RESEARCH ARTICLE

Relationship between efficiency and profitability: The case of Czech swine sector

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Abstract

Aim of study: To examine the link between economic efficiency and profitability of firms belonging to the swine sector.

Area of study: This study is devoted to the Czech swine sector that forms the traditional and essential part of agriculture in the Czech Republic.

Material and methods: Data from the Albertina CZ Gold Edition database for the period 2008-2017 were used. To evaluate the economic efficiency, the data envelopment analysis models are applied. Return on equity, return on assets and return on sales are used to measure profitability. To assess the relationship between economic efficiency and profitability, the Pearson correlation coefficient is used.

Main results: The results demonstrate that there is no clear link between the economic efficiency of firms and their profitability in this industry. The correlation between all three profitability ratios and efficiency score were predominantly positive but not statistically significant in many cases. The economies of scale and scope and the construction of profitability indicators could be the main factors explaining the fact that companies achieving higher efficiency are not also more profitable.

Research highlights: The study provides material useful to owners, managers, and customers of Czech agriculture firms. It identifies the relatively high efficiency of firms measured relatively to the best Czech company. In the European context, however, the efficiency of Czech firms belonging to the swine sector is low. It also reveals that the profitability of the firms is not a representative proxy for economic efficiency.

Additional key words: economic efficiency; animal production; efficiency-profitability relationship; data envelopment analysis

Abbreviations used: BCC (Banker, Charnes and Cooper); CCR (Charnes, Cooper and Rhodes); DEA (data envelopment analysis); DMU (decision making unit); EBIT (earnings before interest and taxes); EU (European Union); ROA (return on assets); ROE (return on equity); ROS (return on sales); SFA (stochastic frontier approach); TE (technical efficiency)

Introduction

The sector of the raising of swine belongs to the traditional and significant segment of agriculture in the Czech Republic. Pork is extremely popular among Czechs. According to Czech Statistical Office data, pork consumption of is about 43 kg per capita which represented approximately 53% of the total consumption of meat in the country in 2018. The growing trend in consumption, is evident wherein consumption was 42.3 kg per capita in 2017 and 43.2 kg in 2018. The Czech Republic is not self-sufficient in pork production in the long term and the self-sufficiency rate has lessened. It reached about 51% in 2019 and compared to 2010, the self-sufficiency rate decreased by 13 percentage points (CSO, 2020; Ministry of the Agriculture of the Czech Republic, 2020). The external trade with live pigs and pork is in deficit. The Czech Republic is net importer of pork and on the other hand, the external trade with live pigs reached a surplus. As a result, the nation

is a net exporter of live pigs (CSO, 2020; Ministry of the Agriculture of the Czech Republic, 2020).

In terms of the overall efficiency of this sector, the industry suffers from the highest production costs within the monitored countries of the European Union (EU). In the Czech Republic, 1.64 €/kg hot carcass weight was spent in 2018, which is approximately 0.18 €/kg hot carcass weight more compared to the average costs of the monitored EU members. (Hoste, 2020).

The swine sector depends heavily on subsidies from common agricultural policy of the EU. This subsector is characterised by relatively low profitability compared to other types of farming (Boudný & Špička, 2012). Since the year 2012, the profitability of the Czech pig farms has grown due to favourable prices and better efficiency. Still there are significant differences among individual firms in this sector with a gap between top and bottom pig farms (Špička, 2014).

The evaluation of the firm performance and firm efficiency is part of the central themes of business economics, and efficiency is the central theme of theoretical economics. Generally, efficiency signifies the use of resources in the best way (Samuelson & Nordhaus, 1998). In business, production or economic efficiency is most often examined, where these terms require minimizing inputs at a given level of outputs or maximizing outputs at a given level of inputs (Farrell, 1957; Ali & Byerlee, 1991).

The issue of evaluation of firm efficiency is not important only for academics but especially for the companies and for managers at all levels. Assessing firm efficiency in the context of competitors offers assumptions for successful business management and supports creating and implementing a successful strategy. Economic efficiency also plays an important role in swine sector; it is an essential condition for sustainable business and the maintenance of this traditional agricultural sector.

This study analyses the link between firm efficiency and its profitability. Higher business efficiency is often associated with higher profitability. Extremely profitable companies are thus considered to be efficient. However, this simplification has its limits, and this link may not be unambiguous. Business economics describes the relationship between profitability and efficiency using the efficiency-profitability matrix. In this context, the firms are divided among four groups based on their profitability and efficiency. The first group consists of firms who enjoy a high level of efficiency and profitability (star). The second group covers firms with low profitability and efficiency (underdog). The third group includes firms with low efficiency and high profitability (lucky), and finally, the fourth group comprises firms with high efficiency and low profitability (unlucky) (Kumar, 2008). The market imperfections are the main argument used to describe the existing unclear relationship between profitability and efficiency where especially the level of competition and the type of product play an especially important role (Kumar, 2008; Keramidou et al., 2013).

