MEASURING THE EFFICIENCY OF THE CZECH PUBLIC HIGHER EDUCATION INSTITUTIONS: AN APPLICATION OF DEA

Pavla Mikušová[✉]

[✉]Department of Public Finance, Faculty of Finance and Accounting, University of Economics, Prague, W. Churchill Sq. 4, 130 67 Prague 3, Czech Republic, +420 725 755 621, pavla.mikusova@vse.cz

Highlights
- *The efficiency score is sensitive to the selected inputs and selected outputs*
- *Dividing the HEIs into groups give us better information about their efficiency*

Abstract

The Ministry of Education, Youth and Sports (MEYS) financially supports the Czech higher education institutions (HEIs). The largest amount of the MEYS's budget intended for HEIs subsidizes the public HEIs. Therefore, the aim of this paper is to measure the efficiency of the public higher education institutions. This will help us to determine which public HEIs can handle the sources (inputs) efficiently and how much the inefficient public HEIs should change their outputs to become efficient. We measure their teaching efficiency using data from 2015 and the DEA methodology. We run two analyses. The first analysis compares all the HEIs with each other. It shows that we have to consider the specialization of the HEIs. The second analysis divides the HEIs into three groups using coefficients of economic difficulties. This analysis shows that dividing the HEIs into groups helps us to eliminate the large differences in inputs and outputs. Therefore, we obtain better information about the efficiency of the HEIs.

Article type

Full research paper

Article history

Received: March 21, 2017
Received in revised form: June 28, 2017
Accepted: June 28, 2017
Available on-line: July 17, 2017

Keywords

Data Envelopment Analysis, efficiency, higher education institutions, public HEIs

Mikušová P. (2017) "Measuring The Efficiency of The Czech Public Higher Education Institutions: An Application of DEA", *Journal on Efficiency and Responsibility in Education and Science, Vol. 10, No. 2*, pp. 58-63, online ISSN 1803-1617, printed ISSN 2336-2375, doi: 10.7160/eriesj.2017.100204.

Introduction

The Czech higher education system includes three types of higher education institutions (hereafter HEIs) – 26 public HEIs, 37 private HEIs and 2 state HEIs (in 2016). Public and private HEIs are financially supported by the Ministry of Education, Youth and Sports (hereafter MEYS). The MEYS is the second-largest chapter in the state budget. Its expenses were 143 668 million CZK in 2015, representing 11.1 % of the state budget (Monitor, 2017). The planned amount of expenses of the MEYS is 156 526 million CZK for the year 2017. 21 627 million CZK (13.8 % of the MEYS's budget; for comparison the ratio was 15.9 % in 2013) is intended for the HEIs and 20 321 million (13.0 % of the MEYS's budget; the ratio was 12.0 % in 2013) is intended for research, experimental development and innovation (Act no. 475/2013 Coll. and Act no. 457/2016 Coll.).

The allowance and subsidies granted to HEIs follow the MEYS's rules (MEYS, 2015a). This budget is divided into budget headings and indicators. Budget heading I focuses on institutional financing of HEIs (indicators A and K), budget heading II combines indicators aimed at supporting students in the form of scholarships or grants (indicators C, J, S and U), budget heading III includes tools for supporting the development of HEIs (indicator I) and budget heading IV includes indicators for international cooperation and other indicators (indicators D and F). The MEYS using this methodology supports the diversification of higher education institutions in the Czech Republic, motivates HEIs to higher and better performance and to higher efficiency of the educational process.

Generally, if we want to measure the efficiency of a production unit, we compare inputs and outputs. Many methods can be used, for example parametric and non-parametric methods. Parametric methods, such as Stochastic Frontier Analysis (SFA), are stochastic and set the concrete production function, usually the cost or profit function. Non-parametric methods, for example Data Envelopment Analysis (DEA) or the Free Disposal Hull (FDH), are deterministic and in general determine the ratio of the weighted sum of inputs and the weighted sum of outputs (Polouček et al., 2006).

