OPTIMIZATION MODEL OF FARM STAGES OF THE PORK MEAT SUPPLY CHAIN

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Annotation: The study provides DEA-ranking and benchmarking of pig meat production in 14 European countries, Brazil and USA in the period 2012 – 2017. One of the Czech SMEs involved in the pig production (named FARM), achieving excellent results, is assigned into the group for the comparison. The research concerns the analysis of the relative costs of the pig meat production and the physical performance up to farmgate level providing comparison and ranking of involved subjects and design of peer processes to improve the manufacturers' performance. The statistically significant correlation detected the links only in one case between "depreciation and finance" and "other variable costs" imputes. The DEA-excellent units are Brazil, USA and FARM, which represent peers for the other countries. The Nederland, Germany and Denmark are well ranked as well (the DEA score higher than 0.9), France, Spain, Belgian and Finland (the DEA score higher that 0.8). The EU average ranking reaches 0.85. The DEA-peer processing assigns each DEA-not-excellent country a set of peers and coefficients "λ" that enables to formulate the recommendations of the imputs´ changes in order to increase the effectiveness of the production. The results can identify the critical success factors both for the countries and for the individual producers including SMEs. DEA procedure is an excellent approach to start mutual benchmarking involving European countries.

Key words: Pork meat production, physical performance of pig production, Data Envelopment Analysis, ranking, peer, decision-making unit.

JEL classification: Q13, C22

1. Introduction

The article follows the previous research concerning evolution of pig prices on the European swine market. The univariate time series model was used to analyse the position of the Czech Republic among other five European pig producers in the period 2010 – 2018 (Smutka at all., 2018). The research proved that there are considerable differences among producers.

In this study, we analyse the imputs and outputs of pig meat production in 14 European countries, Brazil and USA in the period 2012 – 2017. One big Czech pig producer (under name "FARM"), which achieves excellent results among other Czech producers, is assigned to a group of European countries for the comparison. The Data Envelope Analysis (DEA) models are implemented to analyse the effectiveness of the pigs production in the European countries to answer the question "how to change inputs to improve the effectivity of production". In the different geographical conditions of Europe, costs of pig meat production and productivity of the physical performance up to farm-gate level are compare and ranked.

DEA is a non-parametric productive efficiency measurement method for operations with multiple inputs and multiple outputs. DEA models help to identify efficient "decision-making unit" (DMU) and to construct efficient production frontier. DEA models measure the relative efficiency that is the efficiency of each DMU relative to best DMUs in the sample

("peer units"). Applying DEA in evaluating performance of a set of enterprises enables to form two clusters: enterprises that comprise an efficient frontier and inefficient enterprises lying below the frontier. One of the main advantages of the DEA model is that it allows incorporating multiple inputs and outputs. However, the choice of appropriate impute and/or output is sometimes more complicated for example the question "how to treat intellectual property – as inputs or outputs?"

According to recent study by Liu et al. (2013), Yang (2018), and Anon (2018) the largest areas of reported applications of DEA are banking, health care, transportation, education and agriculture. Between 1978-2010 overall, around two-thirds of DEA papers embed empirical data, while the remaining one-third are purely methodological. The applications that have the highest growth momentum recently are energy and environment as well as finance.

The DEA literature suggests several ways of dealing with applications in which DMUs have different specialisations or publication profiles. In agriculture, the problem of specialisation of farms is ubiquitous due to large number of possible farm outputs (Davis, 2017). In the same region, there are usually a variety of different crops and livestock products each produced only by a small farms and SMEs while the big farms may produce several common outputs only. The stronger position of large companies on the market influences the prices of the agricultural products. The bigger pig producers differs from standard farming producers because their production is highly specialised and similar to the industry. Small farmers produce in a disadvantageous competitive environment and have to subsidize the realization prices of products from other sources. Antle et al. (2017) look for solution of the DMU evaluation for the farms where a large number of different crops may be produced in a particular region only a and few farms actually produce each particular crop. The authors illustrate the approach in which various outputs of the production are related to the one main output in different regions of Turkey. Kuo et al. (2014) discuss environmental conditions, which have to be put among other efficiency economic factors at the same time, and which enlarge the number of DEA factors. Thus, the DEA models should respect both people's request for living and environment conservation. Similar study present Picazo-Tadeo et al. (2011) and Coyne et al. (2015).