The study aims to examine the link between economic efficiency and profitability of firms belonging to the swine sector in the Czech Republic. To our knowledge, this is the first study that tests the relationship between economic efficiency and profitability in the industry. It extends the knowledge in the field of the relationship between firm efficiency and profitability and proposes new insights into this issue in the Czech Republic.

Material and methods

Literature review

The efficiency and efficient use of scarce resources are central to theoretical economics. The efficiency and efficient use of scarce resources are also important from other perspectives. They have strong environmental and social overlaps where the efficient use of resources is very important with regard to sustainable development.

From the perspectives of business economics, production efficiency is usually examined. Farrell (1957) distinguishes two components of production efficiency: technical efficiency (TE) and price efficiency. Technical efficiency indicates minimizing inputs at a given level of outputs or maximizing outputs at a given level of inputs. Price efficiency implies the optimal combination of inputs and outputs according to their price. Production efficiency, which is often referred to as economic efficiency, suggests choosing the volume and structure of inputs and outputs that minimize cost or maximize revenue (Farrell, 1957; Ali & Byerlee, 1991).

There are many empirical studies that assess firm efficiency in agriculture and the field of pig farming (e.g. Lansink & Reinhard, 2004; Galanopoulos et al., 2006; Latruffe et al., 2013; Manevska-Tasevska et al., 2017; Calafat-Marzal et al., 2018; Yan et al., 2020). The stochastic frontier approach (SFA), developed by Aigner et al. (1977), and the data envelopment analysis (DEA), created by Charnes et al. (1978) belong among the most frequently used methods to measure firm efficiency in these studies.

A number of studies are devoted to the evaluation of the effectiveness of Czech agriculture. These studies examine various aspects of efficiency in selected agricultural sectors; however, only a small part of them concentrates on pig farming. Čechura (2010) examined the TE of Czech agriculture and concluded that the average level of TE is approximately 90% for agricultural companies. Žáková Kroupová (2016) identified similar TE of dairy farms, where the average TE was approximately 94%. She also examined the system of subsidies and identified the strong negative relationship between operational subsidies and

TE change using the sample of dairy farms. Matulová & Čechura (2016) focused on the TE of individual sectors of Czech agriculture. The results suggested that TE varies in individual sectors (combined, plant, animal and other production), the lowest being animal production (average 83%), and the highest in other production (average 92%). They also examined the impact of subsidies on TE and identified a positive relationship between single area payments and TE. On the other hand, the effect of national additional payments was not statistically significant. Kostlivý & Fuksová (2019) addressed the TE of Czech livestock farms and compared conventional and organic farming. They confirmed that the localisation, economic size, type of farming and organic agriculture are the important determinants of TE of livestock types of farms. Rudinskaya *et al.* (2019) focused on the location of farming and examined the technical effectiveness of farms operating in less favoured areas. They identified the significant impact of location on TE. They concluded that the farms located in areas outside the less favourable areas achieve better TE. The results also showed the higher TE of animal farms compared with plant production and bigger farms compared with small ones.

Friebel & Friebelová (2006) used the DEA model to examine the efficiency of 20 Czech pig farms. The effectiveness of firms was assessed separately in three areas: piglet production, start period of fattening and fattening. The average TE was approximately 90% in each of the examined categories. Malý *et al.* (2011) examined the effectiveness of Czech pig farming with a sample of 32 firms and focused on pig fattening. They estimated the production function and examined the determinants of effectiveness of pig farms. They concluded that there were significant differences among the surveyed farms. The feed compound and new stock weight is among the most important factor of final production. Pechrová & Medonos (2016) reviewed the development of productivity of Czech pig farms in the period 2006-2013. Using a sample of 41 firms while applying the Malmquist productivity index, they found that the total factor productivity declined in the examined period and this explains the low competitiveness of Czech pig farms on the EU market.

The part of the empirical literature is focused on examining the link between efficiency and profitability. This relationship was examined for different industries and the conclusions of individual studies varied. Some studies identified the positive impact of efficiency on profitability (*e.g.* Greene & Segal, 2004; Mostafa, 2010; Guillén *et al.*; 2014; Aissa & Goaied, 2016). In contrast, others found only a small or no relationship between efficiency and profitability (Sellers-Rubio & Nicolau-Gonzálbez, 2009; Olson & Zoubi, 2011; Shieh, 2012; Keramidou *et al.*, 2013; Palečková, 2015; Hedija *et al.*, 2017). According to these studies, the size of the companies and economies of scale and scope, group ownership and vertical integration suggest that the firms producing their products with the best practices are not capable to generate the maximum profits.

