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Modelling technical efficiency of horticulture farming in Kosovo: An application of data envelopment analysis

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Abstract. With a view to integration into the European Union, the efficiency and competitiveness of the Kosovo' different sectors (including agriculture) must be improved. This paper assesses the technical efficiency (TE) of horticultural farms through Data Envelopment Analysis (DEA) applying output orientation. It was founded that the TE of these farms is positively affected by their size, with large-size farms presenting overall higher technical efficiency. The research findings indicate that the degree of agricultural education does not have a significant impact on TE, whereas public assistance through subsidies and grants has a substantial and negative impact on TE, as confirmed by statistical analysis.

Keywords: technichal efficiency, horticultural farming, data envelopment analysis.
JEL codes: Q10, Q18, C14.

HIGHLIGHTS

- With a view to integration into the European Union, the efficiency and competitiveness of the Kosovo' different sectors (including agriculture) must be improved
- We use a model of Technical Efficiency of Horticulture Farming in Kosovo with application of DEA.
- FADN data used on this study are from the years 2015 to 2019, in total 5 years in a row making the total observation 779.
- The study's findings reveals that the majority of farms in the sample show a technical efficiency level below 50%.
- It was found that the TE of these farms is positively affected by their size, with large-size farms presenting overall higher technical efficiency.

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1. INTRODUCTION

A future integration for Kosovo to the European Union (EU) raises significant opportunities but also challenges for the country's economy. One challenge is to improve the competitiveness of several sectors, including agriculture.

According to latest agriculture census, Kosovo has 1.1 million hectares of land, out of which 53% is agricultural land (from which 54.3% belongs to permanent grasslands, 43.6% arable land, 1.9% permanent crops and 0.3% kitchen garden), 41% is forest, and 6% belongs to other land uses (KAS, Agriculture Census, 2015). Kosovo has traditionally supported with direct payment (subsidies) and through investment grants three main agricultural sectors: cereals, horticulture, and livestock, which are divided into 21 subsectors: 11 annual and perennial crops (cereals and horticulture), wine, and organic products, and 10 livestock sectors and milk (Kostov et al. 2020).

In Kosovo, the agriculture sector employs the highest number of people, accounting for 34% of the total employment. This sector also makes a significant contribution to the country's Gross Domestic Product, which was around 8% in 2019. Additionally, agricultural products constitute 17% of the total export value (MAFRD, 2020). Although, 60% of the population lives in rural areas in Kosovo, they do not contribute much to economic growth. According to the Kosovo Ministry of Agriculture, Forestry and Rural Development (MAFRD), "*only a limited number of farms are currently able to compete and grab a greater share of the EU and foreign market*". The low competitiveness of farms can be attributed to several key structural factors, including the small size of most farms, land fragmentation, outdated building and equipment design, and limited access to financial resources (MAFRD, 2014). Furthemore, Kosovo continues to have a relatively high volume of imported agricultural products, which make up approximately 10% of all imports. In Europe, Kosovo ranks among the highest importers of food per capita (ERP, 2018).

In this context and to attain the European standards, improving the competitiveness of the agricultural sector becomes paramount. One way to help agriculture go towards competitiveness in domestic and foreign markets is to improve the technical efficiency (TE) of each agricultural sub-sector. Technical Efficiency refers to the ability to achieve the highest possible output level from a given set of inputs or resources. It measures how effectively inputs are utilized to produce desired outputs within a production process or system. It is a fundamental concept in economics and plays a crucial role in various fields, including agriculture, manufacturing, healthcare, and public services. According to Koopmans (1951, as cited in Farrell, 1957, p. 255; Charnes & Cooper, 1985, p. 72) provided a definition of what we refer to as technical efficiency, stating that an input-output vector is technically efficient if increasing any output or decreasing any input can only be achieved by decreasing some other output or increasing some other input.

In the context of agriculture, Technical Efficiency is particularly significant as it directly impacts food production, resource utilization, and sustainability. By measuring and improving Technical Efficiency, policymakers, farmers, and stakeholders can make informed decisions, allocate resources effectively, and drive agricultural development.

In this study we focus on the horticultural farms from FADN data, which includes TE for vegetables cultivated indoor in greenhouses and vegetables cultivated outdoor. In comparing the 2019 total share of agricultural crops's production to 2018, 2019's vegetables lead with the highest percentage 33.4%, followed by fodder crops, cereals, fruits and others (MAFRD 2020). According to the green report from MAFRD (2020) the total area cultivated with vegetable during 2019 was 18,911 ha. The crops that dominate the largest area in 2019 were potato (20%), pepper (16%), beans (15%), pumpkin (13%), onion (7%) and watermelon (6%). From the total area with vegetables, the different forms of horticulture in Kosovo, with the largest part are produced in open field. In percentage, the main area used for horticulture is in the open field with 83.5% followed by garden with 11.3% and vegetables cultivated in greenhouses with 5.2% (MAFRD, 2020).