Data Envelopment Analysis is very common methodology used for measuring the efficiency of public higher education institutions. DEA is used to evaluate the technical efficiency of homogeneous production units. The basic model was described by Charnes, Cooper and Rhodes (1978). This model was later followed up by Banker, Charnes and Cooper (1984). This methodology treats multiple inputs and multiple outputs. In the case of measuring the efficiency of higher education institutions, the commonly used inputs are expenditure on tertiary education (Johnes, 2008; Kantabutra and Tang, 2010; Nazarko and Šaparauskas, 2014), the number of academic staff (Avkiran, 2001, Abbott and Doucouliagos, 2003) or number of students (St. Aubyn et al., 2009; Wolszczak-Derlacz and Parteka, 2011). On the other hand, the number of graduates (McMillan and Datta, 1998; Abbott and Doucouligos, 2003; Afonso and Santos, 2005; Kempkes and Pohl, 2007; Cuenca, 2011), the number of publications (Athanassopoulos and Shale, 1997; St. Aubyn et al., 2009) or the employment rate (Kantabutra and Tang, 2010) can be used as outputs.

The aim of the article is to measure the teaching efficiency of the Czech public higher education institutions (see Table 2 in Appendix) in 2015 by using DEA methodology and to find implications for improvement of its efficiency score.

Materials and Methods

Data Envelopment Analysis evaluates the technical efficiency of homogeneous production units. Technical efficiency is defined as the ratio of the weighted sum of outputs to the weighted sum of inputs (Flegg et al., 2003). A homogeneous production unit is referred to as a decision-making unit (DMU). Charnes, Cooper and Rhodes (1978) used the name decision-making unit to describe the units being analysed in DEA. This term emphasizes the fact that the focus is not on profits. DMUs are units that produce identical or equivalent outputs and may include banks, supermarkets, hospitals, schools, public universities, public libraries and so forth (Cooper, Seidford and Tone, 2007).

Data Envelopment Analysis is the optimization method of mathematical programming. Its aim is to divide production units into efficient and inefficient production units. DEA can measure the efficiency of DMUs with multiple inputs and multiple outputs. The inputs and outputs can be expressed in monetary and non-monetary forms (e.g. in the area of education: the number of academic staff, the number of non-academic staff or financial resources as inputs and the number of graduates or research quantum as outputs; Cunha and Rocha, 2012).

Using DEA, we are also able to design a virtual (hypothetical) unit for each inefficient unit. Virtual units are part of the efficient frontier and are calculated as a combination of selected efficient units. These selected units are called peer units or peers. Sometimes the efficient unit can be the virtual unit for the inefficient unit.

There are two basic DEA models – the CCR model assuming constant returns to scale (CRS; Charnes, Cooper and Rhodes, 1978) and the BCC model assuming variable returns to scale (VRS; Banker, Charnes and Cooper, 1984). The CCR model is used in situations in which the outputs increase proportionally to an increase in inputs. The BCC model fits situations in which the outputs do not increase proportionally to an increase in inputs. Both models can be input- or output-oriented. The choice of an input- or output-oriented model depends on the production process characterizing the production unit (i.e. minimize the use of inputs to produce a given level of outputs or maximize the level of outputs for a given level of inputs; Pascoe et al., 2003).

There is one fact that is characteristic of all linear programming models. A lot of conditions and restrictions has a negative impact on the solution of the problem. Therefore, it is recommended to use dual model of linear programming. This dual model uses the same data but with less restrictions. From this point of view, the dual model seems to be more practical (for the calculation procedure using the dual model, see Jablonský, 2011, Jablonský and Dlouhý, 2004, or the original work from Charnes, Cooper and Rhodes, 1978, and Banker, Charnes and Cooper, 1984).

Data Envelopment Analysis can be a powerful tool when used wisely. Cornuejols and Trick (1998) reported a few of the characteristics that make DEA powerful; for example, DEA can handle multiple-input and multiple-output models. It does not require an assumption of a functional form relating inputs to outputs, and DMUs are compared directly with a peer or a combination of peers.

Cornuejols and Trick (1998) warned that the same characteristics that make DEA a powerful tool can also create problems; for example, since DEA is an extreme point technique, noise (even symmetrical noise with a zero mean), such as measurement error, can cause significant problems. DEA measures relative efficiency not absolute efficiency. In other words, it can determine how well you are performing compared with your peers but not compared with a theoretical maximum. Since DEA is a non-parametric technique, statistical hypothesis tests are difficult. Since a standard formulation of DEA creates a separate linear programme for each DMU, large problems can be computationally intensive.