The differences in results might be closely related to the industry under examination, its specifics, and the specifics of the country in which the relationship is examined. Despite the existence of many studies that focus on the link between efficiency and profitability, little attention has been paid to this relationship in agriculture.

Methods

To assess the economic efficiency of firms, we used data from the Albertina CZ Gold Edition database that is provided by Bisnode company (Bisnode, 2019). It contains information on all profit and non-profit entities in the Czech Republic that have been assigned a personal identification number (IČ). At present, this database contains data for more than 2.7 million subjects. We chose the data for swine sector (group 01.460 Raising of swine) for the period 2008-2017 using the statistical classification of economic activities in the European Community Rev.2 (NACE Rev.2).

First, we narrowed the sample to analyse only active firms. We selected only firms with sales higher than 100,000 CZK (~ €3,700) per year in all examined years and those which provided all the information necessary to assess economic efficiency and profitability. The final sample comprises data of 68 pig farms. The number of firms in individual years is shown in Table 1. According to the Czech Statistical Office data, the sample represents, on average, approximately 18% of pig farms in individual years.

Pig breeding is concentrated in large farms, where farms with more than 2,000 pigs account for almost 90% of the total number of pigs (Ministry of the Agriculture of the Czech Republic, 2020). Our sample consists mainly of large farms, where the average sales reached the value of 225 million CZK (~ € 9 million) and thus reflects appropriately the situation on the Czech market of pig production.

We used DEA models to evaluate the economic efficiency of the firms. The advantage of DEA is that it does not require a specification of the production function and is suitable also for small sample of firms in comparison to SFA, which can be also used to assess the economic efficiency. The specification of production function is critical in productivity and efficiency analysis (Tian *et al.*, 2015). SFA has the advantage of using various types of functions but it is data intensive requiring a lot of DMUs (decision making units). On the other hand, DEA is suitable for analyses using a relatively small sample of firms with a homogenous product, which is the case of our study (Kumar, 2008; Porcelli, 2009). Following

Table 1. Mean of inputs, outputs of DEA models (in thousands of CZK) and profitability ratios

	2008	2009	2010	2011	2012
Output of DEA models					
Sales and subsidies	140772.90 (251041.2)	136409.30 (222340.5)	147020.1 (212105.9)	165858.20 (259253.5)	202885.7 (287921.7)
Inputs of DEA models					
Personnel costs	17129.30 (22957.96)	15976.91 (21803)	17316.83 (21815.84)	16099.65 (21193.6)	18182.30 (22335.63)
Tangible and intangible assets	72495.74 (90327.13)	72227.83 (86225.99)	78459.9 (89022.41)	78878.73 (91989.09)	89485.61 (98245.45)
Consumption of products	122192.7 (226945)	104540.9 (189292.6)	115559.1 (181037.9)	132711.5 (222818.4)	164679.8 (250905.8)
Profitability ratios					
Return on equity	-0.4020 (0.7698)	-0.0845 (0.6893)	-0.3514 (1.7158)	-0.0375 (0.4204)	0.0727 (0.6442)
Return on assets	-0.1879 (0.5114)	0.1987 (1.3837)	-0.0233 (0.1059)	-0.0505 (0.2035)	0.0647 (0.0823)
Return on sales	-1.013 (6.4470)	0.0621 (0.4350)	-0.0345 (0.1641)	-0.0332 (0.2087)	0.1102 (0.3323)
Number of firms	54	54	48	51	46
	2013	**2014**	**2015**	**2016**	**2017**
Output of DEA models					
Sales and subsidies	198888.4 (279955.7)	178406.5 (282745.5)	181470.5 (286746.9)	203183.7 (308690.1)	225271.3 (330625.7)
Inputs of DEA models					
Personnel costs	17451.61 (22659.9)	16618.73 (23301.5)	17744.68 (25063.8)	20002.33 (27343.62)	23527.59 (31158.76)
Tangible and intangible assets	89543.98 (103656.8)	82415.50 (101896.7)	89756.36 (109053.3)	104801.70 (120233.2)	113868.10 (138248.9)
Consumption of products	164920.9 (252261.3)	142763.6 (247263.6)	146742.5 (252368)	159688 (273712.5)	177850 (292788.3)
Profitability ratios					
Return on equity	-0.0979 (0.7482)	0.0891 (0.2003)	0.0142 (0.5955)	0.0169 (0.5950)	0.1181 (0.1601)
Return on assets	0.0158 (0.1000)	0.0511 (0.0670)	0.0159 (0.0907)	0.0567 (0.1469)	0.0746 (0.0951)
Return on sales	-0.0267 (0.2850)	0.0188 (0.2856)	-0.0980 (1.0929)	0.1244 (0.3365)	0.1172 (0.2164)
Number of firms	49	48	44	39	34

