TECHNICAL EFFICIENCY OF MACEDONIAN PIG FARMS

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Abstract

The economic transition and market globalization processes has triggered structural changes in the Macedonian agriculture. Pig producers face challenges to meet the new market requirements and regulations which cause inefficient and less competitive production compared to foreign markets. This paper aims to identify the level of technical efficiency on pig farms in the Republic of Macedonia. Data Envelopment Analysis approach is used to measure the exact quantity of inputs used in the production in relation to a given quantity of output. Furthermore, the data are 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 on the efficiency. They indicate the type and level of inputs that need to change and the quantity of output that need to increase for the farms to reach the same technical efficiency as the best farmers.

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

JEL classification: C81, D57, Q12

1. 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 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 structure into private pig farms (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 transformed their legal status from cooperatives to joint stock companies (Petrovska, 2011). They have organized production and strong structural hierarchy of labour. They 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). According to SSO (2011), MAFWE (2010) and IPARD (2008) the total number of pigs in the country is around 190 thousand heads and pig production takes the third place within the livestock sector, right after sheep and cattle production.

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.

The paper starts with a conceptual framework of production technical efficiency. Then the data and method section gives an explanation of the data collected for analysis and the applied econometric method based on input-output analysis. The results and discussion section present the actual situation and the possibility for increasing technical efficiency of pig farms productions. The conclusion is given at the end.

2. Method

Since 1951, many researchers were interested on how to increase farm productivity and found out that by providing efficient management the production was improved (Debreu, 1951; Koopmans, 1951; Heady, Johson, & Hardin, 1956; Farrell, 1957). They conclude that by measuring the efficiency farmers can make decisions in terms of rational use of inputs and higher quality of the production process. Hence, farmer's decision making influences long-term efficiency, but especially short-term efficiency in the high-risk sectors such as agriculture (Johansson & Ohlmer, 2007).

Measuring the efficiency is an approach based on two stages (Coelli *et al.*, 2005). Within this approach, input-output measurements are provided in the first stage. The first stage approach measures technical efficiency by solving input and output optimisation problems (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). However, there are other variables that have significant impact on the efficiency score which are evaluated in the second stage. Second stage variables are divided into two groups: environmental factors and farmer's performances.

First-stage analysis

The first stage is provided by estimating efficiency scores using non-parametric Data Envelopment Analysis (DEA) approach. The efficiency measures are calculated by using the computer programme DEAP version 2.1 (Coelli, 1996). DEAP uses linear programming to estimate a frontier production function as a set of decision making units (DMUs) and evaluate a 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 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 quantities. Technical inefficiency can be analysed from input and output perspective. If the amount of inputs used in the production is fixed, output oriented DEA measures how much each DMU can change its output quantities. On the other side, if the amount of output is fixed, input oriented DEA measures how much each DMU can change its input quantities.

Moreover, production characteristics affect the choice of economic scale (Manevska-Tasevska *et al.*, 2011). 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 etc. Hence, a DEA input oriented perspective and Variable Return to Scale (VRS) are assumed to be more appropriate for measuring technical efficiency. Input oriented technical efficiency of each farm that operates under VRS is measured as a linear programme represented in the following equation:

$$
\begin{aligned}
& minimize_{\theta,\lambda}\theta_i \\
& subject\ to -y_i + Y_\lambda \geq 0 \\
& \qquad \theta_{xi} - X_\lambda \geq 0 \\
& \qquad N1\lambda = 0 \\
& \qquad \lambda = 0 \\
& \qquad \theta_i \in (0,1)
\end{aligned}
$$

The equation represents technical efficiency θ_i of the $_i$ farm, X and Y are matrices of all inputs and outputs of N farms in the sample, $Y\lambda$ and $X\lambda$ are estimated frontier efficiency, and $N1\lambda = 0$ is a constraint added because of the variable return to scale.

The scale efficiency on which farms operate is a ratio between constant and variable return to scale. Constant return to scale (CRS) is appropriate when DMUs increase the output for the same amount of increased inputs because there are no other factors that influence on the production process.

$$SE=TE_{CRS}/TE_{VRS}$$

The DEA approach in this study is input oriented with a focus on TE under VRS. However, the results are also compared with the Technical Efficiency (TE) obtained under CRS, whereas scale efficiency (SE) is discussed at the end of the analysis.

Second stage analysis

The second stage estimation is provided by comparative analysis on environmental variables and farmers performance. In general, the emphasis is put on farmer's behaviour and the willingness to apply new technologies in order to achieve more technically efficient production.

The environmental variables are out of farmer's control and have indirect influence. Governmental policies and legislation are just few examples of those variables. Moreover, factors such as farm location, technology used, design of farm buildings, construction materials, ownership structure, long term investments and type of fixed assets also influence the efficiency score, but they can be altered by the decision makers.

Good decision-making processes can contribute to increased farm efficiency (Kilpatrick *et al.*, 1999). Therefore, 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 on 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 ways, production inefficiency appears because of lower level of farmers' education, experience of farming, interpersonal relationship and acceptance of innovations (Kilpatrick *et al.*, 1999; Coelli *et al.*, 2005).

