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BANKING EFFICIENCY IN VISEGRAD COUNTRIES: A DYNAMIC DATA ENVELOPMENT ANALYSIS

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Abstract

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The aim of the paper is to examine the efficiency of the banking sectors in Visegrad countries during the period 2009–2013. The group of Visegrad countries includes the Czech Republic, Hungary, Poland and Slovakia. We apply Dynamic Data Envelopment Analysis (DEA) to data on commercial banks in the group of Viserad countries. Next, we calculated average efficiency of the groups of banks according the total assets. Average efficiency was slightly decreased during the period 2010–2011 and significantly decreased in 2012 which was probably as a result of financial crisis. In 2013 average efficiency increased. The Czech and Hungarian banking sector was the highest efficient. Considering the group of banks according total assets, the group of small banks was the most efficient in CCR model and the group of medium-sized banks was the most efficient in BCC model.

Keywords: banking sector, commercial banks, Dynamic Data Envelopment Analysis, efficiency, Visegrad countries, constant return to scale, variable return to scale

INTRODUCTION

The aim of the paper is to examine efficiency of the banking sectors in Visegrad countries during the period 2009–2013. The group of Visegrad countries (V4) includes the Czech Republic, Hungary, Poland and Slovakia. In order to achieve this aim, we apply Dynamic Data Envelopment Analysis (DEA) to data from commercial banks. We also estimated average efficiency of the groups of banks according the total assets. Dynamic DEA is a new approach which estimates the performance of a group of DMUs during several periods of time. The Dynamic DEA model takes into account the internal heterogeneous organizations of DMUs for which divisions are mutually connected by link variables and trade internal products with each other. Each DMU has carry-over variables that take into account a positive or negative factor in the previous period.

In empirical analysis there is a lack of studies in banking sectors examining efficiency using the Dynamic DEA, which creates an opportunity for this research. According to the author's awareness, in empirical literature exists only a few studies which applied the Dynamic DEA on the banking sector. Řepková (2013a) estimated the Czech banking sector using the Dynamic DEA and Shafiee *et al.* (2013) examined the Iranian banking industry using dynamic slacks-based measure model in DEA. The motivation of this paper is to apply the Dynamic DEA analysis approach on the data of commercial banks in V4 and this paper could fill the gap in empirical literature.

The structure of the paper is following. First literature review and theoretical background of banking efficiency will be described. Next section will present the methodology and dataset used in the empirical part of the paper. Next section presents the estimated results and last section concludes the paper.

Literature Review

Several empirical analyses of the efficiency of the Visegrad countires' banking sectors exist and we refer to some of them. Some empirical studies e.g. Kosak and Zajc (2006), Bems and Sorsa

(2008), Matoušek (2008), Mamatzakis *et al*. (2008) Koutsomanoli-Filippaki *et al*. (2009), Baruník and Soták (2010) or Brissimis *et al*. (2010) examined the banking efficiency in several European countries and the Czech, Slovak, Polish and Hungarian banking sectors were included in panel data.

Stavárek and Polouček (2004) found that the Czech and Hungarian banking sectors were on average evaluated as the most efficient. Anayiotos *et al*. (2010) found the significant decreased in efficiency in emerging European countries during financial crisis. Tsionas *et al*. (2015) estimated the efficiency of European banks during the pre-crisis and post-crisis periods. Stavárek (2005) estimated commercial bank efficiency in the group of Visegrad countries before joining the EU and concluded that the Czech banking sector is the most efficient, followed by the Hungarian with a marginal gap. Also Melecký and Staníčková (2012) estimated banking efficiency of Visegrad region and evaluated the banking sector of the Czech Republic as highly efficient.

Weill (2003) found a positive influence of foreign ownership on the cost efficiency of banks in the Czech Republic and Poland. Erina and Erins (2013) evaluate cost-benefit efficiency of the banks of seven CEE states (the Czech Republic, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia) in the period 2006–2011. Iršová and Havránek (2011) estimated banking efficiency in five countries of Central and Eastern Europe.

Staněk (2010) found that the efficiency of the Czech banking sector has improved. Stavárek and Řepková (2012) found that efficiency increased in the period 2000–2010.

