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Technical efficiency of Macedonian pig farms

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ABSTRACT

The economic transition and market globalization processes have triggered structural changes in the Macedonian agriculture and influence on the efficiency and competitiveness in the pig production sub-sector. This paper aims to identify the level of technical efficiency on pig farms in the Republic of Macedonia. The Data Envelopment Analysis approach is used to measure the efficiency level, taking into consideration the exact quantity of inputs used in the production in relation to a given quantity of output. The data is analysed by making comparative analyses of the managerial behaviour and other non-measurable variables that influence the efficiency. The results determine what managerial activities influence the efficiency. They indicate the type and level of inputs that need to be changed, so that farms could reach the same technical efficiency achieved by the best farmers.

Key words: Data Envelopment Analysis, technical efficiency, Macedonian pig farms

INTRODUCTION

Livestock production is very important for the domestic consumption in the Republic of Macedonia. The economic transition and market globalization processes have triggered structural changes in Macedonian agriculture. They had a significant impact on the whole agricultural sector, including pig production. The pork processing industry plays a significant role in the domestic economy, but pig production is considered as inefficient and less competitive compared to foreign markets (Dimitrievski et al., 2010). During the transition period many of the previously existing pig farms were shut down and those who continue to operate have changed their ownership into private (MAFWE, 2007).

Today, there are only 7 big pig farms left from the transition period. Established during 1970s, the period when the country was a part of Yugoslavia, they managed to overcome the transition and own almost 40% of the total number of pigs in the country. The remaining 60% of pigs are owned by individual producers, mostly small family holdings, and due to the governmental and IPARD support to agriculture the number of commercial family pig farms is constantly growing (MAFWE, 2007).

In recent years, the world faced a number of economic, climate and food crises. As a response, macroeconomic policies and other political decisions implicate a concept of the green economy for sustainable development and the need for fast adaptation on it (Ocampo, 2012). On the other side, pig producers are facing challenges to meet the new market requirements and regulations, and often found difficulties to adjust quickly. Moreover, farmers lack information and knowledge about producing on the competitive markets and they need formal and informal education to increase farm efficiency (Manevska-Tasevska, 2012). According to MAFWE (2007) production efficiency is a challenge based on the current inefficient farm management practises, followed by inadequate technology and high production costs which additionally increase product prices on the domestic market. In this sense, it is necessary to pay more attention on managerial capacity building and explore activities that influence the increase of the efficiency level.

The aim of this paper is to determine the level of technical efficiency on pig farms in Macedonia. Furthermore, the paper analyses the managerial activities that can be changed with a focus on the type and quantity of inputs used in the production in respect to the output quantities produced at the end of the production process. Taking into account that the managerial activities are key contributors for efficient production, changes in their behaviour leads the farms to reach the same technical efficiency as the best farmers.

MATERIAL AND METHODS

Many researchers conclude that farmers can produce efficiently by rational use of inputs (Debreu, 1951; Koopmans, 1951; Farrell, 1957). Farmers influence on farm technical efficiency by choosing certain amount of inputs to produce the most economically beneficial quantities of outputs (Petrovska, 2011). Measuring technical efficiency is an approach based on solving input and output optimisation problems (Farrell, 1957). However, there are other variables that have significant impact on the efficiency score. The influencing variables represent sources of inefficiency.

Technical efficiency variables

Technical efficiency scores are estimated by using non-parametric Data Envelopment Analysis (DEA) approach. The efficiency indicators are calculated by using the computer programme DEAP version 2.1 (Coelli, 1996). DEAP uses linear programming to estimate a production frontier function for a set of decision making units (DMUs), which is used for evaluation of relative efficiency of each unit. The model allows a large number of inputs and outputs with different measurement units and gives individual and multiple efficiency scores for more than one decision making unit. Efficiency scores computed by DEAP lie between 0 and 1. Those units that operate on the frontier line face full technical efficiency and have an efficiency score equal to 1. All other units are less efficient and to increase their technical efficiency they need to make changes in the production process.