Data and model specification

The Ministry of Education, Youth and Sports collect specific data from the higher education institutions. We used this data for our analysis. The data set includes data from 2015 on the number of graduates (we divided these students into two groups – the bachelor and master's graduates and the PhD graduates; MEYS, 2016a), the number of academic staff (MEYS, 2016b) and the indicators A and K (MEYS, 2015b). The bachelor and master's graduates and the PhD graduates represent the outputs of our models. On the other hand, the number of academic staff and the indicators A and K represent the inputs.

The academic staff (see Avkiran, 2001; Abbott and Doucouliagos, 2003) contains professors, associate professors, assistant professors, lecturers, assistants and teaching staff. According to the MEYS, the academic staff is involved in pedagogical or scientific activities. It is not possible to include academic staff among academics who are only scientifically active at the university and do not teach at all. The number of academic staff is calculated as the average number of full-time equivalent employees (MEYS, 2016b).

Institutional financing of higher education institutions is based on the scale and economic demands of the performance of higher education institutions and their quality – the indicators A (the number of students in study programs) and K (quality and performance). Funds are allocated in budget heading I and are provided to universities in the form of a contribution. The volume of expenditure allocated through indicators A and K under institutional funding is set at 76 % and 24 % for 2015 (MEYS, 2015a).

Using these variables, we constructed two models. The first model is CCR model with constant returns to scale. The second one is BCC model with variable returns to scale. The foreign authors usually use models with variable returns to scale – BCC models – in the case of measuring the efficiency of the public higher education institutions. It is common that they construct and compare results of CCR (constant returns to scale) and BCC (variable returns to scale) models. Therefore, we also constructed CCR and BCC models. Both models are output-oriented because we want to find out how HEIs effectively use the resources (inputs). If they do not use them efficiently, using these models we will be able to determine how these inefficient HEIs should change their outputs to become efficient.

There is a formula for dual output-oriented CCR model:

$$\begin{aligned} &\textit{maximize} && g = \phi_q + \varepsilon\,(e^T s^+ + e^T s^-) \\ &\textit{subject to} && X\lambda + s^- = x_q \\ & && Y\lambda - s^+ = \phi_q y_q \\ & && \lambda, s^+, s^- \geq 0 \end{aligned} \qquad (1)$$

where λ is scale, s^+ and s^- are vectors of additional variables, $e^T = (1, 1,\dots, 1)$ and ε is infinitesimal constant, which is usually chosen as 10^{-8}. The value of ϕ_q expresses the need for a proportional increase in outputs to achieve efficiency (Jablonský and Dlouhý, 2004). To allow variable returns to scale in BCC model, it is necessary to add the convexity condition to the CCR model:

$$e^T \lambda = 1 \qquad (2)$$

The descriptive statistics (minimum, maximum, mean, median and standard deviation) of the data sets are presented in Table 1. The calculation was performed in the computer program DEAP Version 2.1 written by Tim Coelli (DEAP, 2011).

Variable	Min.	Max.	Mean	Median	Std. dev.
I: Indicator A	51 216.0	1 988 107.0	470 970.4	347 378.0	432 628.1
I: Indicator K	8 689.0	884 385.0	148 727.5	88 939.5	183 869.6
I: Academic Staff	58.0	3 236.2	587.7	444.5	617.1
O: Graduates Bc and Mgr	49.0	8 125.0	2 629.3	2 147.0	2 224.3
O: Graduates PhD	0.0	657.0	92.2	47.5	134.4

Table 1: Descriptive statistics of data set of the Czech public HEIs in 2015 (source: own calculation based on the data from MEYS)

Results

The efficiency scores of both models using data from 2015 are presented in Table 3 (in the Appendix). The efficient public higher education institutions have the efficiency score equal to 1. Other HEIs are inefficient in teaching. According to the CCR model, there are 12 efficient public HEIs (CU, MU, UVPS, UHK, SU, ICT, BUT, TUO, UE, CULS, CPJ and ITB). The HEIs with very low efficiency score are APA, AFA, AAAD and JAMPA. All these HEIs are art HEIs. The efficiency score also determines how the HEIs should change their outputs to become efficient. AFA, the HEI with the lowest efficiency score, should increase the outputs – the number of bachelor and master's graduates and PhD graduates – by 76.3 %. It means, with the given level of inputs (the funding from MEYS and the number of academic staff), the number should be 86 bachelor and master's graduates instead of 49 and 5 PhD graduates instead of 3. The results show that AFA should produce more people skilled in art. Mathematically speaking it is correct, but this inefficiency is due to the high costs per student (see coefficients of economic difficulties, MEYS, 2012).