DEA operates also in the stochastic environment. For example, Sharma et al. (1997) examine the productive efficiency of a sample of swine producers in Hawaii by estimating a stochastic frontier production function and the constant returns to scale (CRS) and variable returns to scale (VRS) output-oriented DEA models.

Huguenin (2015) analyses the existing SW modules and argues that there are user-friendly and easily accessible SW to practitioners and decision makers. This makes the possibility to provide evaluation using several alternative models including environmental adjustments.

The aim of the research is comparison of performance of pork producers in 14 European countries, Brazil, USA, and one Czech farm (SME), in the period 2012 – 2017. Perform manufacturers' assessments using DEA models and design peer processes to improve manufacturers' performance leading to the recommendation on costs´ reduction and/or changing the structure.

2. Materials and Methods

1. The implemented methodology:

The methodology follows the work of Avkiran and Parker (2010) investigating key dimensions underlying the progress realized by DEA methodologies. The Data Envelope Analysis (DEA) are widely known and many times described. The formulas and computations in this study follow the publication Brožová, Houška and Šubrt (2014).

2. Data search and elaboration:

Searching and processing data from 14 European countries, USA, Brazil and one Czech pig producer (in the model called "FARM"). Utilizing DEA we operate with 6-years data averages (2012 – 2017) which make possible that producers are compared on the same scale. The averages of data were elaborated from the relatively detailed description of the production characteristics available in European *InterPig and EUROSTAT* databases. The data were transformed into the same units (day, kg, Euro), statistically treated and adjusted into the calculation tables. The structure of imputes and outputs follows the *InterPIG* methodology which elaborates data with some national differences in definition, but where this has occurred, the data has been adjusted in the most appropriate way.

3. Input and output data for DEA models:

The use of the European sources of data ensures that a farm structure in one nation is only compared to another nation with a similar structure. Pig production is characterized by multiple outputs and inputs. For the purpose of efficiency analysis, output is aggregated into one category: C*arcase meat production sow/year/kg*. The imputs are aggregated into four categories, namely: *Feed costs, Other variable costs, Labour costs, Depreciation and finance costs.*

4. Processing of data:

DEA models were estimated using the program "DEA-Solver-LV 8.0" (http://www.saitech-inc.com/index.asp) including 28 clusters of DEA and enabling solve models up to 50 DMU. To check the consistency of DEA results with traditional unit ratings models CCR and BCC will calculate the efficiency scores for each country. Countries with the same or very tight ranking will be clustered into groups. The operation may reduce the number of units.

5. Input data:

Table 1. Data for DEA ranking.

	(I) Feed	(I) Other variable costs	(I) Labour	(I) Depreciation and finance	(O) Carcase meat
Countries	Euro/kg/deadweights				Sow/year/kg
AUS	0.982	0.260	0.167	0.272	2 191
BEL	1.192	0.208	0.125	0.197	2 403
BRA	1.025	0.133	0.079	0.100	2 217
DEN	0.941	0.244	0.141	0.211	2 428
FIN	0.916	0.314	0.160	0.250	2 297
FRA	0.945	0.243	0.145	0.213	2 345
GER	0.969	0.291	0.145	0.235	2 494
GB	1.077	0.265	0.162	0.210	1 844

HUN	1.006	0.289	0.148	0.229	2 072
IRE	1.146	0.250	0.133	0.202	2 095
ITA	1.284	0.235	0.166	0.229	2 586
NL	0.951	0.329	0.150	0.203	2 586
SPA	1.037	0.217	0.096	0.137	1 978
SWE	1.013	0.240	0.188	0.394	2 167
USA	0.808	0.153	0.106	0.117	2 167
EU	1.031	0.266	0.147	0.225	2 447
ČR	1.141	0.449	0.150	0.127	2 068
FARM (ČR)	0.685	0.260	0.167	0.272	2 500

Source: InterPIG, EUROSTAT, VÚZE. Own data processing. Complete data, covering the period 2012 – 2017, are available on https://cevema.pef.czu.cz/.

Table 1 presents data, elaborated for the DEA ranking procedure. Average values, covering the period 2012 – 2017, summary the financial performance: *Euro/kg deadweight for imputes (I)* and *carcase meat production sow/year/kg for outputs (O).* The data present the relative average costs of production within each country and makes to provide an accurate comparison within 0.80 – 1.5 €/kg of deadweight. Full list of data is available on https://cevema.pef.czu.cz/.