Following the introduction, section two presents a comprehensive review of the existing literature. Section three provides a detailed explanation of the research methods employed, while section four elaborates on the data utilized for estimating efficiency. Moving forward, the fifth section presents the results of the technical efficiency analysis and identifies the factors that influence it. Finally, in the sixth section, the paper concludes with a summary of the analysis and discusses the policy implications derived from the findings.

2. LITERATURE REVIEW

Despite the fact that there is limited literature that demonstrates the significance of measuring technical efficiency in Kosovo's horticultural sector, there are numerous global studies that explore efficiency in this area, Iráizoz et al. (2003) measured the TE of horticultural production in a sample of Spanish farms. They discovered a significant resemblance between the two technical efficiency estimates. Other authors, Bozoglu and Ceyhan (2007) assessed the technical efficiency of 75 vegetable farms involved in vegetable production and investigated the factors that contribute to technical inefficiency in the Samsun region of Turkey. This study's findings indicate that the technical efficiency of the sample vegetable farms ranged from 56% to 95% (82% in average) and was affected by schooling, experience, credit use, participation by women, and that information score negatively affected technical inefficiency. On the other hand, factors such as age, family size, off-farm income, and farm size were positively related to inefficiency. Another study conducted by Clemente et al. (2015) focused on assessing the technical efficiency of citrus-producing properties in Sao Paulo State during the years 2009 and 2010. Their investigation involved conducting interviews with producers and employing both non-parametric data envelopment analysis (DEA) and econometric methods to determine the levels of technical efficiency and identify factors that influenced efficiency. The study's findings demonstrated that a significant proportion of citrus-producing properties in Sao Paulo operated below optimal efficiency levels. Notably, the factors of "producer schooling" and "experience as a rural producer" emerged as the primary drivers of increased efficiency. The mean technical efficiency score obtained from the study was 0.79, indicating the potential for production growth while maintaining the current input proportions based on the product-oriented model. In a similar vein, a study conducted by Irz and Stevenson (2012) investigated the potential inverse relationship (IR) between farm size and technical efficiency in Philippine brackishwater pond aquaculture. This paper employs a stochastic ray production function to examine the potential inverse relationship in Philippine brackishwater aquaculture, utilizing a cross-sectional sample of 127 farms. The distribution of efficiency scores spans the entire range, with an exceptionally low average value of 0.37. Farm size explains only 13% of the variability in outputs that are not accounted for by physical inputs, while 73% is attributed to unidentified factors and 14% to random shocks. Although the findings of this study are significant for policy formulation, they present a rather negative outcome, as they indicate that variations in efficiency are influenced by unexplained factors. Consequently, further investigation and speculation are necessary to uncover the underlying reasons for the subpar average technical performance of farms.

Previous studies about the technical efficiency in Kosovo mainly focused on livestock and the dairy sector. For example, Sauer et al. (2015) analysed the effect of migration on farm TE and found migration a decreasing effect. More recently, Alishani (2019) investigated the effects of public support policies on technical efficiency in Kosovo, with 394 farms from FADN year 2014.

To the best of our knowledge, few research deals with technical efficiency of horticultural farms in Kosovo. Frangu et al., (2018) assessed the input efficiency of 136 greenhouse farms growing tomatoes and peppers at both the farm and regional levels. The research utilized a combination of linear regression and DEA methods to identify any external factors that impacted efficiency. The study concluded that technical efficiency scores varied between regions, and based on the structural and operational characteristics of the greenhouse farms growing tomatoes and peppers, it was found that there was a possibility for farms and regions with low technical efficiency to enhance their input usage.

While larger farm size is essential for achieving sustained higher productivity in the long term, technical efficiency presents the most promising solution for enhancing productivity in the short to medium term and promoting the growth of Kosovo's agricultural sector. Vegetable production offers the best opportunity for producing viable incomes on small farms while adding significant value to the national economy. According to statistical data from MAFRD, total area for cereals is decreasing, while for vegetables, the area of cultivation is increasing. Kosovo has the quality of land to achieve this but experience shows that when the products are grown by large numbers of small farmers acting independently, without irrigation, greenhouses, cool storage, grading and packaging facilities, and sufficient processing capacity there will be a considerable amount of dumping on oversupplied markets at peak supply.

This study not only measures efficiency, but it also examines the factors that influence efficiency, and uses this analysis to provide additional recommendations for policy. In order to achieve this objective, we employ a two-step method suggested by Simar and Wilson (2007). In the first step, we estimate the relative efficiencies using inputs and outputs and then analyse the effects of the exogenous variables on efficiency. As several authors (Iráizoz et al. 2003; Sauer et al. 2015; Wilson, 2001; Karimov, 2014; Latruffe, 2004; Theodoris et al., 2014; Gaviglio 2021; Morrais, 2021; Alishani 2019), the exogenous variables are age, agricultural training of the manager/holder, gender, irrigation system, altitude, area constrains, total subsidies on crops, rented area (Iráizoz et al. 2003; Sauer et al. 2015; Wilson, 2001; Karimov, 2014; Latruffe, 2004; Theodoris et al., 2014; Gaviglio 2021; Morrais, 2021; Alishani 2019).

