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Assessing technical efficiency of vegetable farms in North Macedonia

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ABSTRACT

Farm economic performance measuring is important for farm management purposes and for assessing the impact of agricultural policy measures. Efficiency studies enable assessment of farm performance since highly efficient farms are considered to have higher potential for operating in a changing economic and technological environment. The aim of this paper is to assess the technical efficiency of vegetable farms in North Macedonia, utilising Data Envelopment Analysis, as a non-parametric approach estimating the relative efficiency of decision making units producing multiple outputs and using multiple inputs. The analysis is based on Farm Monitoring System data including 75 vegetable farms in 2011 survey. Apart from baseline scenario, additional scenarios include available agricultural policy support in 2011 and 2016. The average technical efficiency of vegetable farms is 0.62 considering constant returns to scale, i.e. 0.71 and 0.75 considering variable returns to scale (in output and input oriented perspective, respectively). With better farm management, technical efficiency score can be improved on average by 25%. Technical efficiency increases slightly with subsidies, on average by 2 to 3%. Analyses based on farm level data, are valuable when estimating the effects of implementation of agricultural policy as well as when creating new policy interventions.

Keywords: agricultural policy, data envelopment analysis, decision making, farm performance, North Macedonia

INTRODUCTION

Measuring the economic performance of the farm is an important indicator for assessing the impact of agricultural policy measures. Increasing the farm efficiency is considered among the highly prioritized objectives of the rural development programs in the European Union (Petrick and Weingarten, 2004; Galanopoulos et al., 2006). The concept of measuring the efficiency of decision making units started with the Farrell's (1957) seminal work whereas he suggested that all farms have equal access to inputs but not all farms use the same amounts of inputs. Therefore, the efficiency depends on the inputs used by the farms, the input prices and the outputs produced. The impact of subsidies on farm technical efficiency has particularly become important in public policy evaluation and many studies focus on the relationship between the relevant policies and farm efficiency (Zhu et al. 2012; Atici and Podinovski, 2015; Minviel and Latruffe, 2017). Such analysis, in the context of North Macedonia, could also contribute towards better design and providing evaluation of the effects of policy.

Agriculture in North Macedonia, as third largest sector with share of around 11% in the gross value added of all activities (AgStatDatabase, 2016), has significant contribution to the economic and social stability of the country. As in the other Western Balkan countries, agriculture in North Macedonia does not represent the main economic development driver, but is mostly considered as a social buffer of the economic crisis (Dimitrievski et al., 2014). The productivity of the agricultural production is on a relatively low level, due to the slow consolidation process, inefficient use of the available resources, and increased migration within (rural to urban) and out of the country.

Macedonian agriculture is characterized with dual farm structure, where the family farms dominate. Individual agricultural holdings, i.e. family farms, participate with 89.4% in the total standard agricultural output (SSO, 2017). Family farms are characterised with fragmented and diversified production structure.

Crop production traditionally dominates the total value of Macedonian agricultural production with 76.5%; the rest is attributable to livestock production (SSO, 2016). Within, vegetable production accounts for roughly half of the output value of Macedonian crop production. Macedonian vegetable producers continuously face decision-making and efficiency challenges with regard to optimal production planning and productivity improvement. Many factors influence this situation: the degree of efficient use of available resources (labour, working capital, water, etc.), environmental effects, risks related to agricultural production, expected income levels, general management practices, own preferences, etc. Most of the decisions are made intuitively, based on farmers' previous experience. The decision making is mainly led by two reasons: to ensure welfare and gain profit, or to keep the tradition, i.e. to continue with the family business (Kotevska et al., 2012).

Taking these circumstances into consideration, the objective of this paper is to provide an analytical framework for assessment of the technical efficiency of Macedonian vegetable farms, and a notion of the impact of direct payments on it. The results of this analysis are not intended to be uncritically used for immediate policy decision-making, but rather to show the potential value and importance of such efficiency studies. The study draws on Macedonian farm data for year 2011 to explore vegetable farm efficiency at that time, with simulations of subsidies effects in 2011 and 2016, and hence illustrates how an efficiency analysis could contribute to an informed research-based decision-making.