3. Results and Discussion

First round of ranking

Efficiency scores, calculated for each individual country and the FARM, using CCR and BCC DEA models are presented in the Table 2. Models CCR(I) and CCR(O) give the same values.

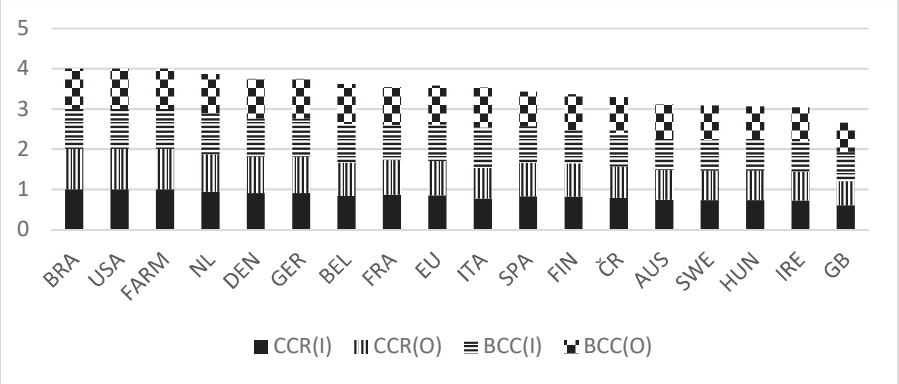
Table 2. Ranking of countries by CCR and BCC DEA models determined in < 0 – 1 scale >.

DMU		BRA	USA	FARM	NL	DEN	GER	BEL	FRA	EU
RANK GROUPS		PEERS - EXCELLENT			GOOD				AVERAGE	
CCR(I)	Score	1	1	0.9349	0.9072	0.9058	0.8309	0.8631	0.8525	0.8309
CCR(O)	Score	1	1	0.9349	0.9072	0.9058	0.8309	0.8631	0.8525	0.8309
BCC(I)	Score	1	1	1	0.9464	0.9509	0.9628	0.8708	0.9050	0.9628
BCC(O)	Score	1	1	1	0.9829	0.9834	0.9912	0.9455	0.9682	0.9912
Average score		1	1	1	0.9675	0.9359	0.9365	0.9040	0.8856	0.8946
Rank		1	1	1	4	5	6	7	8	9

DMU		ITA	SPA	FIN	ČR	AUS	SWE	HUN	IRE	GB
RANK GROUPS		AVERAGE				SUFFICIENT				
CCR(I)	Score	0.7677	0.8211	0.7828	0.7389	0.7325	0.7315	0.7211	0.6012	0.6012
CCR(O)	Score	0.7677	0.8211	0.7828	0.7389	0.7325	0.7315	0.7211	0.6012	0.6012
BCC(I)	Score	1	0.8249	0.8327	0.7742	0.7637	0.7836	0.7498	0.7276	0.7276
BCC(O)	Score	1	0.8935	0.8937	0.8594	0.8574	0.8133	0.8454	0.7250	0.7250
Average score		0.8839	0.8573	0.8402	0.8230	0.7779	0.7715	0.7650	0.7594	0.6638
Rank		10	11	12	13	14	15	16	17	18

Own data processing.

Figure 1. Distribution of ranking values among countries.



Own data processing.

The first round of CCR(I) and CCR(O) DEA procedure put into peers position Brazil, USA, and the FARM. BCC(I) and BCC(O) procedure selected into peers Brazil, Italy, The Nederland, USA and FARM. Practical experience with DEA model applications shows that BCC models give higher number of peer units and are more selective. The same is true in our case.

In DEA models, DMU with the same or very tight ranking usually are clustered into groups to reduce the number of units. Figure 1 demonstrates that score values separate countries well, are selective and there is no need to group countries into clusters.

Two CCR models and two BCC models were used to portion the countries into a subset of *DEA-efficient* and a subset of *DEA-non-so-efficient* producers in pig meat production, see Table 3.

Combining scores the ranking procedure makes enable to categorise countries into four domains, see Table 3.

Table 3. Ranking of countries into domains determined in < 0 – 1 scale >.

1	> 0.90	> 0.80	< 0.79
DEA-excellent	DEA-good	DEA-average	DEA-sufficient
BRA, USA, FARM	NL, GER, DEN, BEL	FR, ITA, SPA, FIN, ČR, EU	AUS, SWE, HUN, IRE, GB

Own data processing.