Rossi *et al*. (2005) examined that banking systems of Slovakia showed significant levels of cost and profit inefficiency. Vincová (2006) found that banking efficiency slightly decreased in Slovakia. Řepková (2013b) found that average cost and profit banking efficiency decreased in Slovakia within the period 2003–2012. Also e. g. Stavárek and Šulganová (2009) or Zimková (2014) examined efficiency of the Slovak banking sector.

Hasan and Marton (2003) examined the cost and profit inefficiency of Hungarian banking sector within the period 1993–1998 and found that banks with foreign involvement were found to be significantly less inefficient than their domestic counterparts. Among the foreign-involved institutions, a higher share of foreign ownership was associated with lower inefficiency.

Nikiel and Opiela (2002) estimated banking efficiency in Poland and found that that foreign banks are more cost-, profit-, and operationally efficient than state-owned or domestic private banks. Large banks were more efficient than small banks in Poland. Havrylchyk (2006) found that banking efficiency has not improved in Poland during the analysed period. Wozniewska (2008) estimated efficiency of the Polish banking sector within the period 2000–2007.

The empirical literature review concluded that only few studies examined the banking sectors of Visegrad countries individually. Most of the empirical studies research several banking sector which included the group of Visegrad countries and the second findings is that the most studies examined banking efficiency during 1990s. Thus, the literature review shows the motivation for this paper. This paper could fill the gap following time line in the empirical literature. Banking efficiency was estimated using the Stochastic Frontier Approach or DEA model. There is a lack of studies examining banking efficiency using dynamic methods, which creates an opportunity for this research.

METHODOLOGY AND DATA

The study of the efficient frontier began with Farrell (1957), who defined a simple measure of a firm's efficiency that could account for multiples inputs. The Data Envelopment Analysis is a mathematical programming technique that measures the efficiency of a decision-making unit (DMU) relative to other similar DMUs with the simple restriction that all DMUs lie on or below the efficiency frontier (Seiford and Thrall, 1990). The DEA measures the relative efficiency of a homogeneous set of decision-making units in their use of multiple inputs to produce multiple outputs. DEA also identifies, for inefficient DMUs, the sources and level of inefficiency for each of the inputs and outputs (Charnes *et al*., 1995). The analysis is performed in only one time period, hampering the measurement of efficiency changes when there is more than one time period. Detailed description of DEA model is presented in Stavárek and Řepková (2012).

Window analysis and the Malmquist index were the first methods used to verify productivity change over time. However, these models do not capture the effect of carry-over activities (links) between two consecutive time periods. The Dynamic DEA model proposed by Fare and Grosskopf (1996) is the first innovative system that formally addresses the activities in different interconnected time periods. Thus, Dynamic DEA is a new approach which estimates performance of a group of DMUs during several periods of time. The Dynamic DEA model takes into account the internal heterogeneous organizations of DMUs for which divisions are mutually connected by link variables and trade internal products with each other. Additionally, each DMU has carry-over variables that take into account a positive or negative factor in the previous period. This model has the huge advantage of being able to evaluate the policy effect on the individual divisions of each DMU (Kawaguchi *et al*., 2013).

The CCR (Charnes, Cooper and Rhodes, 1978) model presupposes that there is no significant relationship between the scale of operations and efficiency by assuming constant returns to

scale (CRS) and it delivers the overall technical efficiency. The CRS assumption is only justifiable when all DMUs are operating at an optimal scale. However, firms or DMUs in practice might face either economies or diseconomies to scale. Banker at al. (1984) extended the CCR model by relaxing the CRS assumption. The resulting BCC (Banker, Charnes and Cooper, 1984) model was used to assess the efficiency of DMUs characterized by variable returns to scale (VRS). The VRS assumption provides the measurement of pure technical efficiency (PTE), which is the measurement of technical efficiency devoid of the scale efficiency (SE) effects.