Finally, the paper contributes to fill the research gap on efficiency in the horticulture sector in Kosovo. We focus on the farms from FADN data, which includes TE for vegetables cultivated indoor in greenhouses, and vegetables cultivated outdoor.

3. METHODOLOGY

Methodologically, we employ Data Envelopment Analysis (DEA) to assess the performance of a group of units. Based on the pioneering work of Farrell (1957), Charnes et al. (1978) developed the DEA model under the constant return to scale (CRS) assumption, and Banker et al. (1984) extended it under the variable returns to scale (VRS) assumption. DEA involves creating a production frontier that illustrates the highest attainable output from inputs, and subsequently measuring the distance between each unit and the efficient frontier (Blancard and Hoarau, 2013). The best performers' group provides practical observations for constructing this frontier. The most efficient units are those closest to the frontier, and so the furthest from the frontier, the highest is the units' inefficiency.

Two approaches can be used to estimate technical efficiency (TE): parametric, which includes both stochastic and deterministic methods, and non-parametric, such as DEA. In agriculture and farming, each approach has its own advantages and disadvantages when it comes to measuring farm performance. Studies comparing parametric and non-parametric methods have revealed disagreements regarding these approaches, particularly in agriculture. Coelli (1995) reviewed literature on frontier function estimation and efficiency measurement and suggested potential applications of these methods in agricultural economics. Further to this debate Sharma (1999) compared two approaches in measuring efficiency of the swine industry in Hawaii and the study revealed the DEA method is a more robust approach for measuring efficiencies compared to the parametric approach, based on the obtained results. DEA is particularly suitable for agriculture because it allows for the assessment of relative efficiencies among multiple decision-making units (DMUs) without requiring explicit functional form assumptions or knowledge about the underlying stochastic production function. It considers the best-practice frontier defined by the most efficient units, providing a benchmark for comparing and evaluating the efficiencies of other units. This is beneficial in the agriculture sector, which encompasses a wide range of production systems and practices, where the assumptions of a specific functional form may not hold universally (Fare et al. 1994).

In our study, we utilized an output-oriented model to estimate TE, which was based on both on (variable returns to scale) and (constant returns to scale).

The term "Decision-Making Unit" (DMU) is used to refer to any entity that is evaluated based on its ability to transform inputs into outputs. In our study, we use this term to refer horticultural farms. Our primary goal is to evaluate efficiency based on the assumption that a DMU can produce a greater amount of output by using the same level of inputs. To achieve this, we use an output-oriented model. We chose output orientation based on the challenges that the horticulture sector in Kosovo faces, as described in the first part of the paper. Moreover, as following numerous studies, we decomposed technical efficiency (TE) into pure technical and scale efficiencies from CCR (Charnes et al., 1978) and BCC (Banker et al.,1984) models to identify the sources of inefficiencies.

Let us consider n farms producing s output from m inputs. For the evaluated farm o, the output-oriented DEA linear programming is written as follow:

$$\max \phi$$

Subject to

$$
\begin{aligned}
&\textstyle\sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{io} && i=1,2\ldots,m \\
&\textstyle\sum_{j=1}^{n} \lambda_j y_{rj} \geq \phi y_{ro} && r=1,2\ldots,s \\
&\textstyle\sum_{j=1}^{n} \lambda_j = 1 (\text{DEA–BCC}) && \\
&\lambda_j \geq 0 \ \ (\text{DEA-CCR}) && j=1,2,\ldots n
\end{aligned}
\qquad (1)
$$

where n, m and s are number of DMUs, inputs and outputs, respectively. DMU$_j$ consumes x_{ij} of input i and produces y_{rj} of output r; λ_j are the weights assigned by the linear program, ϕ is the calculated efficiency.

The summary of the results obtained from the envelopment model interpretation is as follows: if $\phi^* = 1$, then the DMU under evaluation is a frontier point. i.e., there are no other DMUs that are operating more efficiently than this DMU. The DMU under evaluation is inefficient. i.e., this DMU can either increase its output levels or decrease its input levels (Zhu, 2014).

The results of DEA TE_{VRS} model represent pure technical efficiency (PTE). Alternatively, DEA TE_{CRS} model represents the overall technical efficiency (OTE), which consists of two components: scale efficiency and pure technical efficiency. While comparing scores from both DEA TE_{CRS} and DEA TE_{VRS} model, if a DMU has a different efficiency score that means that the particular DMU has scale inefficiency. Scale efficiency can be obtained by:

$$\text{SE} = \frac{TE^{CRS}}{TE^{VRS}} = \text{OTE/PTE} \qquad (2)$$

After obtaining the results from the two models, we employed bootstrapping in the nonparametric model to address potential scepticism regarding the use of DEA in agriculture. Non-parametric efficiency measures are often criticized for lacking a statistical basis. However, Simar and Wilson (1998) argued that nonparametric efficiency measures do indeed have a statistical basis, and used bootstrapping to analyze the sensitivity of non-parametric efficiency scores to sampling variation. To generate the bootstrap estimates, we utilized the algorithm proposed by Simar and Wilson (1998) in R studio, which is a statistical computing software. We used B = 2,000 bootstrap replications, and set the bandwidth at h=0.014 based on empirical evidence from Simar and Wilson (1998) that suggests small values of h provide smooth density estimates that follow the empirical density function, while large values of h yield over-smooth density estimates.