Table 3 illustrates, that among the EU countries, there were considerable differences between the highest-cost and the lowest-cost producers due to a combination of physical performance and input costs (feed, depreciation). The position of the Czech Republic among DEA-average group of DMU is worse than the excellent performance of one chosen farm.

Constituting of the reference sets for DEA-not excellent countries
DEA-peer processing assigns each *DEA-non-so-efficient* country a group of "peer countries", which serve as benchmarking pattern for realisation of changes in organisation of imputes.

The analysis of production efficiency in each of the 17 DMU was performed separately. The computations were performed using DEA-SOLVER-LV8. *As an example*, the optimal solution for CCR(I) model presents Table 4.

The reference set contains three DEA-excellent peers: Brazil, USA and FARM (see Table 2 and Table 4) who originate the DEA excellent frontier. Other countries, being benchmarked with peers, should improve (i.e. lower) their costs to reach the efficiency frontier. Coefficients "λ" indicate the required degree of approach to assigned peer country. Computation of the new imputes is described in Brožová, Houška and Šubrt (2014).

We shall illustrate the procedure on two examples: how to improve impute costs to reach the DEA frontier and become DEA-excellent country.

1) Czech Republic is ranked as DEA-average producer. Two peers, Brazil and USA originate the DEA frontier, coefficients "λ" are 0.619 for Brazil and 0.321 for USA (Table 4). Table 1 presents Feed costs for Brazil (1.025 €), USA (0,808 €) and Czech Republic (1.141 €). The Czech Republic should *reduce Feed costs* from 1.141 € to value 0.619·1.025 + 0.321·0.808 = 0.89 €, e.g. reduce Feed costs by 21%.

Table 4. Peer reference in CCR(I) model for DEA-not excellent countries.

DMU	DEA-Score	lambda 1	Peers	lambda 2	Peers	Feed	Other	Labour	Depreciation	Carcass meat
		Reference set of peers and λ				Recommended costs				Output
AUS	0.74	0,585	USA	0,370	FARM	0.73	0.19	0.12	0.17	2 191
BEL	0.83	0,476	BRA	0.622	USA	0.99	0.16	0.10	0.12	2 402
BRA	1									
DEN	0.91	0.882	USA	0.207	FARM	0.85	0.19	0.13	0.16	2 428
FIN	0.82	0.574	USA	0.421	FARM	0.75	0.20	0.13	0.18	2 297
FRA	0.86	0.809	USA	0.236	FARM	0.82	0.19	0.13	0.16	2 345
GER	0.91	0.908	USA	0.210	FARM	0.88	0.19	0.13	0.16	2 494
GB	0.60	0.664	USA	0.162	FARM	0.65	0.14	0.10	0.12	1 844
HUN	0.73	0.784	USA	0.149	FARM	0.74	0.16	0.11	0.13	2 072
IRE	0.72	0.228	BRA	0.734	USA	0.83	0.14	0.10	0.11	2 095
ITA	0.77	0.112	BRA	1.079	USA	0.99	0.18	0.12	0.14	2 586
NL	0.93	0.884	USA	0.303	FARM	0.89	0.21	0.14	0.18	2 586
SPA	0.83	0.601	BRA	0.298	USA	0.86	0.13	0.08	0.09	1 978
SWE	0.73	0.693	USA	0.266	FARM	0.74	0.18	0.12	0.15	2 167
USA	1									
EU	0.85	0.976	USA	0.133	FARM	0.88	0.18	0.13	0.15	2 447
ČR	0.78	0.619	BRA	0.321	USA	0.89	0.13	0.08	0.10	2 068
FARM	1									

Own data processing.

2) Similarly for Hungarian producers is recommended to *reduce the Labour costs* from 0.148 € to value 0.784·0.106 + 0.149·0.167 = 0.108 €, i.e. reduce Labour costs by 27%, etc.

Similar evaluation will continue for all imputes and *DEA-non-so-efficient* countries.

4. Conclusion

This article´s main method for identifying best practises in pig production in 17 European countries and one Czech producer using DEA models is through use of benchmarking. This should be used to identify the critical success factors, over which producers of pigs and relevant other stakeholders or initiative has some control, in areas or processes which need to be to achieve the best outcomes achievements. The benchmarking tool in our methodological approach was DEA modelling. We stress that the greatest benefit of benchmarking is not the measurement of the DEA-excellence, but the learning effect of how best performance is achieved, i.e. through understanding best practices. This will be our future research.

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