fact that certain farms achieved high efficiency levels compared to others.

The main factors that have a significant impact on the total production costs of apple farms are capital costs, working days, quantity of pesticides, orcharding type and interaction with the irrigation system.

The findings revealed that the farms had a high level of inefficiency of total production costs. Capital stock is defined as a significant factor influencing the efficiency of total production costs. Due to the small farm size, most of the farms involved in apple production had amortized agricultural machinery. Also, it emerged that the applied irrigation systems had a substantial role in the efficiency of production costs.

The relatively high inefficiency level of the production costs, indicates that the farms have great opportunities to increase the efficiency of the total costs incurred for apple production, by optimizing the irrigation techniques, quantity of fertilizers and capital stock. Also, apple producers in Albania may overcome yield instabilities by extending the area planted with apples.

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