The same HEIs plus AFA are also efficient when we use BCC model – model with variable returns to scale. In this case, AFA belongs to the efficient HEIs. The efficiency score of AAAD also was improved. AAAD should increase the outputs by 10.9 %, instead of 64.8 %. Some HEIs (PU, OU, UWB) have efficiency score very similar in both models. It shows that the different specialization of HEIs has different returns to scale.

The efficiency score is sensitive to the selected inputs and selected outputs. Using more variables in the model decreases the sensitivity and increases the efficiency scores – for example, McMillan and Datta (1998) recommended keeping the number of variables smaller than one-third of the number of observations. This is one of the reasons why we did not use other indicators (such as C – scholarships for PhD students, J – subsidies for accommodation and boarding, U – accommodation scholarships, D – international cooperation) in our models, because when we used them, almost all HEIs were efficient. It is also important to consider factors like the specialization of the HEI. The specialization of AFA requires high costs (see coefficients of economic difficulties; MEYS, 2012). Its costs are high, and the graduates/teacher and students/teacher ratios are low. This is because art HEIs require high costs and more teachers per graduate and student than other HEIs with, for example, a specialization in economics (e.g. UE).

In accordance with this conclusion, we divided the HEIs into groups with similar specializations. Some HEIs do not have only one specialization (e.g. CU), and therefore we used coefficients of economic difficulties. The MEYS divides study programmes into seven groups according to the relative costs. The relative costs are represented by cost coefficients, which are between 1.00 (for economics and humanities) and 5.90 (for art; MEYS, 2012; see Fischer, 2015). We calculated the total coefficient of economic difficulties for each HEI as a weighted average of coefficients of economic difficulties and the number of students in study programmes.

According to the total coefficients of economic difficulties, we divided HEIs into three groups with similar coefficients. The average of the total cost coefficients of Group 1 is 1.28, of Group 2 it is 1.60 and of Group 3 it is 5.82. UE (with a total cost coefficient of 1.08), ICT (2.72) and UVPS (3.15) are not included, because they are outliers in these groups. UE is an economic HEI, the specialization of ICT is chemical technology and the specialization of UVPS is veterinary medicine and pharmaceutical sciences, and there are no other HEIs with the same or a similar specialization.

We used the same data and models as in the first analysis. The results of the second analysis are presented in Table 4 (in the Appendix). It is obvious that the efficiency scores are higher than in the first analysis. Using the total coefficients of economic difficulties and dividing the HEIs into groups, we eliminated the large differences in inputs and in outputs. We divided the HEIs into groups that are more homogeneous. On the other hand, the division into three more homogenous groups violated the recommended number of variables in DEA models (in case of Group 1 and Group 3). However, this violation can be justified for the purpose of the additional analysis. Using BCC model, there are many efficient HEIs in each model due to very low discrimination ability in the DEA models. But we can still find HEIs with a low efficiency score.

Group 1: MU, UHK, SU, UWB, CPJ and ITB represent Group 1. These HEIs are much more homogenous than the whole group of all HEIs. Only UWB is inefficient. According to the results of both models, it should increase its outputs (the number of bachelor and master's graduates and PhD graduates) by 9.6 % (CCR model; from 2 835 bachelor and master's graduates to 3 107 and from 69 PhD graduates to 76) or by 6.7 % (BCC model; from 2 835 bachelor and master's graduates to 3 025 and from 69 PhD graduates to 74). When we compared all HEIs together, they were not totally homogenous and it was the reason why we used the coefficients of economic difficulties to divide HEIs into the homogenous groups. Now the results give us better information about the efficiency of HEIs.