MATERIALS AND METHODS

An evaluation of all available farm level data is necessary prior model development, in order to understand the policy framework under which farms operate as well as to provide indication of the potential implications for their development and growth. The most recent source of available data that could be used for the Macedonian farms efficiency exercise was the Farm Monitoring System (FMS) farm income and costs data set for year 2011 (Martinovska Stojcheska and Janeska Stamenkovska, 2012). There are 75 vegetable farms drawn from that survey that are included in this analysis.

The main output variable derived from the data is the farm crop output value, used in the baseline scenario. Considering the farm specific characteristics, as well as the conceptual framework of the study, the effect of the direct support program over the farm efficiency and productivity is analysed through three additional scenarios, with subsidies, for 2011 and 2016. Given that there is no record of subsidies received by the farmer in the original dataset, we include an additional value of "assumed subsidies" in the output variable for the scenario purposes. The assumed subsidies figures were estimated using relevant available sources, and the difference between the scenarios regarding the consideration of different measures. In scenario one (S1), the direct payments per hectare are added for 2011 and 2016, respectively. Scenario two (S2) contains extra direct payments per unit of output, estimated for eligible typical products sold to processing plants (e.g., peppers, cabbage, gherkins etc.) Scenario three (S3), furthermore takes into account the following assumptions: (i) young farmers payments and (ii) less favoured areas (LFA) payments. The data are taken from the Annual programs for financial support in agriculture for 2011 i.e. applicable direct payment rates (per hectare), output subsidy rates (per kg), minimum planted area requirements and modulations in order to simulate the potential subsidy value to be received by the respective farmers (AFSARD, 2011). The data on the real budget transfers to the sector are from the Agricultural Statistics Database (2016) and

Agricultural Policy Measures (APM) database (2016). The input variables typically use such classifications such as KLEMS, eliciting K (capital), L (labour), E (energy), M (materials), and S (services) (Coelli et al., 2005). Given the available dataset, the focus is on the available direct material costs (seeds and planting material, fertilizers, plant protection), machinery costs, other costs (including labour) and land, following as much as the data allow.

The Macedonian vegetable farms technical efficiency analysis is conducted using Data Envelopment Analysis (DEA), as a non-parametric approach estimating the relative efficiency of the decision making units producing multiple outputs and using multiple inputs (Coelli et al., 2005). The analysis is run using OSDEA-GUI software. Since DEA measures the efficiency of a specific unit, in our case, each farm represents a Decision Making Unit (DMU). All variables are taken into account in monetary value (Macedonian denars converted to Euros) and at farm level.

Four different approaches are run during the analysis: measuring technical efficiency assuming constant returns to scale (CSR) and variable returns to scale (VRS), the later analysed from input and output perspective. Farrell's (1957) efficiency concept was applied for the first time in Charnes, Cooper and Rhodes's study (1978) as a linear programming framework (CCR). This CCR framework measures technical efficiency (TE) under the assumption that the given DMU operates relative to a reference technology with constant returns to scale everywhere on the production frontier (Ray, 2004). As such, CCR can be fairly restrictive and unrealistic, hence we also assume the possibility that an increase in inputs does not necessarily proportionally change the outputs, and vice versa, through a model which allows variable returns to scale. The herewith applied Banker, Charnes and Cooper (BCC) model developed by Banker et al. (1984) is basically an extension of the CCR approach that allows for technologies to exhibit increasing, constant or diminishing returns to scale at various points on the production frontier. The addition of the BCC model also enables the distinction of technical efficiency and scale efficiency, i.e. to decompose constant returns-to-scale technical efficiency scores into scale efficiency (SE) and pure efficiency components. Scale efficiency is determined by comparing the CRS and VRS technical efficiency scores ($SE = TEI_{CRS} / TEI_{VRS}$); no difference indicates scale efficient operation, whereas different scores indicate scale inefficiency (Coelli, 1996).