Tone and Tsutsui (2010) developed Fare and Grosskopf (1996) model in to a slacks-based measure (SBM) framework. Tone and Tsutsui (2010) pointed out a concept of carry-over. In this paper we adopted the Dynamic DEA model proposed by Sengupta (1996) or Tone and Tsutsui (2010) and Tone (2001). Mathematical formulation of the Dynamic DEA was described e.g. by Sengupta (1996) or Lotfi and Poursakhi (2012). The Dynamic DEA model can easily be written as:

$$\max z(T-1) = \sum_{t=0}^{T-1}\sum_{j=1}^{n} w'(t)\lambda_j(t), \tag{1}$$

subject to

$$\sum_{j=1}^{n} A_j(t)\lambda_j(t) \le X_k(t), \tag{2}$$

$$\lambda_j(t) \ge 0, \text{ all } t = 0, 1, 2, \ldots, T-1, \tag{3}$$

where z is efficiency of DMU to be estimated, λ_j is the output vector for each DMU, X_k is current input, $A_j(t)$ is the corresponding input coefficient matrices, and $w'(t)$ is a non-negative weight vector for the multiple outputs of each DMU_j, j indicates the n different DMU_s and t denotes time. We estimated the dynamic model in the slacks-based measure (SBM) framework, called Dynamic SBM (DSBM). The SBM model is non-radial and can deal with inputs/outputs individually, contrary to the radial approaches that assume proportional changes in inputs/outputs.

Data and Selection of Variables

The data set used in this paper was obtained from the database BankScope and the annual reports of commercial banks during the period 2009–2013. All the data is reported on unconsolidated basis. We analyzed only commercial banks that are operating as independent legal entities, because we need homogenous data set. One important point is that the calculation of the Dynamic DEA requires strictly balanced panel data. We use balanced panel data from 12 Czech commercial banks, 13 Hungarian commercial banks, 28 Polish commercial banks and 9 Slovak commercial banks.

For the definition of inputs and outputs, we adopted intermediation approach. This approach assumes that the banks' main aim is to transform liabilities (deposits) into loans (assets). We employed three inputs (labor, fixed assets and deposits), and two outputs (loans and net interest income). We measure labor by the total personnel costs covering wages and all associated expenses and deposits by the sum of demand and time deposits from customers, interbank deposits and sources obtained by bonds issued. Loans are measured by the net value of loans to customers and other financial institutions and net interest income (NII) as the difference between interest incomes and interest expenses. Descriptive statistics of inputs and outputs are in Tab. I.

EMPIRICAL ANALYSIS AND RESULTS

We adopted Dynamic SBM models that can evaluate the overall efficiency of decision making units for the whole terms as well as the term efficiencies. We used the Dynamic DEA model to estimate efficiency under the assumptions of constant and variable returns to scale. For empirical analysis we used MaxDEA software. One important point is that the calculation of the Dynamic DEA requires strictly balanced panel data. We use panel data of 12 Czech commercial banks, 13 Hungarian commercial banks, 28 Polish commercial banks and 9 Slovak commercial banks.

We divided banks into three groups of banks according total assets amount. We distinguish between small, medium-sized and large banks based on the amount of their total assets. Following Vodová (2012) we define large banks as banks with total assets greater than 6% of the total assets of the banking sector. Medium-sized banks have total assets of between 2% and 6% of total assets. Small banks are banks with total assets of less than 2% of the total assets of the banking sector.

I: *Descriptive statistics*

Variable	Deposits	Labor	Fixed assets	Loans	NII
Mean	389443	6515	8211	315250	20534
Median	23978	391	193	19740	925
Minimum	0.00	2.22	0.09	0.00	0.29
Maximum	7876341	204277	261523	7047179	656202
St. Dev.	1092663	23278	31382	933918	81557

Source: author's calculation

The results of the Dynamic DEA efficiency scores of the group of V4 are presented in Tab. II. We calculate the average efficiency score in CCR model and BCC model as well as average efficiency in group of small banks, medium-sized banks and large banks. Average efficiency calculated in assumption of CRS reach the value 51–68%. On the other hand, average efficiency with VRS was between 63 to 78%. The BCC model decomposes efficiency into two components: pure technical efficiency and efficiency to scale. The values of efficiency computed by the BCC model reach higher values than efficiency computed by the CCR model by eliminating the part of the inefficiency that is caused by a lack of size of production units. This situation may occur when a bank, which has been marked as ineffective in the CCR model due to its inaccurate size, will be marked as an efficient in the BCC model.