DEA: data envelopment analysis. Standard deviations in brackets. *Source*: Albertina CZ Gold Edition; authors' computations

the studies of Asmild & Hougaard (2006), we applied the output-oriented DEA models to assess economic efficiency. Output oriented models are frequently used in the studies to examine the economic efficiency of firms. The reason to select this type of model is that the behaviour of firms is output-oriented. Firms aim to maximize their outputs, although inputs are also under control (Barros & Alves, 2003). The same is true when analyzing swine sector since the farmers aim to maximize the production of pigs where inputs can be seen as fixed in terms of short-run (Asmild & Hougaard, 2006).

Two variants of output-oriented models are used for comparison: a model with constant returns to scale (CCR-O) and a model with variable returns to scale (BCC-O). However, a BCC-O model is more suitable for swine sector where the non linear relationship between inputs and output is expected. Economies of scale may occur with growing breeding in this industry. Thus, the assumption about linearity of outputs (revenues) and inputs (costs) is not appropriate.

The basic principle of DEA models is to estimate an efficient frontier that is not pre-set, but it is based on the

"best ratio" of the compared DMUs outputs and inputs. A DMU which is on the frontier is referred to as an efficient unit. This relative full efficiency means that performances of other DMUs do not demonstrate that some inputs or outputs are improved without worsening other inputs or outputs (Cooper *et al.*, 2011). One of the results of the DEA models is the efficiency score for each DMU – when the score is equal to 1, the DMU is efficient, otherwise inefficient. Virtual inputs and outputs for inefficient units are also provided by the model. They show the necessary change of input or output for the DMU to be efficient. As it was mentioned previously, DEA models are either input or output-oriented. The output-oriented model assumes a fixed level of inputs, the input-oriented model assumes a fixed level of outputs. The basic DEA model called CCR by authors Charnes, Cooper and Rhodes (Charnes *et al.*, 1978) is used for constant returns to scale. In case of variable returns to scale, BCC model (Banker, Charnes and Cooper) is used (Banker *et al.*, 1984). An overview and detailed information on DEA models is found in Cooper *et al.* (2006). The main idea of the efficiency calculation is based on the linear optimization model with the objective function maximizing the rate of the weighted sum of outputs divided by the weighted sum of inputs. The CCR output-oriented model transformed (Charnes-Cooper transformation) into linear programming form is defined as follows (CCR-O) (Cooper *et al.*, 2006):

$$\text{Minimize} \quad z = \sum_{j=1}^{m} v_j x_{jq} \tag{1}$$

$$\text{Subject to:} \quad \sum_{i=1}^{r} u_i y_{ik} \leq \sum_{j=1}^{m} v_j x_{jk}; \ k = 1, 2, \ldots, n$$

$$\sum_{j=1}^{m} u_i y_{iq} = 1$$

$$u_i \geq \varepsilon, \ i=1,2,\ldots,r, \ v_j \geq \varepsilon, \ j=1,2,\ldots,m, \ v=\text{any value}.$$

where q is the evaluated DMU, y_{ik} are known r outputs, x_{jk} are known m inputs of the k-th DMU out of n DMUs, u_i and v_j represents the variable weights to be determined by the solution of this problem and ε is the infinitesimal constant, which is usually set as 10^{-8}.

The BCC output-oriented model is slightly different, as it uses additional parameter v relating to the convex efficiency frontier. The model is defined as follows (BCC-O) (Cooper *et al.*, 2006):

$$\text{Minimize} \quad z = \sum_{j=1}^{m} v_j x_{jq} + v$$

$$\text{Subject to:} \quad \sum_{i=1}^{r} u_i y_{ik} \leq \sum_{j=1}^{m} v_j x_{jk} + v, \ k = 1, 2, \ldots, n \tag{2}$$

$$\sum_{j=1}^{m} u_i y_{iq} = 1$$

$$u_i \geq \varepsilon, \ i=1,2,\ldots,r, \ v_j \geq \varepsilon, \ j=1,2,\ldots,m, \ v=\text{any value}.$$

The unit U_q is efficient when the optimal value of the objective function (calculated by the model) z is equal to 1. All inefficient units have z higher or lower than 1 depending on the DEA type of the model used. The efficiency score describes the relative distance from the efficient frontier (Cooper *et al.*, 2006). The number of DMUs should be high enough because if many inputs and outputs are included in a model, all or nearly all units are considered to be efficient. When both BCC and CCR models are applied to the same data, the BCC model usually finds more efficient DMUs than CCR model. It is because of the type of the efficiency frontier - convex in BCC and conical hull in CCR (Cooper *et al.*, 2006).