Group 2: Members of Group 2 are CU, USB, JEPU, PU, OU, CTU, TUL, UP, BUT, TUO, TBU, CULS and MUB – 13 HEIs. According to the CCR model, there are only 4 efficient HEIs (CU, BUT, TUO and CULS). The most inefficient HEI is OU. It should increase the outputs by 19.6 % to become efficient. The results of BCC model showed 11 efficient HEIs. Only PU and CTU are inefficient. They should increase the outputs by 11.3 % and 12.6 %.

Group 3: All HEIs in this group are art HEIs (APA, AFA, AAAD and JAMPA). These HEIs were very inefficient in the first analysis (e.g. APA 0.450 in CCR model and 0.480 in BCC model), but comparing APA only with other art HEIs, we got the results that show APA as the efficient HEI. Now we know the effectiveness was not caused by wrong management of funding or academic staff. It was caused by comparing 'wrong' HEIs together.

Discussion

Using groups led to better comparability of HEIs. The efficiency scores showed which HEIs are efficient and which are inefficient in teaching. But it is not all what the efficiency score can tell us. It also can determine how much the inefficient DMUs should change their inputs or outputs to become efficient. In our case, when we used output-oriented model, the efficiency score determines how much the inefficient HEIs should change their outputs to become efficient.

It seems to be easy to say by how much the number bachelor and master's graduates and PhD graduates should be increased. However, we also have to consider other aspects – for example: Do the programmes require high costs and a high number of academic staff? Are we comparing chemistry vs. management programmes? Did the public procurement go wrong? Could the price and the costs be lower? Is the device/equipment fully utilized?

Dividing the HEIs into groups helped us to be more specific about the efficiency of HEIs. However there are still some aspects to consider; therefore, we recommend using faculties or departments as DMUs with the same or similar specializations for further analyses. DMUs can be divided into groups as follows: economics, philosophy, engineering, agriculture, medicine, art and so on (for a comparison see McMillan and Datta, 1998). Or we can focus only on one specialization (see Pietrzak, Pietrzak and Baran, 2016, who focused on only faculties specialized in social sciences). Faculties or departments are more homogeneous than HEIs. This can lead us to more precise results. On the other hand, the data availability for faculties and departments can be crucial.

The faculties prepare annual reports and it is possible to collect data from them, but the problem is, that this data are not standardized like the data from HEIs. There is a pattern form from MEYS that the HEIs have to fill in with data and this data are comparable. Unfortunately, there is no pattern form for faculties. When a faculty publishes the data about the academic staff per departments and the other one not, the missing data has to be collected in different way (e.g. survey). When we decide to use a survey, we have to consider what data we need. We need some data for input(s) and other for output(s). It is very important which data we choose.

When we find the data that are suitable for our analysis, we will be able to identify, which faculties or department are efficient and which are not. We will also be able to recommend to MEYS how to change the distribution of money that is used for financing the universities. Nowadays, MEYS uses the coefficient of economic difficulties, but these coefficients do not say anything about the efficiency – for example, when we compare all economic faculties or departments and some of them are inefficient, MEYS should ask why – Is this inefficiency caused by poor management of finances? Or by something else? When we are able to answer these questions, it could help MEYS effectively distribute the money (not only for teaching) among the universities.

We mentioned earlier the strengths and limitations of DEA. When we have all data that we need for our research, we have to be careful with using DEA methodology. It is necessary to use it wisely and we should try to minimize its limitations.

Conclusion

The Czech public HEIs are financially supported by the MEYS, therefore, we measured the teaching efficiency of the public HEIs and identified the public HEIs that can handle the sources (inputs) efficiently. The results also showed how much the inefficient public HEIs should change their outputs to become efficient.

To measure the efficiency, we used the DEA methodology. We ran two analyses. The first analysis compared all the HEIs with each other. The second one divided the HEIs into three groups with similar coefficients of economic difficulties. The first analysis showed that we have to consider the specification of the HEIs. We mentioned APA as an example. The specialization of APA (the art HEI) requires high costs and therefore its efficiency score was low in the first analysis. Without considering the specific aspects, it looked like APA is very inefficient.

In the second analysis, dividing the HEIs into three groups helped us to eliminate the great differences in inputs and in outputs. The creation of groups of HEIs with similar specializations gave us better information about their efficiency. The efficiency score can also determine how much the inefficient HEIs should change their inputs to become efficient. But we should not increase the outputs only on the base of the efficiency score without considering other aspects (e.g. the costs and the academic staff requirement – compare chemistry vs. management programmes; in public procurement whether the price could be lower; device/equipment utilization).