4. DATA

4.1. Data source

The study uses data from farms covering the entire Kosovo. Kosovo has 7 administrative regions, but a nomenclature of territorial units for statistics has not yet been introduced. It is divided into two territorial levels: municipal and settlement level; it currently has 38 municipalities and 1,469 settlements (MAFRD 2014). In hydrographic terms, Kosovo is divided into river basins: The Drini i Bardhë, Ibri, Morava Binqës and Lepeneci (KAS, 2019). This sector of vegetable production in Kosovo is one of the main branches of agricultural production whilst in some regions of the Dukagjini Plain, it represents the main economic activity (MAFRD 2014). The predominant approach to horticultural cultivation involves cultivating crops in open fields for the purpose of commercial production. Among the various types of crops, vegetable production is typically the most labor-intensive.

Data employed in this study are extracted from the farm accountancy data network (FADN). The development of a sustainable FADN system in Kosovo has been a focus of effort over recent years. Funded by the European Agency for Reconstruction-EU, a FADN pilot project was launched in 2004 involving 50 farms. This network expanded to 159 farms in 2005, increasing the number of farms to 300 in 2008 and 402 in 2013 and 2014. In order to make an adequate selection of the sample, the FADN team applied the stratified simple random sampling. Sampling is carried out by following three fundamental criteria, which include economic size, farm type, and region. These criteria conform to the standardized FADN methodology in line with the European Commission's guidelines.[1], even though it was simplified to suit the specific situation of the country. The decision was made to include around 1,250 farms, which is roughly 2% of all agricultural holdings, in the FADN survey in order to ensure that the sample is as representative as possible (MAFRD, 2020). To account for the possibility of some farms declining to participate in the survey, each entity involved included approximately two additional reserve farms.

In order to assess the technical efficiency (TE) of the horticultural sector of Kosovo, FADN data used are from the years 2015 to 2019, in total 5 years in a row making the total observation 779 (table 2 in appendix). The number of farms is different from year to year, the reason is that some farmers refused to participate in the upcoming years, so there was a number of reserved farms of the same typology which was used in case of refusal, besides this some farms change the category during the five years' period.

4.2. Inputs and output selection

To measure the technical efficiency, we retained four inputs and one output. The chosen inputs are widely employed in the literature for measuring technical efficiency.

The term "total labor" refers to the amount of work completed in a year, equivalent to a full-time job. This is measured in annual work units (AWUs), which represent the amount of work performed by a person who is employed full-time on a farm. In Kosovo, the minimum annual working hours are considered to be 1,800, which is equivalent to 225 workdays of eight hours each. The second input is land or the utilized agricultural area expressed in hectares. It consists of the land in owner-occupation, rented land and land in share-cropping.

The third input is total intermediate consumption, which includes total specific costs (including inputs produced on the farm) and overheads arising from production in the accounting year. The total specific costs included specific crop costs (fertilizers and soil improvers, purchased manure, crop protection products) and other specifics costs (labour and machinery costs and inputs, contract work, and machinery hire, current upkeep of machinery and equipment, motor fuels and lubricants, car expenses). Farming overheads include land improvements and buildings, electricity, heating

[1] Council Regulation (EC) No 1217/2009 of 30 November 2009 setting up a network for the collection of accountancy data on the incomes and business operation of agricultural holdings in the European Community

fuels, water, farm insurance, other farming overheads expressed in the euro.

Finally, we consider one more input which is the average farm capital includes cash & equivalents, receivables, other current assets, inventories, plants, land improvements, farm buildings, machinery and equipment, and intangible assets.

Output is the total value of the crop products, and of other output expressed in Euros, including that of other gainful activities (OGA) of the farms.

The table 2 (appendix) presents the descriptive statistics of variables for farms together indoor and outdoor in the open fields[2]. On average, they produced output in value of 29,319 € for the year 2015 with 139 farms in the sample for this year. In 2016 with 150 farms the total output value was 28,404 € while in 2017, 162 farms produced on average 29,678 €. In 2018, 143 farms produced total output on average of 26,516 € while in the year 2019, 185 farms produced total output in value of 25,550 €.

5. RESULTS AND DISCUSSIONS

5.1. Efficiency results

In our study VRS, CRS and SE were evaluated for horticultural farms. The number of farms is different from year to year, the reason is that some farmers refused to participate in the upcoming years, so there was a number from the list of a reserved farm of the same typology which was used in case of refusal, and besides this some farms change the category during the five years' period.

