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Efficiency of the Slovak Commercial Banks Applying the DEA Window Analysis

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***Abstract*—**The aim of this paper is to estimate the efficiency of the Slovak commercial banks employing the Data Envelopment Analysis (DEA) window analysis approach during the period 2003-2012. The research is based on unbalanced panel data of the Slovak commercial banks. Undesirable output was included into analysis of banking efficiency. It was found that most efficient banks were Postovabanka, UniCredit Bank and Istrobanka in CCR model and the most efficient banks were Slovenskasporitelna, Istrobanka and UniCredit Bank in BCC model. On contrary, the lowest efficient banks were found Privatbanka and CitiBank. We found that the largest banks in the Slovak banking market were lower efficient than medium-size and small banks. Results of the paper is that during the period 2003-2008 the average efficiency was increasing and then during the period 2010-2011 the average efficiency decreased as a result of financial crisis.

***Keywords*—**Data Envelopment Analysis, efficiency, Slovak banking sector, window analysis.

I. Introduction

THE aim of this paper is to estimate the efficiency of the Slovak commercial banks employing the Data Envelopment Analysis (DEA) window analysis approach during the period 2003-2012. The paper employed an extended DEA approach, specifically DEA window analysis for the efficiency assessment of commercial banks in Slovakia. It is based on panel data for the period from 2003 to 2012. We use the DEA window analysis based on an input oriented model to measure banking efficiency in this paper. The contribution should be able to see the bank efficiency evolves over time and to see whether any size effect exists in the banking efficiency. This analysis provides trends of efficiency and the rank of each bank evaluated in terms of its effectiveness. The obtained results allow for an analyses of trends of the overall banking sector efficiency. By this approach, the technical efficiency is analyzed sequentially with a certain window width (i.e. the number of years in a window) using a panel data of the commercial domestic banks. The main idea is to capture the temporal impact on bank technical efficiency and see its short-run evolution from one window to another, in particular the pure technical efficiency and scale efficiency. We include undesirable output into analysis. It is the first application of the window analysis on Slovak commercial banks during the period 2003-2012.

The structure of the paper is follow. Next section describes empirical literature about banking efficiency in the Slovak banking sector. Third section presents the methodology of DEA window analysis and Section IV describes data and selection of variables. Next part of paper reveals the estimated results and last section concluded the paper.

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II. Literature review

Empirical analyses of banking efficiency which included the Slovak banking sector exist several. We mention some of them. Some empirical studies e.g. reference [18], [35], [5], [20] or [19] examined the banking efficiency in several European countries and Slovak banking sector was included in panel data.

Reference [15], [6] or [14] estimated banking efficiency in 1990s and they investigated the impact of bank privatization. They found that private banks were more efficient than state-owned banks and privatized banks with majority foreign ownership were more efficient than those with domestic ownership. Reference [24] examined that the banking systems of Slovakia showed significant levels of cost and profit inefficiency, indicating that on average banks operate far above (below) from the cost (profit) efficient frontiers. But they found that cost efficiency increased between 1995 and 2002.

Reference [30] estimated efficiency and profitability in the selected banking sectors, including Slovakia. They found that Central European Countries are less efficient than their counterparts in the European Union member countries. Their conclusion is the refutation of the conventional wisdom of higher efficiency from foreign-owned banks than from domestic-owned banks, and size is one of the factors that determine efficiency. Reference [29] examined the increasing value of the efficiency of the Slovak banking sector during the period 1999–2003, but they also found that Slovak banking sector was lower efficient banking sector than other Visegrad countries. Reference [34] found that the average efficiency slightly decreased and the number of efficient bank also decreased. Reference [17] estimated banking efficiency in five countries of Central and Eastern Europe including Slovakia. In Slovakia the results showed that the average cost efficiency was 51.8% and profit efficiency reached 43.2% in the years 1995–2006.