Comparing the group of banks we can state that the group of small banks in V4 was the most efficient in CCR model, but the lowest efficiency in BCC model. In BCC model the group of medium-sized banks reached the highest average efficiency.

Tab. III shows average efficiency scores of the Czech commercial banks. We estimated efficiency in CCR model and BCC model. In model with constant return to scale average efficiency reached the value between 50–72%. In BCC model average efficiency was 61–88%.

The highest value of average efficiency was registered in 2009 and then average efficiency was slightly decreasing. Average efficiency rapidly decreased in 2012. This decrease was probably as a result of financial crisis. The decrease in loans and net interest income were registered in the balance sheet of the most Czech commercial banks. In 2013 the average efficiency again increased. When we compare analysed group of banks, we can see that the group of medium-sized banks was the most efficient in CCR and BCC model. In BCC model, the most of medium-sized banks operated in 100% efficiency frontier besides year 2012.

Average efficiency of the Hungarian banking sector is presented in Tab. IV. The development of the Hungarian banking efficiency is similar as development in the Czech banking sector. Average efficiency decreased in 2011 and 2012 as a result of a financial crisis. In CCR model, the highest average efficiency was registered in the group of small banks within the period 2009–2010, since 2011 the highest efficient has been the group of large banks. In BCC model the most efficient was the group of medium-sized and large banks. Large banks attained the highest value of efficiency in BCC model. Thus large banks in the market are too large and have improperly chosen their size (range of operation).

In the Polish banking sector (Tab. V), average efficiency was increasing during the period 2009–2011. Banking efficiency decreased in 2012 and then

II: *Banking efficiency of Visegrad countries (in %)*

Return to scale	**CRS**					**VRS**				
Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2009**	**2010**	**2011**	**2012**	**2013**
Mean	61	62	65	51	68	74	73	75	63	78
Median	51	55	61	46	63	68	70	69	56	75
Min	20	18	20	13	25	22	29	23	14	26
Max	100	100	100	100	100	100	100	100	100	100
St. Dev.	23	24	20	23	21	23	25	23	25	22
Small banks	66	65	66	55	67	75	73	72	61	74
Medium-sized banks	55	64	66	50	69	69	78	80	66	87
Large banks	55	54	60	46	66	74	68	74	63	78

Source: author's calculation

III: *Efficiency of the Czech banking sector (in %)*

Return to scale	**CRS**					**VRS**				
Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2009**	**2010**	**2011**	**2012**	**2013**
Mean	72	66	67	50	70	88	75	76	61	81
Median	66	65	64	48	64	100	87	92	60	100
Min	37	18	20	13	25	47	32	23	14	26
Max	100	100	100	100	100	100	100	100	100	100
St. Dev.	23	30	29	26	26	19	28	30	30	26
Small banks	78	65	67	49	64	91	69	67	54	72
Medium-sized banks	78	89	81	60	91	100	100	100	75	100
Large banks	53	47	53	40	70	69	65	71	60	85

Source: author's calculation

IV: *Efficiency of the Hungarian banking sector (in %)*

Return to scale	CRS					VRS				
Year	2009	2010	2011	2012	2013	2009	2010	2011	2012	2013
Mean	60	63	58	44	57	85	86	81	74	82
Median	51	60	57	40	56	79	100	100	78	100
Min	42	45	41	25	34	62	50	42	32	35
Max	100	100	82	71	100	100	100	100	100	100
St. Dev.	20	19	9	16	16	15	20	22	25	25
Small banks	70	70	52	43	54	82	74	58	51	60
Medium-sized banks	48	58	60	39	59	76	95	100	82	100
Large banks	58	60	62	53	62	94	92	92	100	100

Source: author's calculation

V: *Efficiency of the Polish banking sector (in %)*

Return to scale	CRS					VRS				
Year	2009	2010	2011	2012	2013	2009	2010	2011	2012	2013
Mean	58	62	67	56	71	64	67	72	59	75
Median	47	54	63	48	64	57	57	66	54	70
Min	20	28	32	24	40	22	29	32	24	40
Max	100	100	100	100	100	100	100	100	100	100
St. Dev.	27	27	22	25	21	25	25	22	24	20
Small banks	65	65	71	61	74	69	71	76	64	76
Medium-sized banks	47	57	61	51	69	54	60	65	53	77
Large banks	44	51	61	43	61	62	56	69	52	69