3. Data and variables

Although there are a few programs collecting farm level data on farm inputs and outputs (for example FADN), there are not enough data available in the country according to DEA requirements. Also, a complete list of pig farms in the Republic of Macedonia is still not officially available. Therefore, direct interviews were carried out in order to collect adequate data concerning the pig farms in the country. For the purpose of this study, the surveyed farms are categorised into three groups: big, medium and small. The categorisation of pig farms is made according to Official Gazette (53/2005) whereas big farms have more than 750 sows, medium farms have 51-749 sows and small farms have less than 50 sows. Also, there are only 7 big farms in the country (Petrovska, 2011) and all of them are included in the analysis. There is a lack of farm accounting and evidence provided by farmers. Therefore, 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. The data were obtained by previously prepared questionnaire to provide data to be used as first and second stage variables.

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

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. of workers	16.86	17.28	2.00	43.00
Price for labour	EUR/LU	36.54	25.56	2.35	107.63
Price for energy	EUR/LU	19.55	21.27	3.12	102.62
Price for materials	EUR/LU	32.88	34.05	1.46	104.48
Price for 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
Farm experience	%	18.48		2	37
Farm accounting	%	52.38		0	1
Marketing	%	28.57		0	1
Investment	%	57.14		0	1

The data collected for 2010; (n=21).

First stage variables

For the first stage analysis, variables are 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). At first, livestock unit values are calculated for each pig category, and then all values are summed in total LU per each farm.

In general, the output of a pig farm consists of different animal categories, within fattening pigs, piglets and sows. Moreover, each farm produces different animal output categories. This causes difficulties in measuring the technical efficiency, and therefore the analysis is simplified in a single output of total LU produced in the analysed period.

The inputs are collected according the KLEMS approach. This approach consists of: capital (K), labour (L), energy (E), materials (M) and services (S) (Manevska-Tasevska *et al.*, 2011). Because most of the farm buildings and machineries are very old and already depreciated, it is very difficult to properly determine the capital price. As a reason, the capital is not included in the DEA analysis. However, due to the importance of the capital assets for estimating technical efficiency only the utilisation of new technologies in the production is included in the second stage analysis.

Five input categories are defined to meet the requirement of this study. In that way, many studies confirmed that almost half of the productions costs are spend for feed (Sharma *et al.*, 1996; NAERLS, 2011), and therefore feed input is analysed separately since it is the most important in pig breeding. Feed is measured in total kilograms per LU spent on each farm during the analysed period.

Prices for labour include employees and hired workers for the one year period, but usually the most common labour activities are provided by the family members. Also, most of the farms operate as private family holdings, which do not provide evidence on the total working hours of each family member. Since family members are always available on the farm, in this paper the labour is analysed in total Euros per LU and in total number of workers, including both family members and employees who have been involved in the farm operational activities during the analysed year.

The other inputs with a significant impact on technical efficiency are: veterinary costs, vaccination and insemination doses, hygiene and disinfection costs, energy costs, ecology cost, cost for transport and insurance. To reduce the number of other inputs, they are all summarised in two groups: cost for materials and cost for services.

Second stage variables

One of the second stage variables that are analysed in the paper is distance to the closest market of a bigger city. Some studies analysed the distance of the farm and explain its importance for farm efficiency in respect to the transportation costs and environmental regulations (Galev & Lazarov, 1968). In the study, the distance to the closes market or big city is represented in kilometres (km).

Further, descriptive statistics is used to evaluate the relationship between the use of different technology types and the other second stage variables. For the purpose of the study, the technology is divided into new and old, according to the applied production technology and the year of instalation. In that way, 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 farm accounting variable shows how many farmers are providng bookkeeping of the production activities in quantities and prices spent, and marketing includes the activities provided by farmers to represent their farms, by using internet technology and other marketing sources.

Moreover, farmers knowledge should also give an answer to the existence of a link between formal and informal education and the type of production technology. 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 on three variables: participation in agricultural associations and the years of farmers experience, while seminar, conferences and workshops are estimated with 3, 2 and 1 depending on farmers participation often, rarely or never, respectively.

4. Results and discussion

First stage results

The results show that 23.8% 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, 71.42% operate on increasing return to scale (IRS) and thus the response should be towards reducing the utilisation of inputs 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

	TE_{CRS}	TE_{VRS}	SE
Mean	0.468	0.941	0.475
SD	0.393	0.151	0.388
Min	0.002	0.509	0.002
Max	1.000	1.000	1.000

DEA results on TE; (n=21).