Dividing the HEIs into groups helped us to be more specific about their efficiency, but there are still some aspects to consider; therefore, we recommend using faculties or departments as DMUs with the same or similar specializations for further analysis. Faculties or departments are more homogeneous than HEIs and can lead us to more precise results. On the other hand, the data availability for faculties and departments can be crucial.

Acknowledgement

This article was supported by the Internal Grant Agency of the University of Economics under Grant 'Public finance in the Czech Republic ant the EU', number F1/1/2016.

References

Abbott, M. and Doucouliagos, C. (2003) 'The efficiency of Australian universities: A data envelopment analysis', *Economics of Education Review,* Vol. 22, No. 1, pp. 89-97. http://dx.doi.org/10.1016/S0272-7757(01)00068-1

Act no. 475/2013 Coll., On the state budget of the Czech Republic for the year 2014.

Act no. 457/2016 Coll., On the state budget of the Czech Republic for the year 2017.

Afonso, A. and Santos, M. (2005) 'Students and Teachers: A DEA Approach to the Relative Efficiency of Portuguese Public Universities', *NEP: New Economics Papers Education*.

Avkiran, N. K. (2001) 'Investigating technical and scale efficiencies of Australian universities through data envelopment analysis', *Socio-Economic Planning Sciences*, Vol. 35, No. 1, pp. 57-80. http://dx.doi.org/10.1016/S0038-0121(00)00010-0

Athanassopoulos, A. D. and Shale, E. (1997) 'Assessing the comparative efficiency of higher education institutions in the UK by the means of Data Envelopment Analysis', *Education Economics*, Vol. 5, No. 2, pp. 117-134. http://dx.doi.org/10.1080/09645299700000011

Banker, R.D., Charnes, A. and Cooper, W.W. (1984) 'Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis', *Management Science,* Vol. 30, No. 9, pp. 1078-1092. http://dx.doi.org/10.1287/mnsc.30.9.1078

Charnes, A., Cooper, W.W. and Rhodes, E.L. (1978) 'Measuring the Efficiency of Decision Making Units', *European Journal of Operational Research*, Vol. 2, No. 6, pp. 429 - 444. https://doi.org/10.1016/0377-2217(78)90138-8

Cooper, W.W., Seidford, L.M. and Tone, K. (2007) *Data Envelopment Analysis – A Comprehensive Text with Models, Applications, References and DEA-Solver Software*. Springer, 490p, ISBN 978-0-387-45283-8.

Cornuejols, G. and Trick, M. (1998) 'Quantitative Methods for the Management Sciences', *Carnegie Mellon University*, Pittsburgh.

Cuenca, J.S. (2011) 'Efficiency of State Universities and Colleges in the Philippines: A Data Envelopment Analysis', *Discussion Paper Series,* No. 2011-14.

Cunha, M. and Rocha, V. (2012) 'On the Efficiency of Public

Higher Education Institutions in Portugal: An Exploratory Study', *FEP Working Paper*, No. 468.

DEAP V2.1 (2011) 'A Data Envelopment Analysis (Computer) Program'. Centre for Efficiency and Productivity Analysis. [Online], Available: http://www.uq.edu.au/economics/cepa/deap.php [29 May 2017]

Fischer, J. (2015) 'Financování vysokých škol v kontextu novely VŠ zákona'. *Presentation at Seminář Financování vysokého* školství *2015 – problémy a perspektivy*, Prague. [Online], Available: http://kredo.reformy-msmt.cz/download/w-19-5/05_KREDO_prezentace_Fischer.pdf [30 May 2017].

Flegg, A.T., Allen, D.O., Field, K. and Thurlow, T.W. (2003) 'Measuring the Efficiency and Productivity of British Universities: An Application of DEA and the Malmquist Approach', *University of the West of England, Department of Economics, series Discussion Papers*, No. 304.

Jablonský, J. (2011) 'Models for Efficiency Evaluation in Education', *Proceedings of the 8th International Conference on Efficiency and Responsibility in Education (ERIE 2011),* Prague, pp. 110-119.