Models (1) and (2) calculate the efficiency score only for 1 DMU. That is why the calculation must be run n times when n is the number of DMUs to find all results. In that case, usage of the specialized software for the solution of DEA models is suitable. In our case, STATA software was used for the DEA models solution.

To estimate the economic efficiency of firms, we used the DEA model with one output and three inputs. This number of inputs and outputs assures the distinction between efficient and inefficient units achieved in DEA results, as the number of DMUs for all years is more than 3 times higher than the number of criteria (inputs and outputs) selected. It is in line with the recommendations of Cooper *et al.* (2006).

As the output, we used sales and subsidies that represents the value of final production. Sales are calculated as the sum of revenues from sold own products and services and merchandise since they reflect the revenues from production without subsidies. However, subsidies represent a significant income of pig farmers and it is appropriate to take it into account when assessing the effectiveness of pig farms. Hence we used indicator "sales and subsidies" which also covers subsidies and it is calculated as the sum of sales and other operating revenues, which represent just subsidies.

As the inputs, we employed (i) personnel costs, (ii) tangible and intangible assets, and (iii) consumption for products which consists of costs of goods sold, material, energy and services consumption. The data about these categories are available from financial statements of firms and represent suitably the main costs of pigmeat production which include in particular feed cost, labour cost, building and capital cost and other variable costs (artificial insemination and sow replacement costs, health costs, energy, maintenance of buildings, levies, manure disposal costs and miscellaneous variable costs) (Hoste, 2020).

All inputs and outputs of the DEA models reached positive values. A DEA model was applied for each of the selected years (2008-2017) separately to observe changes in the sector. The output and inputs of the DEA models and descriptive statistics are shown in Table 1.

The aim of the study is to examine the link or correlation between efficiency (obtained by the DEA model) and profitability. We used three frequently employed

indicators of profitability: return on equity (ROE), return on assets (ROA) and return on sales (ROS) (Hult *et al.*, 2008). ROE is calculated by dividing the earnings after tax (EAT) by equity; ROA is calculated as a ratio of earnings before interest and taxes (EBIT) and total assets; and ROS is calculated by dividing earnings before interest and taxes (EBIT) by sales. The use of ROE as a profitability indicator is associated with the problem of false positivity if both equity and profit reach negative values. Another problematic situation can occur when a company makes a profit, but due to its negative equity, ROE is negative. In order to eliminate these problems, we used the absolute value of equity computing the ROE. The means of profitability ratios in individual years are shown in Table 1.

To assess whether there is a direct link between profitability and efficiency, the Pearson correlation coefficient was used (Rose *et al.*, 2015). We used STATA software for the calculations.

Results and discussion

As was mentioned before, we analyzed data from 68 companies, but not all of them have data available for all examined years. That is why the first part of the results is connected with all years and all companies with necessary data, the second part is based on the companies with all data for all years – this balanced panel consists of 25 firms only.

To assess the efficiency of firms in the swine sector, we used output oriented DEA models (equations 1 and 2). For comparison, we present the results of DEA models based on constant returns to scale (CCR model) and also variable returns to scale (BCC model). Table 2 summarizes the main results of both applied DEA models for the unbalanced panel.

The average efficiency score in the CCR model was ~ 0.7 in the examined period 2008-2017. The highest value was reached in the year 2015, the lowest in 2009, when the average efficiency score amounts 0.469. It clearly shows the impact of the economic crisis on the pig farms in the year 2009, where the mean efficiency score reaches significantly lower values compared to other years. The crisis affected individual pig farms with varying intensity. The average efficiency is more or less rising from year 2009 and a small decrease is visible in 2016, but the achieved value is still better than in 2013 and earlier. Using the BCC model, the average efficiency score was higher as compared with the CCR model. The average efficiency score reaches ~ 0.8. The results of BCC models have similar trends with the difference in the depth of the decline in the average efficiency rate in 2009. Also the fluctuation in efficiency score are not so noticeable here, which is common for this type of model. This can be explained by different assumptions about returns to scale and the related different applied form of a production function.

The average efficiency score in both models is relatively high, which confirms the fact that most firms performed quite well in comparison with each other. However, the minimum values still point to some not-well-functioning companies. These conclusions confirming the relatively high average efficiency score of the Czech swine sector are in line with previous research. According to Čechura (2010) the average TE of Czech agricultural companies is high and the efficiency score is ~ 0.9. Matulová & Čechura (2016) examined the TE of individual sectors of Czech agriculture and concluded that the efficiency score is ~ 0.8 in animal production. Finally, Friebel & Friebelová (2006) examined the TE of Czech pig farms and stated that the average efficiency score reached the value 0.9.

If we look at the numbers of efficient firms, they are very similar throughout the period under review.