Results of [4] were that the foreign-owned banks were bit more cost efficient than domestic private banks, state-owned banks were significantly less cost efficient when compared to domestic private banks. Reference [1] estimated relative efficiency of banks in emerging Europe before the recent boom, just before the crisis and right after the crisis using the Data Envelopment Analysis. Their results suggested that the

banking efficiency in Slovakia decreased during the pre-crisis boom and also fell during the crisis. They found the significant decreased in efficiency during the period 2004–2009.

Mentioned studies examined efficiency in several banking sector, on contrast [31] estimated banking efficiency in Slovakia. They applied the parametric Stochastic Frontier Approach and Cobb–Douglas production function on commercial banks in the period 2001–2005 and found that the average efficiency increased and their results point out a better ability of Slovak banks to use the inputs in the production process. References [23] and [22] estimated the cost and profit efficiency of the Slovak commercial banks and they found that the average cost and profit efficiency was decreasing in the Slovak banking sector during the period 2003-2012. And then they found that small and medium-sized banks were more efficient than the largest banks in the Slovak banking market.

The empirical literature review concluded that only few studies examined the Slovak banking sector individually. Most of the empirical studies research several banking sector which included Slovakia 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. Efficiency of the Slovak banking sector was estimated using the Stochastic Frontier Approach or DEA model. The contribution of this paper is the fact, that the DEA window analysis approach will be applied on the Slovak commercial banks. Also we consider undesirable output.

III. Methodology

The study of the efficient frontier began with [13], who defined a simple measure of a firm's efficiency that could account for multiples inputs. The term Data Envelopment Analysis was originally introduced by [8] based on the research of [13]. DEA is a non-parametric linear programming approach, capable of handling multiple inputs as well as multiple outputs [2].

This methodology allows handling different types of input and output together. A DEA model can be constructed either to minimize inputs or to maximize outputs. An input orientation objects at reducing the input amounts as much as possible while keeping at least the present output levels, while an output orientation aims at maximizing output levels without increasing the use of inputs [11].

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 [27]. 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 output [9]. It provides a means of comparing the efficiency of DMUs with each other based on several inputs and / or outputs. It derives its name from a theoretical efficient frontier which envelops all empirically-observed DMUs.

This analysis is concerned with understanding how each DMU performs relative to others, the causes of inefficiency, and how a DMU can improve its performance to become efficient. In that sense, the focus of the methodology should be on each individual DMU rather than on the averages of the whole body of DMUs. DEA calculates the relative efficiency of each DMU in relation to all the other DMUs by using the actual observed values for the inputs and outputs of each DMU. It also identifies, for inefficient DMUs, the sources and level of inefficiency for each of the inputs and outputs [9].

The CCR model is the basic DEA model, as introduced by [8] and then it was modified by [3] and became the BCC model, which accommodates variable returns to scale. The CCR (Charnes, Cooper, Rhodes) model presupposes that there is no significant relationship between the scale of operations and efficiency by assuming constant returns to scale (CRS) and delivery of 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. Reference [3] extended the CCR model by relaxing the CRS assumption. The resulting BCC (Banker, Charnes, Cooper) 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 scale efficiency (SE) effects. If there appears to be a difference between the TE and PTE scores of a particular DMU, then it indicates the existence of scale inefficiency [32].

As e.g. [25] showed, the DEA has some limitations. When the integrity of data has been violated, DEA results cannot be interpreted with confidence. Another caveat of DEA is that those DMUs indicated as efficient are only efficient in relation to others in the sample. It may be possible for a unit outside the sample to achieve higher efficiency than the best practice DMU in the sample. Knowing which efficient banks are most comparable to the inefficient bank enables the analyst to develop an understanding of the nature of inefficiencies and reallocate scarce resources to improve productivity. This feature of DEA is clearly a useful decision-making tool in benchmarking. As a matter of sound managerial practice, profitability measures should be compared with DEA results and significant disagreements investigated.