The summary of results is presented in the table 1. The year 2017 showed the highest efficiency score with a pure technical efficiency level of 0.72 for farms horticulture indoor, which means that 28% can increase the output to reach the efficiency frontier. The majority of farms in the sample show a technical efficiency level of above 50%, besides the year 2018, which is with the level of efficiency of 45%. On the contrary, farms operated in the open field have a lower efficiency score, with the largest efficiency level of 0.56 in the year 2017, while similar to horticulture indoor, also at the open field, the year 2018 has the lower efficiency score below the 50%. For the farms, horticulture indoor the highest average score on scale efficiency (0.92) was in the year 2017 while the lowest score (0.77) was in 2019. While for the farms in the open field the highest average score on scale efficiency (0.91) in the year 2017 and the lowest in the year 2015 and the lowest score of SE (0.74). From the average aggregate results for farms (Indoor and open fields together), most of the farms in the sample show a technical efficiency level that is less than 50%. The highest efficiency score with a pure technical efficiency level of 0.50, which means that 50% can increase the output to reach the efficiency frontier. The lowest pure technical efficiency score (0.36) is in the year 2018. The highest average score on scale efficiency (0.94) was in the years 2017 and 2018 while the lowest score (0.87) was in 2015.

Table 1. Descriptive results of efficiency estimate for horticultural open field farm.

2015	Mean	SD	Min	max	no of farms
PTE	0.52	0.28	0.11	1.00	
OTE	0.36	0.24	0.10	1.00	121
SE	0.74	0.21	0.10	1.00	
2016					
PTE	0.49	0.27	0.13	1.00	
OTE	0.36	0.23	0.12	1.00	130
SE	0.77	0.21	0.28	1.00	
2017					
PTE	0.56	0.26	0.13	1.00	
OTE	0.51	0.24	0.12	1.00	144
SE	0.91	0.14	0.31	1.00	
2018					
PTE	0.46	0.28	0.13	1.00	
OTE	0.39	0.24	0.10	1.00	124
SE	0.87	0.19	0.21	1.00	
2019					
PTE	0.48	0.28	0.14	1.00	
OTE	0.42	0.24	0.12	1.00	164
SE	0.89	0.16	0.17	1.00	

Source: Author's composition.

From the FADN methodology, farms are defined as being commercial only when they pass the Standard Output of 2,000 Euros. This implies that a commercial farm is able to provide the farmer with a sufficient level of income to support the welfare of his family. Thus, based on this classification the table 5 in appendices present the technical efficiency score categorized by economic sizes of farms. The large-size farms had overall higher technical efficiency under the category 6 (100,000 - < 500,000).

5.2. Biased corrected efficiency scores

Figure 1 to 10 present a graphical illustration of the distribution of farms (in appendices), using box plots to

[2] Descriptive statistics for each of inputs and output variables for the three categories horticultural farms indoor, outdoor in open field are presented in table 3 and 4 in appendices.

facilitate the comparison among farms efficiency score in addition to the bias corrected. For each group of farms, the box represents the 50% mid-range values of efficiency scores and biases corrected. The interquartile range (IQR) is depicted by the length of each box, and the natural limits of the distributions are defined by the whiskers (which correspond to the mean ±1.5 (IQR)). Any outliers that fall beyond the natural limits are represented by round circles. Each group of farms are determined based on the bias corrected scores, the allocation of farms is different than the groups obtained based on the efficiency scores. Due to this different scope of the groups, we get these differences that appeared in the charts with red colors. Groups of farms are determined based on bias-corrected scores, for example group of farms with bias corrected scores from [0-0.10[belong to group 1, while [0.10-0.20[belong to group 2 and the rest until group 10. From the graph its clear the homogeneity of farms in respect to efficiency scores within each group and those to be noted are in group 7 the differences within group in each year under VRS and CRS. In addition, there are substantial differences between the two measures.

On average, under this determination, in the year 2019 the efficiency score is 0,46, while under the bootstrap PTE model, it is only 0.39. Further for the same year, the OTE average score of TE is 0.39, while under the bootstrap OTE the score is 0.34. For instance, none of farms found entirely efficient under the PTE model and OTE model in each year (2015-2019) do not remain so after accounting bias-corrected scores through the bootstrap procedure. In this case, farmers should consider increasing the output while maintaining the same inputs. The results show there is a lot of space for using efficiently the inputs, area, labour, total intermediate consumption and average farm capital.

5.3. Determinants used to explain efficiency

This section explains the second stage of technical efficiency study. The objective of this stage is to identify shared common characteristics among the most efficient farms. Two step procedures are used in the same scenario as Irazoz et al. (2003), so OLS and analyses of variance are used to determine the link between efficiency and exogenous variables. Although the one-stochastic frontier method has a clear technical advantage over the two-step procedures, the two-step procedures may be more logically appealing for policy analysis and decision making because they directly relate the exogenous variables to the observed efficiency performance of the firms. Furthermore, identifying the sources of inefficiency may aid in the development of policy recommendations (Yu 1998; Theodoris 2014). In this case we want to show the effects of exogenous variables in technical efficiency of horticultural production for further policy analysis in national level.