RESULTS AND DISCUSSION

The analysis of the sample of 75 vegetable growers shows that 33% of all farms can be considered as technically efficient farms (estimated in input-oriented variable returns to scale (VRS) model, see Table 1). Considering that the average farm size of the efficient and inefficient farms is very similar, i.e. 2.22 ha versus 2.27 ha, the farm size did not have effect in the sample. Burja and Burja (2016) argued that the complexity of the relationship between the farm size and the efficiency depends on a lot of economic and social factors, as the soil type, agro-climatic conditions, technology involved, available labour force, transaction costs of production factors, etc. On the other side, the efficiency analysis of the Macedonian grape producers showed negative relationship between total area and efficiency, i.e. total area decreased the farm efficiency (Manevska Tasevska, 2012).

When analysing the output and the input values from the efficient and inefficient farms perspective (€/farm on farm level and €/ha on area level, Table 1), efficient farms have higher farm output value compared to the inefficient ones. The average farm output for the efficient farms amounts 7,933 €/farm or 6,577 €/ha, i.e. is around 40% higher than the inefficient farm output value.

The results further show that the average estimated subsides value was 677 € per farm or 335 € per hectare in 2011 (i.e. 8% for the efficient farms and slightly higher (10%) in the total farm revenue of the inefficient farms). The direct payments per area have the largest share (78 to 79% in efficient versus inefficient farms). Available subsidies for eligible farms have increased in 2016, being assumed with an average of 742 €/farm, i.e. 404 €/ha.

Table 1. Outputs, direct inputs and size of efficient and inefficient farms

	Efficient		Inefficient		All farms	
Number of farms	25		50		75	
Farm size (average ha)	2.27		2.22		2.23	
Farm size (minimum ha)	0.23		0.42		0.23	
Farm size (maximum ha)	15.6		10.0		15.6	
Output and subsidies:	€/farm	€/ha	€/farm	€/ha	€/farm	€/ha
Farm output (base 2011)	7,933.3	6,577.4	6,136.3	3,747.7	6,735.3	4,690.9
DP per area 2011	548.1	276.6	525.8	255.4	533.2	262.5
DP per output 2011	96.9	48.2	127.6	72.3	117.4	64.2
Add. payments 2011*	56.2	13.9	12.0	5.3	26.8	8.1
2011 total subsidies	701.2	338.7	665.4	332.9	677.4	334.8
DP per area 2016	545.1	356.6	641.6	326.8	609.4	336.8
DP per output 2016	127.9	52.5	113.3	62.8	118.2	59.3
Add. payments 2016*	27.0	13.7	8.7	4.4	14.8	7.5
2016 total subsidies	700.0	422.8	763.6	393.9	742.4	403.6
Inputs (base 2011):	€/farm	€/ha	€/farm	€/ha	€/farm	€/ha
Seeds	686.8	824	826.6	489.5	780.0	601.0
Fertilisers	469.1	475.6	522.6	294.9	504.8	355.1
Plant protection	189.6	215.7	300.4	170.8	263.5	185.8
Machinery costs	267.3	170.3	347.1	184.4	320.5	179.7
Other direct costs	597.9	778.1	599.9	396.4	599.2	523.6
Total direct costs	2,210.8	2,463.8	2,596.6	1,535.9	2,468.0	1,845.2

Source: own calculations; Note: Technical efficiency estimated in input-oriented variable returns to scale (VRS) model (Banker et al. 1984); * Payments for young farmers (67 observations) and LFA (over 600 m altitude)

The estimated subsidies in €/ha are higher for the efficient farms in both 2011 and 2016. The direct payments per area in 2011 are in average 277 €/ha for the efficient farms, which is around 8% higher than the average direct payments provided for the inefficient farms. The same relationship also stands for 2016.