Data Envelopment Analysis is performed in only one time period, hampering the measurement of efficiency changes when there is more than one time period. A DEA model is sometimes applied on a repeated basis, e.g. the so-called window analysis method [9] when a panel data set comprising both time series and cross-section samples is available, but this produces little more than a continuum of static results, when in fact a static perspective may be inappropriate [28].

Window analysis is one of the methods used to verify productivity change over time. As [26] showed, window analysis technique works on the principle of moving averages [9], [36] and [10]. DEA window analysis was proposed by [7] in order to measure efficiency in cross sectional and time varying data. Thus, it is useful in detecting performance trends

of a decision making unit over time. Each DMU (i.e. bank) is treated as a different bank in a different period which can increase the number of data point. In the other word, each DMU in a different period is treated as if it was a different DMU (independent) but remains comparable in the same window [12]. Such capability in the case of a small number of DMUs and a large number of inputs and outputs would increase the discriminatory power of the DEA models [12]. Therefore, small sample sizes problem can be solved. And another advantage of DEA window analysis is that the performance of a bank in a period can be contrasted against themselves and against other banks overtime [2].

The performance of a unit in a particular period is contrasted with its performance in other periods in addition to the performance of other units. This results in an increase in the number of data points in the analysis, which can be useful when dealing with small sample sizes. Varying the window width, that is the number of time periods included in the analysis, means covering the spectrum from contemporaneous analysis, which include only observations from one time period, to intertemporal analysis, which include observations from the whole study period [21]. A DEA window analysis, with a window width somewhere between one and all periods in the study horizon, can be viewed as a special case of a sequential analysis. It is assumed, that what was feasible in the past remains feasible, and all previous observations are included. This is not the case in the window analysis, where only observations within a certain number of time periods (i.e. a window) are considered. Once the window is defined the observations within that window are viewed in an intertemporal manner and the analysis is therefore better referred to as locally intertemporal [33].

The number of firms that can be analyzed using the DEA model is virtually unlimited. Therefore, data on firms in different periods can be incorporated into the analysis by simply treating them as if they represent different firms. In this way, a given firm at a given time can compare its performance at different times and with the performance of other firms at the same and at different times. Through a sequence of such windows, the sensitivity of a firm's efficiency score can be derived for a particular year according to changing conditions and a changing set of reference firms. A firm that is DEA efficient in a given year, regardless of the window, is likely to be truly efficient relative to other firms. Conversely, a firm that is only DEA efficient in a particular window may be efficient solely because of extraneous circumstances. In addition, window analysis provides some evidence of the short-run evolution of efficiency for a firm over time. Of course, comparisons of DEA efficiency scores over extended periods may be misleading (or worse) because of significant changes in technology and the underlying economic structure [36].

Following [2] and [16], consider N DMUs $(n = 1,2,..,N)$ observed in $T\,(t = 1,2,\dots,T)$ periods using r inputs to produce s outputs. Let DMU_n^t represent an DMU_n in period t with a r dimensional input vector $x_n^t = (x_n^{1t}, x_n^{2t}, \dots, x_n^n)'$ and s dimensional output vector $y = (y_n^{1t}, y_n^{2t}, \dots, y_n^{st})'$. If a window starts at time $k\,(1 \le k \le T)$ with window width$w\,(1 \le w \le t - k)$, then the metric of inputs is given as follows:

$$x_{kw} = \begin{pmatrix} x_1^k, x_2^k, \dots, x_N^k, x_1^{k+1}, x_2^{k+1}, \dots, x_N^{k+1}, \\ x_1^{k+w}, x_2^{k+w}, \dots, x_N^{k+w} \end{pmatrix}', \quad (1)$$

The metric of outputs as:

$$y_{kw} = \begin{pmatrix} y_1^k, y_2^k, \dots, y_N^k, y_1^{k+1}, y_2^{k+1}, \dots, y_N^{k+1}, \\ y_1^{k+w}, y_2^{k+w}, \dots, y_N^{k+w} \end{pmatrix}', \quad (2)$$