Moreover, production characteristics affect the choice of the efficiency scale (Manevska-Tasevska et al., 2011). The efficiency scale on which farms operate is a ratio between a constant and variable return to scale. Because pig production as a primary agricultural production is very sensitive to external factors such as climate, diseases, market situation, managerial abilities to finalise all activities on time, Variable Return to Scale (VRS) DEA model is more appropriate for measuring technical efficiency. Due to the nature of production process, farmers cannot influence on the produced quantities and therefore input oriented DEA is used to measure for how much each DMU can reduce the utilised inputs, with output levels held constant. Input oriented technical efficiency of each farm that operates under VRS DEA is measured as a linear programme represented in the following equation:

$$
\begin{aligned}
&\min_{\theta,\lambda} \theta,\\
&\text{subject to } -q_i + Q\lambda \geq 0,\\
&\qquad \theta x_i - X\lambda \geq 0,\\
&\qquad I1'\lambda \leq 1\\
&\qquad \lambda \geq 0,
\end{aligned}
$$

According to Coelli et al. (2005) the equation assumes that there are data on N inputs and M outputs for each of I firms. For the ith firm they are represented by the column vectors xi and qi, respectively. X is (NxI) input matrix and Q is (MxI) output matrix. θ is a scalar and represents an efficiency score that should be estimated for each ith firm. λ is a (Ix1) vector of constants. A convexity constraint (I1'λ≤1) is used to account VRS which indicated whether the farm is operating in an area of increasing or decreasing return to scale.

For the purpose of this study, the surveyed farms are categorised into three groups: big, medium and small. The analysis is based on direct data collected concerning the production activities of pig farms in 2010. Due to the small number of pig farms in the Republic of Macedonia, the data collection was conducted with face to face interviews with 21 farmers from the whole country.

For the first stage analysis, financial variables were collected in Macedonian currency (MKD) and then converted into Euro. To receive quantitative results for each farm, all variables are normalised per Livestock Unit (LU). To simplify the analysis a single output of total LU produced is considered for each farm. Also, four inputs are considered as: feed, energy, labour and other inputs. The other inputs are sum of inputs that have a significant impact on technical efficiency: veterinary costs, vaccination and insemination doses, hygiene and disinfection costs, ecology cost, cost for transport and insurance.

Sources of inefficiency

Influencing variables are not measurable units and therefore cannot be analysed with DEA model. Their significance is analysed by using Tobit regression model and a comparative analysis. In general, the emphasis is put on farmers' behaviour and the willingness to apply new technologies in order to achieve more technically efficient production. Farmers' behaviour is important for an efficient production planning process. This process includes decision-making through planning, choosing among alternatives, implementation of decisions and their control. Indeed, knowledge influences the output increase while using the same amount of inputs (Rivera & Alex, 2008) and choosing the right production alternatives. Not only formal, but also informal knowledge, such as participation at conferences and workshops and consultations with other farmers or experts can contribute in sharing the experience and more flexible acceptance of new technologies and modern market requirements (Fulton, 1995; Miller, 1994; Millar & Curtis, 1997). In that way, good decision-making processes can contribute to increased farm efficiency, while production inefficiency appears because of a lower level of farmers' education, experience in farming, interpersonal relationship and acceptance of innovations (Kilpatrick et al., 1999; Coelli et al., 2005).

RESULTS AND DISCUSSION

Descriptive statistics is used to evaluate the relationship between the use of different technology types and the other second stage variables. The farm accounting variable shows how many farmers are providing bookkeeping of the production activities in quantities and prices spent, and marketing includes the activities provided by farmers to present their farms, by using internet technology and other marketing sources.

The level of education variable is the formal education that farmers have (no formal education is estimated with 1, primary education with 2, secondary education is equal to 3 and higher education to 4). The informal education of farmers is divided into three variables: participation in agricultural associations and the years of farmers experience, while seminars, conferences and workshops are estimated with 3, 2 and 1 depending on farmers' participation often, rarely or never, respectively. The descriptive statistics for the variables used in both first and second stage analysis is presented below in Table 1.

Table 1. Variables used in the first and second stage analysis (n=21)

Variable		Unit	Mean	SD	Min	Max
First stage variables	Farm revenue	EUR/LU	468.20	160.27	206.00	873.99
	Total output	LU	2,137.41	2,978.89	46.19	10,276.50
	Feed quantities	kg/LU	1,350.17	574.77	726.35	2,755.54
	Price of feed	EUR/LU	291.01	125.26	134.64	675.69
	Labour	No.	16.86	17.28	2.00	43.00
	Price of labour	EUR/LU	36.54	25.56	2.35	107.63
	Price of energy	EUR/LU	19.55	21.27	3.12	102.62
	Price of materials	EUR/LU	32.88	34.05	1.46	104.48
	Price of services	EUR/LU	38.60	39.97	1.71	122.66
Second stage variables	Distance to the closest market	km	1.70		0.50	6.50
	Mortality	%	5.55		1	15
	Level of education		3.69		3	4
	Participation in associations	%	42.86		0	1
	Seminars		2.28		1	3
	Farmer's experience	%	18.48		2	37
	Farm accounting	%	52.38		0	1
	Marketing	%	28.57		0	1
	Investment	%	57.14		0	1

Technical efficiency results

The results show that 14% of the analysed farms have full scale efficiency, with scale efficiency equal to 1 (SE=1) and operate on the production frontier line. The remaining farms show variability in technical inefficiency which does not depend on farm size. Most of them, 85% operate on increasing return to scale (IRS) and thus the response should be towards reducing the utilisation of inputs per unit of output in order to optimise the farm technical efficiency. The overall technical efficiency scores are given below in Table 2.