Source: author's calculation

VI: *Efficiency of the Slovak banking sector (in %)*

Return to scale	CRS					VRS				
Year	2009	2010	2011	2012	2013	2009	2010	2011	2012	2013
Mean	55	56	65	49	70	66	73	71	60	82
Median	51	55	61	45	67	65	68	67	50	73
Min	42	43	51	33	46	49	52	53	41	61
Max	71	66	100	100	100	100	100	100	100	100
St. Dev.	11	7	15	20	15	15	20	16	24	18
Small banks	46	52	60	43	62	74	97	83	80	100
Medium-sized banks	59	65	72	56	74	64	72	74	62	75
Large banks	60	54	62	46	71	61	55	63	48	77

Source: author's calculation

efficiency increased in 2013. Estimation of efficiency in the group of banks showed that the most efficient were small banks in CCR and BCC models. The group of large banks was the lowest efficient in both models.

Tab. VI presents average efficiency in the Slovak banking sector in CCR and BCC model. The development of average efficiency is similar as in other analyzed banking sectors. Average efficiency was increasing within the period 2009–2011. Decreased of average efficiency in 2012 was probably caused by a financial crisis. In 2013 average efficiency increased and attained the highest value in both models. Average efficiency in CCR model was ranged between 49–70% and in BCC model was 60–82%. In CCR model the most efficient were medium sized banks, but in BCC model were the most efficient small banks.

DISCUSSION AND CONCLUSION

The aim of the paper was to examine the efficiency of the banking sectors in Visegrad countries during the period 2009–2013. The results show that average efficiency was slightly decreasing within the period 2010–2011. But significant decrease in efficiency in 2012, it was probably as a result

of financial crisis. Then average efficiency increased in 2013. This finding confirms results of Anayiotos *et al*. (2010) who presented that banking efficiency decreased during the crisis period.

The values of efficiency computed by BCC model reach higher values than efficiency computed by CCR model by eliminating the part of inefficiency that is caused by a lack of size of production units. We found that the Czech banking sector was the highest efficient under the assumptions of constant return to scale. On the other hand, the Hungarian banking sector was the most efficient under the assumptions of variable return to scale. Because the Hungarian banking sectors was the lowest efficient in CCR model, it shows that the Hungarian commercial banks, especially large banks in the market, have improperly chosen their size. The lowest efficient were the Polish and Slovak banking sectors. Our result is consistent with the conclusion of Stavárek and Polouček (2004), Stavárek (2005) or Melecký and Staníčková (2012) who evaluated the Czech banking industry as the highest efficient. The reason of the inefficiency of the banks were the excess of clients deposit in banks' balance sheet. To improve efficiency banks should reduce deposits in balance sheet and reduce fixed assets. The result of DEA estimation shows that the reduction of inputs would lead to higher efficiency more than increasing of outputs. Thus banks should orient to reduction of their inputs rather than increasing their outputs.

Next, we distinguish between efficiency of the group of large banks, medium-sized banks and small banks in Visegrad countries as well as in the Czech Republic, Hungary, Polish and Slovakia. Results show that the group of small banks was the most efficient in CCR model and the group of medium-sized banks was the most efficient in BCC model. The group of small banks was the most efficient in Poland. In the Czech Republic and Slovakia, medium-sized banks were the most efficient and large banks were the most efficient in Hungary. On the contrary, Nikiel and Opiela (2002) found that large banks were more efficient that small banks in Poland during 1990s. Our results show that small banks were the most efficient in the period 2009–2013. Difference in results can be due to different periods. In Slovakia we confirm the result of Řepková (2013b) that large banks were the lowest efficient. Result of the paper is consistent with Stavárek and Řepková (2012) who found that largest banks performed significantly worse than medium-sized and small banks. Result indicates that banks operate in an incommensurate size. It could recommend that banks should concentrate to operate in optimal range of operation to increase banking efficiency. The further research could also be focus on estimating the reason and determinants of the low efficiency of the large banks in Czech Republic, Slovakia and Poland. The further research could also include the dividing the DMUs into groups according their belonging to a financial conglomerate.