Table 2. Main results of CCR-O and BCC-O models – Unbalanced panel

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CCR-O										
Mean	0.692	0.469	0.653	0.694	0.685	0.667	0.742	0.746	0.702	0.702
St. dev.	0.181	0.234	0.165	0.177	0.158	0.157	0.148	0.140	0.142	0.136
Minimum	0.394	0.133	0.313	0.261	0.333	0.446	0.215	0.282	0.480	0.417
Maximum	1	1	1	1	1	1	1	1	1	1
BCC-O										
Mean	0.826	0.814	0.771	0.746	0.813	0.832	0.850	0.855	0.814	0.894
St. dev.	0.161	0.200	0.175	0.187	0.161	0.155	0.157	0.144	0.154	0.130
Minimum	0.504	0.269	0.424	0.262	0.416	0.484	0.215	0.282	0.480	0.458
Maximum	1	1	1	1	1	1	1	1	1	1
Number of firms	54	54	48	51	46	49	48	44	39	34

CCR-O: output-oriented models with constant returns to scale. BCC-O: output-oriented models with variable returns to scale. *Source*: Albertina CZ Gold Edition; authors' computations in STATA software

The results are shown in Table 3. Around 10% of firms using the CCR model and around 20-30% of firms using the BCC models reached efficiency (except the year 2017 with 41% of efficient companies). On the other hand, around 90% of firms had a score > 0.5 in all examined years except for the year 2009 using the CCR model.

The results presented above reflects the situation of the swine sector. However, the results could be biased to some extent due to the fact that the sample of firms varies in individual years according to data availability. The higher average efficiency achieved in the industry in individual years may be the result not only of generally better efficiency scores achieved by firms, but may reflect the fact that the data of firms that achieved lower efficiency were missing in the given year. On the other hand, the use of an unbalanced panel allows to include the companies that leave the industry during the reporting period into the sample.

To assess the economic efficiency of comparable samples, we used a balanced panel including only companies with all data for all years. This sample covers data of 25 pig farms. The results are shown in Table 4 and Table 5. The average efficiency scores in CCR and BCC models were higher compared with the unbalanced panel. The average efficiency score was ~ 0.8-0.9 that indicates 80-90% average efficiency of firms in this industry. It can be stated that almost all the firms in the balanced sample achieved the efficiency scores better than 0.5 in the period 2008-2017. The higher values of efficiency scores could be expected due to the fact that the sample was cleared out of companies that left the market during the period under review due to worse economic results and that were less efficient. The sample of companies was also more homogeneous in terms of size. The reaction of these companies to market stimuli is thus probably very similar and thus also the impact on the efficiency of companies. Thanks to this fact, the analysis does not show a fall in the efficiency of firms in 2009.

As already mentioned, the results of the applied DEA models show that the efficiency were relatively high in the period under review and the value was relatively independent of the estimation method and sample used. The efficiency of individual companies in the industry did not differ significantly and a high percentage of companies achieved relatively high efficiency. However, it must be emphasized that efficiency was measured relatively to the best company in the Czech swine sector.

The Czech Republic belongs to the countries with the highest production costs in swine sector from the EU countries. In 2018, the average costs of Czech pig farms were approximately by 0.18 €/kg hot carcass weight higher compared to the average costs of the monitored EU countries. In terms of main cost items, the Czech Republic is fully competitive in personnel costs, feed costs and building and capital costs. On the other hand, the problematic items are other variable costs, which consist of artificial insemination and sow replacement costs, health costs, energy, maintenance of buildings, levies, manure disposal costs and miscellaneous variable costs. These reach the highest values within the compared countries of the EU and they are the cause of high total costs of Czech pig farms in comparison with other countries of the EU (Hoste, 2020)

Table 3. Results of CCR-O and BCC-O models by efficiency score value (number of firms) – Unbalanced panel

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CCR-O										
Effic. score = 1	8	3	5	6	4	5	5	4	3	3
	(15%)	(6%)	(10%)	(12%)	(9%)	(10%)	(10%)	(9%)	(8%)	(9%)
Effic. score > 0.75	18	10	11	17	14	13	20	20	11	10
	(33%)	(19%)	(23%)	(33%)	(30%)	(27%)	(42%)	(46%)	(28%)	(29%)
Effic. score > 0.5	46	19	42	46	40	45	47	43	36	33
	(85%)	(35%)	(88%)	(90%)	(87%)	(92%)	(98%)	(98%)	(92%)	(97%)
BCC-O										
Effic. score = 1	18	16	11	11	9	13	13	11	9	14
	(33%)	(30%)	(23%)	(22%)	(20%)	(27%)	(27%)	(25%)	(23%)	(41%)
Effic. score > 0.75	35	36	24	24	32	34	37	35	26	29
	(65%)	(67%)	(50%)	(47%)	(70%)	(69 %)	(77%)	(80%)	(67%)	(85%)
Effic. score > 0.5	54	50	46	48	44	48	47	43	38	33
	(100%)	(93%)	(96%)	(94%)	(96%)	(98%)	(98%)	(98%)	(97%)	(97%)
Number of firms	54	54	48	51	46	49	48	44	39	34