The CCR model of DEA window problem for DMU_t^k is given by solving the following linear program:

$$\min \theta, \quad (3)$$

$$\theta' X_t - \lambda' X_{kw} \ge 0 \quad (4)$$

subject to

$$\lambda' Y_{kw} - Y_t \ge 0, \quad (5)$$

$$\lambda_n \ge 0\ (n = 1,2,\dots,N \times w). \quad (6)$$

BCC model formulation can be obtained by add the restriction $\sum_{n=1}^{n} \lambda_n = 1$[3]. The objective value of CCR model is designated technical efficiency and the objective of BCC model is pure technical efficiency. The BCC model is illustrated as:

$$\min \theta, \quad (7)$$

$$\theta' X_t - \lambda' X_{kw} \ge 0, \quad (8)$$

subject to

$$\lambda' Y_{kw} - Y_t \ge 0, \quad (9)$$

$$\sum_{n=1}^{n} \lambda_n = 1, \quad (10)$$

$$\lambda_n \ge 0\ (n = 1,2,\dots,N \times w). \quad (11)$$

Reference [2] point out that there are no technical changes within each of the windows because all DMUs in each window are compared and contrast against each other and suggest a narrow window width should be used. Reference [9] found that w = 3 or 4 tended to yield the best balance of in formativeness and stability of the efficiency scores. In order to be sure that the results will be credible, a narrow window width must be used. Therefore, a 3 year window has been chosen in this paper (w = 3).

IV. 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 2003–2012. All the data is reported on an unconsolidated basis. We analyze only commercial banks that are operating as independent legal entities. As we have reliable data extracted directly from annual reports, we eliminate the risk that incomplete or biased data may distort the estimation results. We use unbalanced panel data from 12 Slovak commercial banks (with regard to mergers and acquisitions of banks).

In order to conduct a DEA window analysis estimation, inputs and outputs need to be defined. Four main approaches (intermediation, production, asset, and profit approach) have been developed to define the input-output relationship in financial institution behavior. We adopted an intermediation approach which assumes that the banks' main aim is to transform liabilities (deposits) into loans (assets). Consistent with this approach, we assume that banks collect deposits to transform them, using labor, in loans. We employed two inputs (labor 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. We consider loan loss provision as undesirable output. Descriptive statistics of inputs and outputs are in Table I.

TABLE I
DESCRIPTIVE STATISTICS OF VARIABLES

	Loans	NII	Deposit	Labor	Loanloss provision
Mean	1972.73	112.99	38193.70	530.26	19.95
Median	1051.50	42.27	1378.45	18.01	7.90
Max	7266.50	465.70	3536153.17	45917.77	179.11
Min	17.60	3.40	87.40	0.22	-2.41
St.Dev.	1971.74	122.43	335794.88	4406.55	33.22

V. EMPIRICAL ANALYSIS AND RESULTS

We adopted DEA window analysis SBM (slack based model – non-radial) models that can evaluate the overall efficiency of decision-making units for the whole terms as well as the term efficiencies. We used the DEA window analysis to estimate efficiency under the assumptions of constant and variable returns to scale. For empirical analysis we used MaxDEA software.

Banking efficiency was estimated using DEA window analysis models, especially an input-oriented model with constant returns to scale and input-oriented model with variable returns to scale. The reason for using both techniques is the fact that the assumption of constant returns of scale is accepted only in the event that all production units are operating at optimum size. This assumption, however, is in practice impossible to fill, so in order to solve this problem we calculate also with variable returns of scale. We use panel data of 12Slovak commercial banks (with regard to mergers and acquisitions of banks).

The results of the DEA efficiency scores under constant variable of scale during the period 2003-2012 are presented in Table II. Moving average efficiency is shown in three-year window. During the period 2003–2012, the average efficiency calculated using the CRS ranges from 77% to 91%. This development shows that Slovak commercial banks are on average considered to be efficient, with only marginal changes over time. The results show that the average inefficiency of the Slovak banking sector in the CCR model was in range 9-23%. The reason for the inefficiency of Slovak banks is mainly the excess of client deposits on the balance sheet of banks.