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REFERENCES

ANAYIOTOS, G., TOROYAN, H. and VAMVAKIDIS, A. 2010. The efficiency of emerging Europe's banking sector before and after the recent economic crisis. *Financial Theory and Practice*, 34(3): 247–267.

BANKER, R. D., CHARNES, A. and COOPER, W. W. 1984. Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. *Management Science*, 30: 1078–1092.

BARUNÍK, J. and SOTÁK, B. 2010. Influence of Different Ownership Forms on Efficiency of Czech and Slovak Banks: Stochastic Frontier Approach. *Politická ekonomie*, 2010(2): 207–224.

BEMS, R. and SORSA, P. 2008. Efficiency of the Slovene Banking Sector in the EU context. *Journal for Money and Banking (Bančni Vestnik)*, 57(11).

BRISSIMIS, S. N., DELIS, M. D. and TSIONAS, E. G. 2010. Technical and allocative efficiency in European banking. *European Journal of Operational Research*, 204(1): 153–163.

CHARNES, A., COOPER, W. W., LEWIN, A. Y. and SEIFORD, L. M. 1995. *Data Envelopment Analysis: Theory, Methodology and Applications*. New York: Springer-Verlag.

ERIŅA, J. and ERIŅŠ, I. 2013. Efficiency of the CEE Countries Banking System: a DEA Model Evaluation. In: *Vision 2020: Innovation Development Sustainability Economic Growth. In 21st IBIMA Conference*, Vienna: ASV.

FARE, R. and GROSSKOPF, S. 1996. *Intertemporal Production Frontiers: with Dynamic DEA*. Norwell: Kluwer.

FARRELL, M. J. 1957. The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society (Series A)*, 120(2): 253–281.

HASAN, I. and MARTON, K. 2003. Development and efficiency of a banking sector in a transitional economy: Hungarian experience. *Journal of Banking and Finance*, 27: 2249–2271.

HAVRYLCHYK, O. 2006. Efficiency of the Polish banking industry: Foreign versus domestic banks. *Journal of Banking and Finance*, 30(7), 1975–1996.

IRŠOVÁ, Z. and HAVRÁNEK, T. 2011. Bank Efficiency in Transitional Countries: Sensitivity to Stochastic Frontier Design. *Transition Studies Review*, 18(2): 230–270.

KAWAGUCHI, H., TONE, K. and TSUTSUI, M. 2013. Estimation of the Efficiency of Japanese Hospitals Using a Dynamic and Network Data Envelopment Analysis Model. In: *Proceedings of Workshop 2013 on Dynamic and Network DEA*. Tokio: National Graduate Institute for Policy Studies.

KOSAK, M. and ZAJC, P. 2006. Determinants of bank efficiency differences in the new EU member countries. *Financial Stability Report*. Ljubljana: Bank of Slovenia, 27–54.

KOUTSOMANOLI-FILIPPAKI, A., MARGARITIS, D. and STAIKOURAS, C. 2009. Efficiency and productivity growth in the banking industry of Central and Eastern Europe. *Journal of Banking and Finance*, 33: 557–567.

LOTFI, F. H. and POURSAKHI, N. 2012. A Mathematical Model for Dynamic Efficiency Using Desirable and Undesirable Input-Output. *Applied Mathematical Sciences*, 6: 141–151.

MAMATZAKIS, E., STAIKOURAS, C. and KOUTSOMANOLI-FILIPPAKI, A. 2008. Bank efficiency in the new European Union member states: Is there convergence? *International Review of Financial Analysis*, 17(5): 1156–1172.

MATOUŠEK, R. 2008. Efficiency and scale economies in banking in new EU countries. *International journal of monetary economics and finance*, 1(3): 235–249.

MELECKÝ, L. and STANÍČKOVÁ, M. 2012. National Efficiency Evaluation of Visegrad Countries in Comparison with Austria and Germany by Selected DEA Models. In: *Proceedings of 30th International Conference Mathematical Methods in Economics*. Karviná: Silesian University in Opava, School of Business Administration in Karvina, 575–580.