Table 2. Summary statistics for technical efficiency scores (n=21)

	TE_{CRS}	TE_{VRS}	SE
Mean	0.417	0.895	0.434
SD	0.321	0.196	0.310
Min	0.014	0.500	0.027
Max	1.000	1.000	1.000

Also, the efficiency score gave different values in constant and variable return to scale. The variable return to scale approach proves to be more appropriate for application in agricultural production due to the large number of factors influencing farm efficiency. According to the results, farms face very high technical efficiency under VRS represented with an 89% average. On the other hand, there is a big difference between the two scales, which is due to the low mean efficiency of an average 43%. Technical efficiency under CRS is lower than TEVRS for about 41%, which is confirmed by the theory for estimating DEA efficiency (Coelli et al., 2005; Coelli, 1996).

Despite the high level of average technical efficiency under VRS, and considering that there are farms that are only 10% efficient, farmers could still make improvements. That way, the most important thing for the farmer to decide is how much he should reduce the amount of utilised inputs without reducing the amount and quality of final products. Overall, the results show a 22% inefficiency in feed input and, to increase the efficiency, farmers should reduce feed quantities used in the production. However, only minimum quantities of the feed input should be reduced considering that it is the most valuable input for quality pig production. In DEAP labour input is analysed in quantity (the number of workers including family members) and in price unit (total cost spent for labour). These two approaches do not give any differences in the results which show that there should be no changes in the utilisation of labour. According to the results, the cost of energy increases farm relative inefficiency for about 23% and therefore this input should be reduced, as well. Inefficient farms can increase their overall efficiency score by spending less for other inputs including costs of other materials and services for a given level of output. The other inputs increase the inefficiency for about 42%. The highest level of inputs that has been estimated on some of the farms is 91% for energy and services costs.

Significance of the influencing variables

There are many variables that have a significant impact on technical efficiency of production, such as: governmental regulations regarding pig breeding and animal welfare, environmental laws and the type of production. Governmental regulations support pig production by laws and all farmers are obligated to implement. The influence of environmental regulations is closely related to the location of farms. Galev & Lazarov (1968) confirmed that the best location of the farm is to be at least 1 km far from the market, but closer to the main road and slaughterhouses. Smallar distance may cause environmental problems in regard to the disposal of manure, but also in regard to water and air pollution, while larger distance leads to increased transportation costs. According to the results, the average distance to the closest market or big city is 1.7 km. There are also some small farms that are located 0.5 km and 6.5 km away.

Table 3. Relationship between the second stage variables (n=21)

Variable	Technology	Mean	SD	Min	Max
Feed consumption (kg/LU)	New	4.66	2.21	2.52	7.89
	Combination	3.87	0.45	3.33	4.67
	Old	5.14	1.79	3.64	9.39
Mortality (%)	New	3.40	2.67	1.20	8.00
	Combination	5.70	5.28	1.20	15.00
	Old	6.89	4.51	1.00	13.00
Piglets/sow (No. of piglets)	New	12.50	3.73	8.00	18.00
	Combination	13.50	3.73	9.00	15.00
	Old	10.67	1.12	9.00	12.00

The descriptive statistic analysis show a relation between the type of production technology used and farms' sustainability. The impact of changing the old technology of production is analysed in respect to the mortality, feed consumption and the number of piglets per sow in one farrowing. The average mortality is estimated in percentage, while the investment variable explains how many farmers have a new technology of production including those who have changed all production and those who have changed only a part of the production system. The statistical analysis shows that farmers, who had decided to change the old technology of production and to use new production systems, managed to increase the number of piglets per one farrowing. Also, this activity resulted in decreasing the mortality rate by more than 1.1% and the consumption of feed per live weight by around 1%. The descriptive statistic is given in Table 3.

Farmers' behaviour is very important for making proper decisions regarding farm operational activities. Many studies confirmed that by increasing knowledge, farmers can increase the overall efficiency of production (Kilpatrick et al., 1999; Koopmans, 1951). Using a descriptive statistic shows how formal and informal education of farmers influences the decisions for implementing new technology of production (see Table 4).