Input costs are in average lower for efficient farms (2,211 €/farm) as compared with those that were technically inefficient (2,597 €/farm). However, analysed on per hectare basis, efficient farms spent substantially more on inputs to achieve the given output (2,464 € as compared to 1,536 € in inefficient farms). The inputs costs analysis show that the plant protection costs (11%) have lowest share in the total direct costs for the efficient farms, followed by the costs for machinery and fertilisers (13% and 20% respectively). The costs for seeds have the largest share in the total direct costs for all farms (32% of the total costs). The allocation of costs in relative terms is rather similar between efficient and inefficient farms.

The overall farm technical efficiency and the assumed subsidies effect, comparatively for 2011 and 2016 is presented in Table 2.

Table 2. Comparison DEA technical efficiency (TE) of Macedonian vegetable farms, different scenarios

Scenarios:	Base 2011	S1_2011	S2_2011	S3_2011	S1_2016	S2_2016	S3_2016
CONSTANT RETURNS TO SCALE (CRS TE)							
Efficient farms	13	13	13	13	13	13	13
Average TE	62.41%	63.68%	64.13%	63.98%	63.82%	64.01%	63.80%
Minimum TE	14.67%	16.32%	16.19%	16.17%	15.78%	15.55%	15.52%
OUTPUT ORIENTATION: VARIABLE RETURNS TO SCALE (VRS TE)							
Efficient farms	25	25	25	25	25	25	25
Average TE	71.21%	72.36%	72.68%	72.56%	72.48%	72.61%	72.45%
Minimum TE	14.81%	16.46%	16.32%	16.3%	15.92%	15.68%	15.65%
Scale efficiency (SE)							
Average SE	88.43%	88.70%	88.92%	88.86%	88.76%	88.84%	88.78%
Minimum SE	46.55%	48.43%	48.02%	47.83%	48.51%	47.72%	47.49%
Operating Returns to Scale (RS)							
Farms Increasing RS	38	38	38	37	38	39	39
Share	51%	51%	51%	49%	51%	52%	52%
Farms Decreasing RS	23	23	22	23	24	23	23
Share	31%	31%	29%	31%	32%	31%	31%
INPUT ORIENTATION: VARIABLE RETURNS TO SCALE (VRS TE)							
Efficient farms	25	25	25	25	25	25	25
Average TE	75.21%	75.88%	76.25%	76.14%	75.95%	76.11%	75.96%
Minimum TE	26.66%	28.66%	28.55%	28.49%	29.43%	29.23%	29.14%
Scale efficiency (SE)							
Average SE	82.70%	83.66%	83.9%	83.82%	83.75%	83.87%	83.78%
Minimum SE	29.94%	33.30%	33.05%	33.00%	32.22%	31.74%	31.69%
Operating Returns to Scale (RS)							
Farms Increasing RS	56	54	53	53	53	53	53
Share	75%	72%	71%	71%	71%	71%	71%
Farms Decreasing RS	6	8	9	9	8	9	9
Share	8%	11%	12%	12%	11%	12%	12%