NIKIEL, E. M. and OPIELA, T. P. 2002. Customer Type and Bank Efficiency in Poland: Implications for Emerging Market Banking. *Contemporary Economic Policy*, 20(3): 255–271.

ŘEPKOVÁ, I. 2013b. Estimation of the cost and profit efficiency of the Slovak banking sector, In: *Proceedings of 9th Internation Scientific Conference Financial Management of Firms and Financial Institution*. Ostrava: VŠB – Technická univerzita, 753–762.

ŘEPKOVÁ, I. 2013a. Estimation of Banking Efficiency in the Czech Republic: Dynamic Data Envelopment Analysis. *DANUBE: Law and Economics Review*, 4(4): 261–275.

ROSSI, S. P. S., SCHWAIGER, M. and WINKLER, G. 2005. *Managerial behavior and cost/profit efficiency in the banking sectors of Central and Eastern European countries*. Working paper No. 96. Wien: Oesterreichische Nationalbank.

SEIFORD, L. M. and THRALL, R. M. 1990. Recent developments in DEA: the mathematical programming approach to frontier analysis. *Journal of Econometrics*, 46: 7–38.

SENGUPTA, J. K. 1996. Systematic measures of dynamic Farrell Efficiency. *Applied Economics Letters*, 3: 91–94.

SHAFIEE, M., SANGI, M. and GHADERI, M. 2013. Bank performance evaluation using dynamic DEA: A slacks-based measure approach. *Journal of Data Envelopment Analysis and Decision Science*, 2013: 1–12.

STANĚK, R. 2010. Efektivnost českého bankovního sektoru v letech 2000–2009. In: *Konkurenceschopnost a stabilita*. Brno: Masaryk University.

STAVÁREK, D. 2005. *Restrukturalizace bankovních sektorů a efektivnost bank v zemích Visegrádské skupiny*. Karviná: Silesian University in Opava, School of Business Administration in Karvina.

STAVÁREK, D., POLOUČEK, S. 2004. Efficiency and Profitability in the Banking Sector. In: POLOUČEK, S. (ed.), *Reforming the Financial Sector in Central European Countries*. Hampshire: Palgrave Macmillan Publishers.

STAVÁREK, D. and ŘEPKOVÁ, I. 2012. Efficiency in the Czech banking industry: A non-parametric approach. *Acta Universitatis Agriculturae et Silviculturae Mendeleianae Brunensis*, 60: 357–366.

STAVÁREK, D. and ŠULGANOVÁ, J. 2009. Analýza efektívnosti slovenských bánk využitím Stochastic Frontier Approach. *Ekonomická revue – Central European Review of Economic Issues*, 12(1): 27–33.

TONE, K. 2001. A slacks-based measure of efficiency in data envelopment analysis. *European Journal of Operational Research*, 130: 498–509.

TONE, K. and TSUTSUI, M. 2010. Dynamic DEA: A slacks-based measure approach. *Omega*, 38: 145–156.

TSIONAS, E. G., ASSAF, A. G. and MATOUSEK, R. 2015. Dynamic technical and allocative efficiencies in European banking. *Journal of Banking and Finance*, 52: 130–139.

VINCOVÁ, K. 2006. Neefektívnosť z rozsahu v bankovom sektore. Komparácia slovenského a českého bankového sektora. In: *International Conference Proceedings: National and Regional Economics VI*. Herľany: Technická Univerzita v Košiciach, 440–445.

VODOVÁ, P. 2012. Liquidity ratios of Hungarian banks. In: *Řízení a modelování finančních rizik*. Ostrava: VŠB – TU, 664–672.

WEILL, L. 2003. Banking efficiency in transition economies: The role of foreign ownership. *Economics of Transition*, 11: 569–592.

WOZNIEWSKA, G. 2008. Methods of measuring the efficiency of commercial banks: an example of Polish banks. *Ekonomika*, 84: 81–91.

ZIMKOVÁ, E. 2014. Technical Efficiency and Super-efficiency of the Banking Sector in Slovakia. *Procedia Economics and Finance,* 12: 780–787.

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