Running DEA and creating a regression model with the DEA efficiency scores as the dependent variable and other possible factors as explanatory factors. This is a well-known two-stage technique that has been widely criticized for producing skewed results. However, it is frequently utilized, at the very least, to figure out which determinants are relevant. Contrary to a number of authors using Tobit, in second stage data envelopment analysis (DEA), McDonald (2003), is not a fan of using this model. In the two articles written by McDonald (2009, 2010), he describes OLS as a better replacement and a sufficient second stage DEA model. As he mentioned for many applied researchers, familiar and easy to compute, OLS may be the best option. Throughout the paper when referring to DEA, he dealt with the single output, output-oriented case. After comparing, in a stage 2 analysis, OLS, 2LT and 1LT marginal effects were similar.

Output oriented frontiers are constructed under both the assumptions of variable returns to scale (VRS) and constant Return to Scale (CRS). The effect of the determinants is investigated with Ordinary Least Squares (OLS) regressions on each of the three TE scores for the period of 2015 to 2019 with total of 779 observations specialized in horticultural farming. This methodology is used by Latruffe (2017) to measure effect of subsidies on technical efficiency, contrary to us he used only variable return to scale (VRS) as our purpose is not only to measure the effect of subsidies on technical efficiency, in addition to that also we tend to measure other determinants which effect on technical efficiency on horticultural farming.

Regarding the determinants that affect the efficiency scores, the most common variable used are farm size, the age of holder, qualifications, experience and specialization of the farmer and combination of inputs (Iráizoz et al., 2003). In this study they found limitations to get this information in their sample data, while in our case, we could have accesses to raw data from FADN and get this information. We classified farm level data based on specialization of farms in horticultural (open field and indoor), match them with farm code and efficiency results of each farm. These similar determinants mentioned above were used also from Sauer et al., (2015) who investigated the effect of migration on farm technical efficiency in Kosovo. Another important study is to analyse the managerial drivers and practices due to business planning in farm and relation to the technical efficiency. Results from the research by Wilson on influence of management characteristic on technical efficiency of wheat farmers in eastern England shows that, those farmers who seek information, have more years of managerial experience, and have a large farm are also associated with higher levels of technical efficiency (Wilson, 2001).

Age and education are commonly cited as factors that may impact technical efficiency (Karimov, 2014). He stressed the important role formal education (university degree and educational background in agriculture) and informal education such as participating in workshops and seminars of farmers are associated with efficiency-improving results (Karimov, 2014). Other authors stressed that farmers that are more educated are considered more likely to be efficient farms associated with higher scores of TE (Latruffe, 2004). And there is a strong significance between agricultural trainings and efficiency (Theodoris et al., 2014). Farmers who are younger may have a greater tendency to adopt innovative technologies aimed at reducing input usage. In contrast, older farmers may have greater efficiency due to their extensive experience in addressing efficiency-related issues (Hadley, 2006). Exceptionally to these authors, Gaviglio (2021) found in his research that in fact, the level of education does not significantly improve the level of efficiency (Gaviglio, 2021).

In terms of the socio managerial aspect, we involved the variables age of owner/manager of farm, level of education in agriculture with only practical agricultural experience, basic agricultural training, full agricultural training, with the aim of seeing if the level and type of experience in agriculture affects the inefficiency. Other variables were: specialization of farm that produce vegetables indoor and in open field, form of irrigation, irrigation system used on the farm, not applicable (when no irrigation on the farm), surface, sprinkler or drip. In similar research on effects of irrigation in technical efficiency Morrais, (2021) results indicated that farms with irrigation had higher average technical efficiency compared to non-irrigators, which implies that irrigation technology has a significant effect on the efficiency gain for those groups. We also included variables on altitude of farms and the location, areas facing natural and other specific constraints. Also, we divided regions in two main plains of Kosovo, Dukagjini Plain and Kosovo Plain, to see which farms are more efficient based on their location, although the plain of Dukagjini is well known for cultivating vegetables due to weather conditions, farm experience and tradition etc. However, the other part (mainly, the east part of the Kosovo plains) in recent years has benefited from increased investment in this sector based on data from Agency for Agricultural Development of Kosovo.

Following other determinants, we included size to measure this we used the total output expressed in physical units (kg) of vegetables produced by farms. Alike Iraizoz et al. (2003), they explain that they expected to obtain a positive coefficient for size, because horticultural production could present scale economies, in our case we follow this conclusion. We included the same determinants involving the combination of inputs.

Additionally, we considered the total output coming from other gainful activities (OGA) directly related to the farm such as processing of farm products. We measured this by the share of total OGA in total Output (%). We want to see if there is higher technical efficiency on farms that diversify their activities, and if large farms operate more efficient with higher share of OGA.

Furthermore, we included as other determinants the share of subsidies to total output. Various studies have investigated the effect of subsidies on farms' technical efficiency, and in general the effect reported is negative. According to Minviel and Latruffe (2017) direct payments are common negatively associated with farm technical efficiency. In another study of the impact of support policies on technical efficiency of farms in Kosovo, subsidies had negative effect on technical efficiency (Alishani, 2019). Drawing from these related studies, Latruffe (2017) conducted a study on the impact of subsidies on technical efficiency with respect to environmental outputs. The study highlights that the policy implications are important, as a farm utilizing subsidies to increase environmental good outputs or reduce environmental bad outputs may have a lower traditional technical efficiency as compared to a farm receiving the same level of subsidies but using them solely for producing marketed outputs. Therefore, the effect of subsidies on traditional technical efficiency could be negative for the former farm and positive for the latter farm. However, this case doesn't necessarily fully apply to for Kosovo's scenario because cross-compliance subsidies are still not introduced in national level support, but it still remains a recommendation from EU commission to Kosovo for initiating this form of subsidies.