TABLE II
EFFICIENCY OF SLOVAK COMMERCIAL BANKS IN CCR MODEL

DMU	2003-2005	2004-2006	2005-2007	2006-2008
CitiBank	0.8965	0.7868	0.7378	0.7002
CSOB	0.5091	0.6788	0.7974	0.9140
DEXIA	0.8591	0.8672	0.9551	0.9024
Istrobanka	0.9185	0.9599	0.9295	0.9527
OTP	0.6670	0.9880	0.9760	0.9614
Postova banka	0.9131	0.9097	0.9357	0.9992
Privatbanka	0.7150	0.8240	0.8742	0.8734
Slovenska sporitelna	0.8254	0.9194	0.9631	0.9619
Tatrabanka	0.7391	0.7833	0.8267	0.7952
UniCredit	0.8127	0.8314	0.9915	0.9867
Volksbank	0.8810	0.9114	0.9197	0.8694
VUB	0.5009	0.8707	1.0000	0.9812
Mean	0.7698	0.8609	0.9089	0.9081
DMU	2007-2009	2008-2010	2009-2011	2010-2012
CitiBank	0.7150	0.6702	0.6327	
CSOB	0.9957	0.9662	0.9573	0.8914
DEXIA	0.9027	0.9163	0.8285	0.8015
Istrobanka	0.9427	0.9842		
OTP	0.9658	0.9640	0.9440	0.9756
Postova banka	1.0000	0.9674	0.9248	0.9676
Privatbanka	0.7489	0.6138	0.4888	0.4703
Slovenska sporitelna	0.9771	0.9402	0.9567	0.9825
Tatrabanka	0.7996	0.7952	0.8199	0.8546
UniCredit	1.0000	1.0000	0.9688	0.9947
Volksbank	0.8952	0.8996	0.8589	0.8241
VUB	0.9794	0.9677	0.9771	0.9760
Mean	0.9102	0.8904	0.8507	0.8738

The results of the efficiency of individual banks show that the most efficient banks were Postovabanka, UniCredit Bank and Istrobanka. On the other hand, the lowest efficient banks were Privatbanka, CitiBank and TatraBanka. We found that the largest banks in the Slovak banking market are lower efficient than medium-size and small banks. The reason for this inefficiency is that the group of large banks has excess of deposits in balance sheet. Thus, the excess of deposits reflected negatively to net interest income by increasing interest costs of banks.

Table III presents the efficiency of the Slovak commercial banks estimated under the variable return to scale. The average efficiency calculated in BCC model reached the value from 83 to 94%. The most efficient banks were Slovenskasporitelna, Istrobanka and UniCredit Bank. Also in BCC model, the lowest efficient bank was Privatbanka and then CitiBank and CSOB.

TABLE III
EFFICIENCY OF SLOVAK COMMERCIAL BANKS IN BCC MODEL

DMU	2003-2005	2004-2006	2005-2007	2006-2008
CitiBank	0.8965	0.7868	0.7536	0.7427
CSOB	0.6522	0.8067	0.8045	0.9292
DEXIA	0.9485	0.9696	0.9849	0.9271
Istrobanka	0.9185	0.9603	0.9386	0.9642
OTP	0.6670	0.9926	0.9801	0.9680
Postova banka	0.9131	0.9279	0.9426	0.9995
Privatbanka	0.7150	0.8240	1.0000	0.9537
Slovenska sporitelna	1.0000	0.9921	0.9966	1.0000
Tatrabanka	0.9757	0.9624	0.9576	0.9475
UniCredit	0.8185	0.8599	0.9928	0.9926
Volksbank	0.9354	0.9167	0.9388	0.8914
VUB	0.6432	0.9768	1.0000	1.0000
Mean	0.8403	0.9146	0.9408	0.9430
DMU	2007-2009	2008-2010	2009-2011	2010-2012
CitiBank	0.7150	0.6702	0.6327	
CSOB	0.9982	0.9666	1.0000	0.8763
DEXIA	0.9226	0.9163	0.8224	1.0000
Istrobanka	0.9427	0.9842		
OTP	0.9658	0.9640	0.9106	0.9268
Postova banka	1.0000	0.9674	0.8192	0.9029
Privatbanka	0.7489	0.6138	0.5156	0.5006
Slovenska sporitelna	1.0000	0.9530	0.9135	1.0000
Tatrabanka	0.9932	0.9629	0.7723	0.8053
UniCredit	1.0000	1.0000	0.9065	1.0000
Volksbank	0.8952	0.8996	0.8530	0.8856
VUB	1.0000	1.0000	0.9887	0.9522
Mean	0.9318	0.9082	0.8304	0.8850