CCR-O: output-oriented models with constant returns to scale. BCC-O: output-oriented models with variable returns to scale. *Source*: Albertina CZ Gold Edition; authors' computations in STATA software

Table 4. Main results of CCR-O and BCC-O models – Balanced panel

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
					CCR-O					
Mean	0.817	0.824	0.760	0.722	0.801	0.847	0.908	0.885	0.896	0.822
St. dev.	0.128	0.159	0.152	0.155	0.139	0.103	0.088	0.090	0.092	0.113
Minimum	0.597	0.367	0.386	0.411	0.429	0.668	0.692	0.665	0.644	0.526
Maximum	1	1	1	1	1	1	1	1	1	1
					BCC-O					
Mean	0.855	0.880	0.841	0.802	0.876	0.911	0.939	0.915	0.936	0.914
St. dev.	0.120	0.146	0.164	0.169	0.141	0.099	0.076	0.089	0.090	0.115
Minimum	0.605	0.369	0.432	0.431	0.431	0.703	0.765	0.700	0.669	0.550
Maximum	1	1	1	1	1	1	1	1	1	1
Number of firms	25	25	25	25	25	25	25	25	25	25

CCR-O: output-oriented models with constant returns to scale. BCC-O: output-oriented models with variable returns to scale. *Source:* Albertina CZ Gold Edition; authors' computations in STATA software

Table 5. Results of CCR-O and BCC-O models by efficiency score value (number of firms) – Balanced panel

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
					CCR-O					
Effic. score = 1	7	5	3	2	2	3	6	5	4	4
	(28%)	(20%)	(12%)	(8%)	(8%)	(12%)	(24%)	(20%)	(16%)	(24%)
Effic. score > 0.75	16	18	14	11	16	18	24	23	23	17
	(64%)	(72%)	(56%)	(44%)	(64%)	(72%)	(96%)	(92%)	(92%)	(68%)
Effic. score > 0.5	25	24	24	24	24	25	25	25	25	25
	(100%)	(96%)	(96%)	(96%)	(96%)	(100%)	(100%)	(100%)	(100%)	(100%)
					BCC-O					
Effic. score = 1	8	10	9	7	7	11	9	9	11	11
	(32%)	(40%)	(36%)	(28%)	(28%)	(44%)	(36%)	(36%)	(44%)	(44%)
Effic. score > 0.75	19	22	18	13	20	22	25	23	23	22
	(76%)	(88%)	(72%)	(52%)	(80%)	(88%)	(100%)	(92%)	(92%)	(88%)
Effic. score > 0.5	25	24	24	24	24	25	25	25	25	25
	(100%)	(96%)	(96%)	(96%)	(96%)	(100%)	(100%)	(100%)	(100%)	(100%)
Number of firms	25	25	25	25	25	25	25	25	25	25

CCR-O: output-oriented models with constant returns to scale. BCC-O: output-oriented models with variable returns to scale. *Source*: Albertina CZ Gold Edition; authors' computations in STATA software

In terms of profitability, Czech swine sector is loss-making without subsidy in the long run. In 2018, the net profit without subsidies reached -0.30 €/kg hot carcass weight, in 2016 and 2017 it ranged from -0.11 to -0.15 €/kg hot carcass weight. The reasons for this situation can be seen in the higher costs associated with pork production and also in lower realization prices compared to the EU average (Ministry of the Agriculture of the Czech Republic, 2020).

After having assessed the efficiency of pig farms, we examined the relationship between firm efficiency and firm profitability using the Pearson correlation. The re-

sults are shown in Table 6. The correlation coefficients are predominantly statistically insignificant. It varies depending on the efficiency and profitability indicators used and also between samples (balanced and unbalanced panel). It was found that the examined relationship was positive if it was detected. This fact means that companies with higher efficiency also show higher profitability. Negative coefficients of correlation indicating indirect proportions are also recorded in Table 6. However, these results are not statistically significant.