DEA efficiency scores are calculated utilizing two different approaches, one allowing for constant returns-to-scale, and the other one based on the variable returns-to-scale, from both input and output perspective. The results from the CRS model show that 17% of all farms are on the efficient productivity frontier (efficient farms) in all scenarios (Table 2). The average TE of the sample in the base year 2011 was 62.4%, whereas the lowest score amounted 14.6%. This suggests that not all farmers were utilizing their production resources efficiently, hence not obtaining maximum output from the given quantities of inputs, and vice versa. Given the current technology, if better using the available inputs, the vegetable growers could increase their efficiency by 37.6%. In the scenario analysis, the results show that including the direct subsidies per hectare in the total farm revenue has a slightly positive influence on the farm efficiency, with a TE efficiency of 63.6% and 63.8% in 2011 and 2016, respectively. This marginal difference could result from the linear allocation of the assumed subsidies, since no real farm data were available for this indicator. A slight increase in the technical efficiency could be observed also when the payments per output for the crops supplied in the processing industry are added to the direct subsidies per hectare (S2_2011 and S2_2016); the TE shows an increasing trend, reaching its average highest level of 64.1% and 64% in 2011 and 2016, respectively. If the specific support for the young farmers and the LFA is considered (S3_2011 and S3_2016), the increase in the farm efficiency is also evident, as compared to the baseline scenario, but is not increasing comparing to scenario two. The estimated subsidies overall increase the efficiency, but do not make difference whether a farm is efficient or not, which is an interesting result, because it shows that 'subsidy harvesters' are not necessary the most efficient one. Motivation of farmers to work efficiently is also found to be lower when they depend to a higher degree on subsidies as a source of income, and the composition of subsidies has a much smaller effect on efficiency than does the composition of total farm income (Zhu et al., 2012).

The vegetable producers in the sample mostly have diversified production structure and their production of different crops is often sensitive on different factors, as pests, diseases and mostly the managerial approach in organizing the production process. Thus, a specific DEA model based on input oriented perspective utilizing the VRS is also included, showing that if compared with the CRS model, the number of efficient farms under VRS increases; 33% of all farms operate on the efficient productivity frontier, with a higher average TE in all scenarios, as expected.

While TE scores are identical for both input and output orientation under assumed constant returns to scale, those can differ under variable returns to scale. Nevertheless, both input and output oriented models would produce the same frontier, and would identify precisely the same set of farms as being efficient (Coelli et al., 2005). In an output-oriented DEA model, a proportional expansion of outputs is allowed provided that the farms use their current input endowment i.e. the linear programme determines the farms potential output given its inputs if it operated as efficiently as those farms along the best practice. In the sample, the overall average variable returns to scale technical efficiency was 71.2% (in output orientation), meaning that the inefficient vegetable farms could, on average, produce 29% more outputs given that the inputs are held fixed. In the various scenarios where public subsidies support is included, the room for improvement is between 27% and 28%.

With input-oriented DEA, the linear programming model is configured to determine how much of the input use could be (proportionally) reduced in order to achieve the same output level (without altering the output produced), while applying the fully efficient farms practices. In the baseline scenario, the mean sample TE in the input-oriented model is 75.2%, indicating that the farmers better use their available production factors, but also that there is still potential for its improvement. If farmers adjust their input use according to the best practice, the TE score can be improved by 25%, pointing to the need for different interventions in the farmers' management practices as well as knowledge and skills improvement. Considering the policy impact through the direct support schemes, TE has slightly increased to 75.8% and 75.9% in the first scenario for 2011 and 2016, respectively. Highest TE scores are obtained if the subsidies include both the direct payments per hectare and the direct payments per output; 76.2% in 2011 and 76.1% in 2016. Similar results are obtained by Manevska Tasevska (2012) and Asogwa et al. (2011).

Scale efficiency as an additional efficiency parameter is also calculated, indicating how close the observed farm is to the most productive scale size (Charnes et al., 1978; Coelli et al., 2005). The two different DEA outputs were compared: one using the assumption of constant returns to scale, and other using variable returns to scale. This measure showed that 13 farms operate at their optimal size for the particular input-output mix. The nature of scale inefficiencies of the 62 farms was further determined. This expresses if the farm is not operating at its optimal size (most productive scale size, Banker et al., 1984), then using by further comparisons of DEA outputs or inputs (applying increasing or decreasing returns to scale) it is possible to see whether they are too big or too small in terms of scale. Apart from the 13 farms that are fully CRS and scale efficient, the 12 farms that are fully efficient only under variable returns to scale are already using the best practises, but are unable to achieve the same productivity because of economies of scale. In most of these 12 cases, these farms are exhibiting increasing returns to scale, hence could increase their operations in order to achieve scale efficiency.