The results show that farmers use all types of technology, despite their different preferences. However, well educated farmers and those who invest in increasing their informal knowledge are

Table 4. Relationship between the type of technology and knowledge (n=21)

Variable	Technology	Mean	SD	Min	Max
Formal knowledge	New	3.83	0.41	3	4
	Combination	3.83	0.41	3	4
	Old	3.33	0.71	2	4
Seminars, conferences and workshops	New	2.33	0.52	2	3
	Combination	2.67	0.52	2	3
	Old	2.11	0.60	1	3
Associations and cooperatives	New	1.33	0.52	1	2
	Combination	1.50	0.55	1	2
	Old	1.44	0.53	1	2
Sources of information	New	1.83	0.41	1	2
	Combination	1.78	0.44	1	2
	Old	1.67	0.52	1	2

flexible to innovations. They use new or make changes to the existing type of production technology. Overall, farmers who have a higher educational level are open to innovations and easily accept new regulations and technologies. The informal knowledge is represented by participation on seminars, conferences and workshops, participation in agricultural associations and cooperatives and the source of information received by farmers. Here, only participation in associations and cooperatives does not give a relation to the type of technology used.

The environmental variables and farmer's performances have significant influence in increasing farms' efficiency. The Tobit regression results are shown in Table 5. Given the results, only one variable "formal education" is not significant for the efficient production. All other variables that affect technical efficiency are statistically significant at 1%.

Table 5. Tobit regression results of the influencing variables (n=21)

Variable	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Farm location	-0.157	0.047	-3.330	0.008[a]	-0.262	-0.052
Piglets per sow	-0.012	0.003	-3.620	0.005[a]	-0.019	-0.005
Mortality	-0.234	0.049	-4.740	0.001[a]	-0.344	-0.124
Technology	0.189	0.051	3.670	0.004[a]	0.074	0.303
Formal education	0.003	0.018	0.190	0.856	-0.036	0.042
Informal education	0.156	0.040	3.940	0.003[a]	0.068	0.245
Farmer's experience	-0.012	0.003	-3.390	0.007[a]	-0.019	-0.004
Constant	0.026	0.269	0.100	0.924	-0.573	0.626

[a]statistically significant at 1%

Especially, farm location, number of piglets per sow in one farrowing, percent of mortality of piglets and farmer's experience are significant for lowering production inefficiency.

CONCLUSIONS

Relative technical efficiency in input orientation depends on many variables. In this paper, inputs and outputs are analysed by using a frontier production function. The results show a relative technical efficiency score for each farm from an input perspective. Only 5 farms operate on a full scale efficiency, while the other pig farms operate on an increasing return to scale and they can improve farm inefficiency by providing proper production structure. Since it is very difficult to manage the output amounts because of the nature of production, the best way to increase the efficiency is for farmers to decide on the amount of inputs. Input surpluses should be reduced for estimated quantities, different for each farm, without changing quantity and quality of the final products.

The influencing variables that concern the environmental factors and managerial behaviour have a significant influence in technical inefficiency. That is how new policies are emphasising the environmental factors as a key issue for sustainable agricultural production. This modern policy does not allow old production types, since pig production is known as one of the biggest pollutants of the environment. However, this trend is still a big challenge in Macedonia and results in additional costs for farmers, even if the analysis shows that changing the old production technology is significant for increasing overall efficiency.

Farmers who have a higher level of education and invest to improve their knowledge are more flexible in applying new production technologies. Managerial factors that contribute to more efficient production are informal knowledge and farmer's experience.

This analysis leads to the conclusion that rational use of inputs for a given level of output can improve the overall technical efficiency by 20%. Proper production structure and managerial behaviour are significant for increasing the technical efficiency of production.

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Tehnička učinkovitost makedonskih svinjogojskih farmi

SAŽETAK

Procesi ekonomske tranzicije i tržišne globalizacije potaknuli su promjene u makedonskoj poljoprivredi i izvršili utjecaj na učinkovitost i konkurentnost u svinjogojskom podsektoru. Cilj ovoga rada je određivanje razine tehničke učinkovitosti na svinjogojskim farmama u Republici Makedoniji. Korištena je metoda analize omeđivanja podataka kako bi se izmjerila razina učinkovitosti, pri čemu se uzela u obzir točna količina inputa u proizvodnju u odnosu na dobivenu količinu outputa. Podaci su analizirani pomoću komparativne analize menadžerskog ponašanja i ostalih nemjerljivih varijabli koje utječu na učinkovitost. Oni ukazuju na to da se vrsta i razina inputa moraju promijeniti na farmama, kako bi se dosegla razina učinkovitosti koji postižu najbolji poljoprivrednici.

Ključne riječi: metoda analize omeđivanja podataka, tehnička učinkovitost, makedonske svinjogojske farme