A stronger and most similar link between efficiency and profitability is identified when using ROA and ROS

Table 6. Pearson correlation coefficients – Efficiency and profitability (for individual years)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Unbalanced panel										
CCR-O										
ROE	0.3213**	-0.059	0.219	0.013	0.267*	0.105	0.201	0.302**	0.228	0.537***
ROA	-0.105	0.294**	0.268*	0.177	0.379***	0.154	0.334**	0.267*	0.472***	0.558***
ROS	-0.218	0.290**	0.066	0.222	0.166	0.150	0.592***	0.561***	0.481***	0.507***
BCC-O										
ROE	0.246*	-0.025	0.246*	-0.020	0.240	0.031	0.282*	0.143	0.277*	0.488***
ROA	-0.013	0.100	0.186	-0.047	0.223	0.190	0.361**	0.290*	0.424***	0.590***
ROS	-0.132	0.111	0.073	0.074	0.034	0.292**	0.641***	0.636***	0.320**	0.278
Balanced panel										
CCR-O										
ROE	0.352*	0.242	0.241	-0.014	0.295	0.338*	0.005	0.422**	-0.164	0.373*
ROA	0.458**	0.396*	0.452**	0.301	0.355*	0.363*	0.315	0.459**	0.148	0.607***
ROS	0.449**	0.682***	0.632***	0.267	0.091	0.382*	0.270	0.479**	0.140	0.679***
BCC-O										
ROE	0.471**	0.246	0.335	0.147	0.240	0.343*	-0.040	0.474**	-0.081	0.407**
ROA	0.569***	0.432**	0.379*	0.347*	0.310	0.329	0.296	0.545***	0.227	0.597***
ROS	0.556***	0.774***	0.577***	0.320	0.038	0.324	0.311	0.570***	0.176	0.600***

ROE: return on equity. ROA: return on assets. ROS: return on sales. CCR-O: output-oriented models with constant returns to scale. BCC-O: output-oriented models with variable returns to scale. ***$p<0.01$. ** $p<0.05$. * $p<0.1$. *Source*: Albertina CZ Gold Edition; authors' computations in STATA software

indicators as the measurement of profitability. This can be explained by the fact that the level of ROE is strongly influenced by the proportion of equity and liabilities used. If companies achieved the same efficiency (efficiency score) and have different leverage, their ROE would most likely differ in favour of the company with a higher proportion of liabilities.

In general, no clear link between profitability and efficiency has been identified. Using the classification of relationship power for social science research by Vaus (2002), the coefficients of correlation r indicate the existence of a moderate (r from 0.3 to 0.49) or a substantial (r from 0.5 to 0.69) statistically significant relationship only in the year 2017. The r for this year ranged from 0.373 to 0.679 depending on applied indicators of profitability and variants of the DEA model and they were statistically significant (except in the case of the indicator ROS). This was confirmed using both balanced and unbalanced panel. It is probably due to the fact that this year was very successful for firms, which is confirmed by the high values of the ROA, ROE and ROS indicators. They achieved high profitability values with relatively low standard deviations. This fact, together with the relatively high efficiency of all the companies surveyed, made it possible to identify the existence of a significant positive relationship between efficiency and profitability this year. On the other hand, in years when the market situation is not so favourable and companies have to deal with sales problems and respond flexibly to the situation, which may be reflected differently in the rate of profitability. Here, the relationship between profitability and efficiency becomes ambiguous.

Our conclusions that there is not the clear link between firm efficiency and firm profitability and that the capability of produce the products with the best practices are not the guarantee for generating the maximum profits are the same as the findings of Keramidou *et al.* (2013) examining the relationship in Greece meat processing industry. Using the Czech data, also Palečková (2015) for the banking sector and Hedija *et al.* (2017) for sub-sector of travel agents came to a similar conclusion. The economies of scale and scope and the construction of profitability indicators could be the main factors explaining the fact that companies achieving higher efficiency are not also more profitable. According to Eurostat (2014) the larger European pig farms achieve better performance benefiting greater economies of scale. Smaller companies thus can achieve lower profitability, even though they achieve high values of TE. The construction of traditional profitability indicators can also play a role, where the amount of profit is related to equity (ROE) or total assets (ROA). Different leverage or different market value of total assets thus affects the rate of profitability regardless of the level of TE the company.

In conclusion, the study was devoted to the pig farms and the issue of efficiency and profitability of this industry. They examined these factors and proved the relationship between economic efficiency and profitability, being both very important indicators of firm economic activity. This work provides material useful to owners, managers, and customers of Czech agriculture firms. Using DEA models, the study presents the data assessing the efficiency of the industry and identifies the relatively high efficiency of these firms. The average efficiency of firms was high and ranged from 70 to 90% depending on the method and sample used. The results further confirmed that the profitability indicators may not correspond to the economic efficiency of firms in the swine sector and the profitability of the firms is not a representative proxy for economic efficiency.

The study extended the existing knowledge about the link between firm efficiency and profitability and brought new insight into the Czech swine sector. Due to the relative lack of studies on this topic and existence of industry-specific factors that could form this relationship, here is the space for further research focusing on testing the relationship between firm efficiency and profitability in other Czech industries.

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