Moreover, other determinates we used are the share of paid labour to total AWU (annual working unit), and the share of rented land to total UAA (Utilized agriculture area). For these two variables results, a study by Alishani (2019) found out the paid labour to total AWU affects negatively the technical efficiency score, while the determinant of rented land to total UAA was insignificant.

Finally, we incorporated the factor of machinery and equipment into the analysis, which encompasses various items such as tractors, motor cultivators, lorries, vans, cars, and other farming equipment that are valued in euros. In the study by Sauer et al., (2015) results show that physical capital (machinery and farm equipment) decreases technical inefficiency, but this stands mainly because of outdated machinery and equipment.

Our model with all determinates of inefficiency is presented on the table 8 (appendices). The adjustment shows corrected R squared coefficients of 0.38 for VRS, 0.44 for CRS and 0.26 for SE. Similar results are found by different author, Iraizoz et al. (2003) obtained coefficients of 0.31 and 0.68, and in addition, they found similarities to different authors as cited in (Parikh ,1995) who obtain a coefficient of 0.214, (Sharma, 1999,) with a coefficient of 0.23, and (Wadud and White, 2000) with a coefficient of 0.66.

Concerning the socio managerial aspect in our results, the determinant age of the holder does not have significance with TE scores. Under the VRS and CRS, full agricultural training significantly does not affect the TE scores, while under the scale efficiency, there is a strong positive significance of full agricultural training to TE scores. These results have relation to different reports that shows either formal or informal education in the field of agriculture remains insufficient compare to EU and neighbouring countries. According to the report from (National Research Programme of the Republic of Kosovo from 2010), research and technological development (RTD) in agriculture is still a marginal undertaking in Kosovo, despite the fact that agriculture is an important economic sector. Compared to other countries in EU and the region, Kosovo has the lowest budget allocated for research per GDP, amounting to 0.1%. Only 0.19% of budget was allocated (0.05% of GDP), while in 2016, around 0.33% of budget (0.1% of GDP) (Kaçaniku, 2018).

Considering the differences of horticultural farms if they operate more efficiently in open field or indoors in greenhouses, results show not any significance. In terms of irrigation system used on the farm, drip system shows significance on 10% under VRS and CRS. This system of irrigation is the most recommended to use in crops, as drip irrigation reduces deep percolation, evaporation and controls soil water status more precisely within the crop root zone (Singandhupe, 2003). Furthermore, Lattrufe and Desjeux (2014) indicate that farm size in Kosovo increases integration into the output market and that irrigated crop output is more marketable than livestock output.

With respect to demographic contents in term of altitude, there is no particular significance. There is strong significance in scale efficiency to altitude below 300m and above 600m. For specific vegetables there are different requirements to produce yields, for example potato according to Haverkort (1990) it is shown that is adapted to a wide range of environments and hints are given on further exploitation of its potential in the various ecosystems. For the regional determinant, there is a negative significance under the scale efficiency in Dukagjini Plain, although it is well known for cultivating vegetables, this confirms our supposition that investment is being increased in the recent years in the east part of the Kosovo plain and the area covered by vegetables.

As regard to farm size measured as total production in kg, the study shows a positive relationship with technical efficiency under VRS, CRS and SE, with a strongly significance of 1%, in this case, the most efficient farms produce more in physical units. These results were also found by Iraizoz et al. (2003) in horticulture production in Spain.

With respect to cultivation costs per hectare of land as a determinant relating to a combination of inputs, results show statistically no significant correlation with technical efficiency, contrary to Iraizoz et al. (2003) who found negative correlation indicating that higher cultivation costs do not guarantee better results, in terms of efficiency.

Following other determinants, the partial productivity indices (output per unit of land and output per unit of labour), and the outcome are as expected, because the farms with higher productivity is an indicator for obtaining higher levels of technical efficiency. There is strong statistically significant under VRS, CRS and SE.

With respect to subsidies, as we expected there, is a negative and statistically strong significant correlation between this determinant and technical efficiency under VRS and CRS. Public expenditure on Kosovo's agriculture and rural development is based on two pillars; Grant aid to encourage investments in the means of production (the Rural Development Measures) and payments for quantities of horticulture and livestock produced (Direct Payments).