Jablonský, J. and Dlouhý, M. (2004) *Modely hodnocení efektivnosti produkčních jednotek*. 1. Ed. Prague, Professional Publishing, 184p, ISBN 80-86419-49-5.

Johnes, J. (2008) 'Efficiency and productivity change in the English higher education sector from 1996/97 to 2004/5', *The Manchester School*, Vol. 76, No. 6, pp. 653-674. 10.1111/j.1467-9957.2008.01087.x

Kantabutra, S. and Tang, J. C. S. (2010) 'Efficiency Analysis of Public Universities in Thailand', *Tertiary Education and Management*, Vol. 16, No. 1, pp. 15-33. http://dx.doi.org/10.1080/13583881003629798

Kempkes, G. and Pohl, C. (2007) 'The Efficiency of German Universities – Some Evidence from Non-Parametric and Parametric Methods', *CESifo Venice Summer Institute* 2007, 18-19 July.

McMillan, M. L. and Datta, D. (1998) 'The Relative Efficiencies of Canadian Universities: A DEA Perspective', *Canadian Public Policy*, Vol. 24, No. 4, pp. 485-511. http://dx.doi.org/10.2307/3552021

Ministry of Education, Youth and Sports (MEYS), (2012) *Koeficienty ekonomické náročnosti.* [Online], Available from http://www.msmt.cz/vzdelavani/vysoke-skolstvi/koeficienty-ekonomicke-narocnosti [29 May 2017].

Ministry of Education, Youth and Sports (MEYS), (2015a) 'Pravidla pro poskytování příspěvku a dotací veřejným vysokým školám Ministerstvem školství, mládeže a tělovýchovy', No. MSMT-2067/2015-1, [Online], Available: http://www.msmt.cz/vzdelavani/vysoke-skolstvi/pravidla-pro-poskytovani-prispevku-a-dotaci-verejnym-vysokym-2 [29 May 2017].

Ministry of Education, Youth and Sports (MEYS), (2015b) '*Rozpis rozpočtu vysokých* škol *na rok 2015'*. [Online], Available: http://www.msmt.cz/vzdelavani/vysoke-skolstvi/rozpis-rozpoctu-vysokych-skol-na-rok-2015 [29 May 2017].

Ministry of Education, Youth and Sports (MEYS), (2016a) 'Data o studentech, poprvé zapsaných a absolventech vysokých škol. [Online], Available: http://www.msmt.cz/vzdelavani/skolstvi-v-cr/statistika-skolstvi/data-o-studentech-poprve-zapsanych-a-absolventech-vysokych [17 Mar 2017]

Ministry of Education, Youth and Sports (MEYS), (2016b) 'Výroční zprávy o hospodaření veřejných vysokých škol za rok 2015'. [Online], Available: http://www.msmt.cz/vzdelavani/vysoke-skolstvi/vyrocni-zpravy-o-hospodareni-verejnych-vysokych-skol-za-rok [17 Mar 2017].

Monitor (2017) *State budget overview.* [Online], Available: http://monitor.statnipokladna.cz/en/2015/statni-rozpocet/# [17 Mar 2017]

Nazarko, J. and Šaparauskas (2014) 'Application of DEA method in efficiency evaluation of public higher education institution', *Technological and Economic Development of Economy*, Vol. 20, No. 1, pp. 25-44. http://dx.doi.org/10.3846/20294913.2014.837116

Pascoe, S., Kirkley, J.E., Gréboval, D. and Morrison-Paul, C.J. (2003) 'Measuring and assessing capacity in fisheries. 2. Issues and methods', *FAO Fisheries Technical Paper*. No. 433/2. Rome, 130p.

Pietrzak, M., Pietrzak, P. and Baran, J. (2016) 'Efficiency assessment of public higher education with the application of Data Envelopment Analysis: The evidence from Poland', *Online Journal of Applied Knowledge Management,* Vol. 4, No. 2, pp. 59-73.

Polouček, S. at al. (2006) '*Bankovnictví'*, 1. Edition. Praha, C. H. Beck, ISBN 80-7179-462-7.

St. Aubyn, M., Pina, A., Garcia, F. and Pais, J. (2009) 'Study on the efficiency and effectiveness of public spending on tertiary education', *Economic Papers* No. 390, European Comission.