Also, the inefficiency 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 94% in average. On the other hand, there is a big difference between the two scales, which is due to the low mean efficiency of average 47%. Technical efficiency under CRS is lower than TE_{VRS} for about 48%, 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 50% efficient, farmers could still make improvements. In that way, the most important for the farmer is to decide how much he should reduce the amount of utilised inputs. Overall, to increase the efficiency, the farmer should reduce the utilisation of feed by 40%. In DEAP labour input is analysed in quantity (the number of workers) and in price unit (total cost spent for labour). These two approaches do not give any differences in the results which confirm that this input increases farm inefficiency for 32%. However, due to the results, the cost of energy increases farm inefficiency the most and could be reduced for about 55%. Inefficient farms can increase their overall efficiency score by spending 42% less material costs and 49% less costs for services. Hence, minimum quantities of the labour and feed input should be reduced considering that they are the most valuable inputs for quality pig production. The highest level of inputs that has been estimated on some of the farms is 91% for energy and services costs.

Comparing the size of farms, their overall technical efficiency under VRS is almost the same in both big and medium farms and present 0.936 and 0.929, respectively. On the other side, all small farms face full technical efficiency under VRS.

Overall technical efficiency of big, medium and small farms is much smaller under CRS. In that respect, big farms are only 16.86% efficient, medium farms are around 60% efficient and small farms are almost 67% efficient. Concerning the fact that not only input and output variables influence the efficiency and that they are not taken into account under CRS, these results are not assumed as important for this study.

Second stage results

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 that farmers are obligated to implement. However, farmers do not provide evidence on this issue and there are no data that can be analysed in connection to the efficiency, so governmental impact is not analyzed in this study.

Table 3. Relationship between the type of technology and other second stage variables

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

Descriptive statistics; (n=21).

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 couse environmental problems in regard to the disposal of manure, but also in water and air pollution, while bigger distance lead 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.

There is a relation between the type of production technology used and farms' sustainability. Hence, it is assumed that farmers who have 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 the knowledge farmers can increase the overall efficiency of production (Kilpatrick *et al.*, 1999; Koopmans, 1951; Johansson and Ohlmer, 2007; Manevska-Tasevska, 2012; Petrovska, 2011). This study analyses how formal and informal education of farmers influences the decisions for implementing new technology of production. The relationship between farmers' knowledge and the type of technology is presented in Table 4. According to the results, only 6 of all 21 farms produce in completely new technology of production. Also, 6 more farms are having both new and old technology, while the other 9 farms use old technology. The results show that farmers use all technology types, despite of their different behaviour. However, well educated farmers and those who invest in increasing their informal knowledge are flexible to innovations. They use new or make changes on the existing technology types of production. In overall, farmers who have higher educational level, are open to innovations and easily accept new regulations and technologies. The formal knowledge analysis explains that farmers who use new technology have at least secondary education, and farmers with lower education use old technology. 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.

Table 4. Relationship between the type of technology and knowledge

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

Descriptive statistics; (n=21).

5. Conclusion

Technical efficiency of pig farms production depends on many variables, and in this paper they are analysed on two stages. The first stage variables are estimated in a frontier analysis of inputs and outputs used in the production. The results show that 94% of pig farms are technically efficient according to the TE_{VRS}. In comparing with TE_{CRS}, pig farms have 47% average technical efficiency. The ratio between variable and constant return to scale gives an average scale efficiency of 47%. Only 5 farms operate on full scale efficiency, while most of the other pig farms operate on increasing return to scale. This explains that there is still possibility for improving farm efficiency of those farms that have inefficient scale. Since it is very difficult to manage the output amounts because of the nature of the production, the best way for increasing the efficiency is farmers to decide on the amount of inputs. All five input categories that are used in the analysis (feed, labour, energy, materials and services) can be reduced for given quantities, different for each farm. In overall, feed and labour input should be reduced the less, with 40% and 32.34% respectively. The most inefficiency is due to the energy and services costs that should be reduced for around 50%. In respect to the farm size, TE_{VRS} is 93% and 92% for both big and medium farms, respectively. Only small farms are full efficient. In respect to the TE_{CRS} all farms are around 60% technically efficient with the biggest efficient score of all small farms.

The second stage variables consist of environmental factors and managerial behaviour. The external factors, such as governmental policy and regulations, environmental laws, are out of farmers' control. Even though pig production is regulated by laws and governmental policy, the penalty provisions and new regulations are not fully applied in the country. Moreover, new policies are emphasising the environmental factors as 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 pig farmers even if the analysis shows that it is a key for increasing overall production efficiency.

On the other side, the results confirmed that new technologies influence on increasing farm productivity and higher technical efficiency. According to the descriptive statistic, the utilisation of new technology is provided with bigger number of piglets per sow in one farrowing. Also, farmers who use new technology are faced with reduction of the feed quantities consumed by pigs and overall decrease in mortality.

Furthermore, farmers who have higher level of education and invest to improve their knowledge are more flexible in applying new production technologies. In that way, formal and informal education represented with participation and professional training on seminars, conferences and workshops and using more than one source of information are crucial for increasing the production efficiency.

This analysis provokes the conclusion that the production efficiency can still be improved and the best way for farmers is to apply new technologies and innovations in order to meet the new market requirements. In order to be familiar with new trends, farmers need to increase their capacities by continuous improvement of their formal and informal education.

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