In term of commercialization, direct payments have positive effects for horticultural and fruits farms (Kostov et al. 2020). Regarding size, the authors suggest that the impact on commercialization will be more significant if a larger number of semi-subsistence farms receive payments based on their size. In Kosovo, eligibility requirements for direct payments related to fruits and vegetables (open field) have lower size thresholds compared to most other payments, making them more attainable for semi-subsistence farmers (Kostov et al. 2020). In every year, expenditure on direct payments has exceeded the amount contracted for investment grants, and overall accounts for 56% of the total public expenditure in the agricultural sector. At the outset, it should be recognized direct income support has a vital role to play in the management of the transition from a production-oriented to a market-oriented food production sector. Last but not least, the lack of producer organization in the fruit and vegetable sector, lack of specialist advice and training, and lack of support for innovation, are not being addressed. Continuing the following determinants, utilized agricultural areas rented by the holder does not have any significance on TE scores, while paid labour to total annual working unit is statistically significant under VRS only at 10%, contrary to Alishani (2019), this determinant affected negatively the technical efficiency score.

With respect to other gainful activities in farms concerning the diversification of economic activities, and contrary to what we expected, the results shows this determinant presents negative and statistically significant correlation with TE scores, indicating that higher time spending on processing horticultural products does not guarantee a better TE score. While as we expected based on results, large farms operate more efficient under VRS and SE with higher share of OGA.

Lastly, machinery and equipment's decrease technical inefficiency on farms, there is a negative and statistically strong significant correlation with TE scores under CRS and SE. This finding are is similar as Sauer et al. (2015) on migration and farm technical efficiency evidence from Kosovo. This is consistent with our study's observations regarding the continued use of old technology and machinery by farmers in Kosovo.

With regards to five years of research data, from the results we can show that the year 2017 is strongly positive correlation with TE scores under CRS, VRS and SE, and it has the highest average TE score compare to other year. This mean that farms in horticulture operated more efficiently in the year 2017.

5.3. Implications (limitations of our study)

A limitation of using the FADN (Farm Accountancy Data Network) for measuring technical efficiency is the potential for selection bias. The FADN database collects data from a sample of farms that voluntarily participate in the program. This self-selection process can introduce bias if participating farms differ systematically from non-participating farms in terms of their characteristics or behavior. Therefore, the findings based on the FADN data may not be representative of the entire agricultural sector, potentially limiting the generalizability of the results. To address these limitations, we employed appropriate statistical techniques, consider conducted robustness checks. The future research idea is to compare nonparametric methods with parametric methods for measuring technical efficiency scores in the agriculture sector in Kosovo. This study will offer valuable scientific insights for researchers and provide assistance to policymakers in addressing the issue of inefficiency.

6. CONCLUSION AND POLICY IMPLICATION

The study's findings reveals that the majority of farms in the sample show a technical efficiency level below 50%. The insufficient level of sore of TE implies that the remaining potential output could not be realized due to technical inefficiency. This means that 50% can increase the output to reach the efficiency frontier. The highest efficiency scores are in the region of Prizren and Prishtina, the biggest regions in Kosovo. Concerning the exogenous factors affecting the efficiency scores with respect to subsidies, there is a negative and statistically strong significant correlation between this determinant and technical efficiency under VRS and CRS. Time spending on processing horticultural products does not guarantee a better TE score, although large farms operate more efficient under VRS and SE with higher share of OGA. The results suggest that farmers should consider increasing the output while maintaining the same inputs. The findings indicate that there is considerable room for improvement for using efficiently the inputs, area, labour, total intermediate consumption and average farm capital. In this respect, policy makers MAFRD[3] should consider these low results of technical efficiency of farms to focus on a better program for extension services in order to promote better use of inputs.

Vegetables are produced often in rather small areas and is very labour intensive; this fact fits the current situation with plenty of underemployed family labour and unemployed. However, it seems that sooner than later, the abundance in the workforce will be gone, mainly because young people do not see agriculture as a business but just as an unwanted heritage. The mechanization is again low due to the small parcel sizes, but also due to missing financial means. Tractors, ploughs, trailers are old and just bigger farmers can afford machines like good sprayers or e.g., carrot-harvesting machines. The situation is improving when dealing with bigger farmers with modern orchards of 5 ha and more. Small farms struggle to access the market and to be commercialized, in this case considering the results from our

[3] Ministry of Agriculture, Forestry and Rural Development.

study it was found that the TE of these farms is positively affected by their size with large-size farms presenting overall higher technical efficiency. For instance, small farms in horticultural sector should consider gathering in cooperatives.

Kosovo's agricultural policy is focused on semi-commercial and commercial farmers; the difference is that commercial farmers bring all their products to the market whereas the semi-commercial ones keep a substantial part of their harvest for on-farm consumption. There seems to be a shortage in modern storage facilities for all kinds of vegetables; storage, cold storage (4°C) and cooling rooms (-15°C), and warehouses under a controlled atmosphere. Nonetheless, there is sufficient support in various forms such as investment grants for the processing industry, as well as subsidies for primary production. Furthermore, there is a larger group of donors like the European Commission (as funds cannot be used for IPARD because the ADA is not accredited yet), USAID, GIZ, SDC, and others. However, the performance of the vegetable processing sector is not yielding satisfactory results, eventually as there was too much support and in an uncoordinated form. Investments should be focused on the direction of strengthening the primary production by indirect support through processing companies, and improvement of hygiene conditions and certifications with food safety standards in order to have easy access to the EU market.

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