Wolszczak-Derlacz, J. and Parteka, A. (2011) 'Efficiency of European public higher education institutions: a two-stage multicountry approach', *Scientometrics,* 89, pp. 887-917. 10.1007/s11192-011-0484-9

Appendix

Abbreviation	Name of the Czech public HEIs
AAAD	Academy of Arts, Architecture and Design in Prague
AFA	Academy of Fine Arts, Prague
APA	Academy of Performing Arts in Prague
BUT	Brno University of Technology
CPJ	College of Polytechnics Jihlava
CTU	Czech Technical University in Prague
CU	Charles University in Prague
CULS	Czech University of Life Sciences Prague
ICT	Institute of Chemical Technology in Prague
ITB	The Institute of Technology and Business
JAMPA	Janáček Academy of Music and Performing Arts
JEPU	Jan Evangelista Purkyně University in Ústí nad Labem
MU	Masaryk University
MUB	Mendel University Brno
OU	University of Ostrava
PU	Palacký University of Olomouc
SU	Silesian University, Opava
TBU	Tomas Bata University in Zlín
TUL	Technical University of Liberec
TUO	Technical University of Ostrava
UE	University of Economics, Prague
UHK	University of Hradec Králové
UP	University of Pardubice
USB	University of South Bohemia in České Budějovice
UVPS	University of Veterinary and Pharmaceutical Sciences, Brno
UWB	University of West Bohemia

Table 2: Definition of abbreviations of the Czech HEIs

HEIs	CRS	Rank	VRS	Rank
CU	1.000	1	1.000	1
USB	0.838	17	0.864	19
JEPU	0.702	21	0.758	23
MU	1.000	1	1.000	1
PU	0.859	14	0.865	17
UVPS	1.000	1	1.000	1
OU	0.785	18	0.785	21
UHK	1.000	1	1.000	1
SU	1.000	1	1.000	1
CTU	0.843	16	0.865	17
ICT	1.000	1	1.000	1
UWB	0.766	19	0.766	22
TUL	0.652	22	0.701	24
UP	0.754	20	0.791	20
BUT	1.000	1	1.000	1
TUO	1.000	1	1.000	1
TBU	0.882	13	0.920	14
UE	1.000	1	1.000	1
CULS	1.000	1	1.000	1
MUB	0.859	14	0.881	16
APA	0.450	23	0.480	25
AFA	0.237	26	1.000	1
AAAD	0.352	24	0.891	15
JAMPA	0.309	25	0.437	26
CPJ	1.000	1	1.000	1
ITB	1.000	1	1.000	1
Mean	*0.819*		*0.885*	
Std. dev.	*0.232*		*0.155*	

Table 3: The efficiency scores of the Czech public HEIs in 2015 (source: own calculation)

HEIs	CRS	Rank	VRS	Rank
GROUP 1				
MU	1.000	1	1.000	1
UHK	1.000	1	1.000	1
SU	1.000	1	1.000	1
UWB	0.904	6	0.933	6
CPJ	1.000	1	1.000	1
ITB	1.000	1	1.000	1
Mean	*0.984*		*0.989*	
Std. dev.	*0.036*		*0.025*	
GROUP 2				
CU	1.000	1	1.000	1
USB	0.862	9	1.000	1
JEPU	0.821	10	1.000	1
PU	0.867	8	0.887	12
OU	0.804	11	1.000	1
CTU	0.872	6	0.874	13
TUL	0.662	13	1.000	1
UP	0.757	12	1.000	1
BUT	1.000	1	1.000	1
TUO	1.000	1	1.000	1
TBU	0.962	5	1.000	1
CULS	1.000	1	1.000	1
MUB	0.870	7	1.000	1
Mean	*0.883*		*0.982*	
Std. dev.	*0.103*		*0.043*	
GROUP 3				
APA	1.000	1	1.000	1
AFA	0.594	4	1.000	1
AAAD	1.000	1	1.000	1
JAMPA	0.981	3	0.984	4
Mean	*0.894*		*0.996*	
Std. dev.	*0.173*		*0.007*	

Table 4: The efficiency scores of the Czech public HEIs divided into three groups based on coefficient of economic difficulties in 2015 (source: own calculation)