The average scale efficiency score in output orientation was 88%. On the whole, rather expectedly, increasing returns-to-scale are observed to be the predominant form of scale inefficiency among the Macedonian vegetable farms. There were increasing returns to scale in half of the cases (49-52%, depending on the scenario), implying that that their farm revenue could increase by a greater proportion, hence they need to enhance their size in their pursuit to achieve optimal scale with constant returns to scale in the given input-output mix. On the other hand, for 29%-31% of the cases an appropriate strategic direction would be to reduce their size to achieve optimal scale.

In input-orientation perspective, the overall average sample farms achieved 83% of the optimal scale efficiency. Increasing returns to scale are present in most of the cases (71-75%), and only few of the farms have been observed to exhibit decreasing returns to scale (8-12%), where downsizing could be considered as strategic option in order to reduce unit costs.

CONCLUSIONS

This study assesses technical efficiency of vegetable farms in North Macedonia. In that respect, a mathematical programming model based on Data Envelopment Analysis (DEA) was developed for analysing the technical efficiency scores and simulating different scenarios for subsidies impact.

The findings from the analysis suggest that 17% of farms are on the efficient productivity frontier (efficient farms) in all scenarios, assuming constant returns to scale, i.e. 33% of farms, when exhibiting variable returns to scale. The average technical efficiency is 62.4% in CRS, 71.2% in output oriented VRS and 75.2% in input oriented VRS. The average technical efficiency from input perspective showed that 25% cost savings could be achieved on average if all farms operated on the frontier, and 29% increase in revenue from output perspective. In all scenarios, the additional revenue from assumed subsides in the output variable indicate a slight increase in the average farm efficiency. Only 17% of the farms achieved scale efficiency and operate at their optimal size for the specific input-output combination. Increasing returns to scale seem to be the prevalent mode of scale inefficiency among the Macedonian vegetable farms.

The research reported in this study has provided grounds for several recommendations how to overcome certain issues and encountered limitations in future efforts. Firstly, since DEA is a mathematical programming approach to frontier estimation and a deterministic technique, no noise or measurement error is assumed. Hence, any deviation from the production best practice frontier is attributed to inefficiency, although in reality some may arise as a result of other influencing factors. Applying an econometric approach, through an additional stochastic frontier analysis, might prove to be useful in future research in this domain. Secondly, a second stage analysis would allow exploring the factors which influence the efficiency of the farms (e.g. farm and farmer's characteristics, agri-environmental circumstances, locational characteristics, institutional settings, ownership, etc.). Such analysis can be applied to the technical efficiency scores. Thirdly, the analysis reported herewith is based on farm inputs and outputs for year 2011. The agricultural policy measures were gradually increasing over the last period and also some socio-economic circumstances are changing with time. Fourthly, due to the nature of available data, and the lack of full costs of production, we could include only the direct costs on the input side and classify them according to the available cost categories from the source. Last but not least, assuming better data availability, further research can be conducted on estimating the productivity and efficiency on Macedonian farms in terms of different farm specialisations, geographical/regional coverage, partial productivity or time-period.

Investigating farms' technical efficiency and its links to subsidy measures is turning out to be a key topic in applied policy analysis, and will continue to provide policy-makers with useful and current insights. The decision making in the context of the agricultural policy development means following up of the agricultural policy impacts over the different types, structures or sizes of the farms. Analysis such as this one could also contribute towards providing monitoring and evaluation of the effects of policy approximation process with the EU in agriculture and rural development and help to better design and improve national support and IPARD programmes. Considering that such analytical tools are still missing in North Macedonia, the development of a model for analysing policy relevant issues, such as the level of technical efficiency of the farms and further investigations such as the effect of the subsidies, is particularly needed, above all to boost research-based decision making and policy creation and evaluation.

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