The development of the efficiency showed that the average efficiency was increasing during the period 2003-2008. After year 2008 the average efficiency decreased. This decrease was probably as a result of financial crisis. The decrease in the net profit was registered in the balance sheet of the most Slovak commercial banks. In the last window 2010-2012 the average efficiency increased.

VI. CONCLUSION

The aim of this paper was to estimate the efficiency of the Slovak commercial banks employing the Data Envelopment Analysis (DEA) window analysis approach during the period 2003-2012. It was the first application of the DEA window analysis approach on the Slovak banking sector. The research was based on unbalanced panel data for the period from 2003 to 2012. It was applied the DEA window analysis based on an input oriented model to measure banking efficiency.

We found that in CCR model the most efficient banks were Postovabanka, UniCredit Bank and Istrobanka. On contrary, the lowest efficient bank was found Privatbanka, CitiBank and TatraBanka. We found that the largest banks in the Slovak banking market are lower efficient than medium-size and small banks. In BCC model the most efficient banks were Slovenskasporitelna, Istrobanka and UniCredit Bank. The lowest efficient bank was Privatbanka and then CitiBank and CSOB in assumption of variable return to scale. The average efficiency score in BCC model reached the higher value than in CCR model. Other results of the paper is that whereas during the period 2003-2008 the average efficiency was increasing, during the period 2010-2011 the average efficiency decreased as a result of financial crisis. The results confirm the study of [1] who presented that the banking efficiency in Slovakia decreased during the pre-crisis boom and also fell during the crisis.

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REFERENCES

[1] G. Anayiotos, H. Toroyan, and A.Vamvakidis, "The efficiency of emerging Europe's banking sector before and after the recent economic crisis," *Financial Theory and Practice*,vol. 34, no. 3, pp. 247–267, 2010.
[2] M. Asmild, J. C. Paradi, V. Aggarwall, and C. Schaffnit, "Combining DEA Window Analysis with the Malmquist Index Approach in a Study of the Canadian Banking Industry," *Journal of Productivity Analysis*, vol. 21, no. 1, pp. 67-89, 2004.
[3] R. D. Banker, A. Chanes, and W. Cooper, "Some Model for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis," *Management Science*, vol. 30, pp. 1078-1092, 1984.
[4] J. Baruník, and B. Soták, "Influence of Different Ownership Forms on Efficiency of Czech and Slovak Banks: Stochastic Frontier Approach," *Politickáekonomie,* vol. 2010, no. 2, pp. 207–224, 2010.
[5] R. Bems, and P. Sorsa, "Efficiency of the Slovene Banking Sector in the EU context," *Journal for Money and Banking(BančniVestnik*), vol. 57, no. 11, 2008.
[6] J. P. Bonin, I. Hasan, and P. Wachtel, "Privatization matters: Bank efficiency in transition countries," *Journal of Banking and Finance,* vol. 29, pp. 2155–2178, 2005.
[7] A. Charnes, T. Clark, W. W. Cooper, and B. Golany, B., "A developmental study of data envelopment analysis in measuring the efficiency of maintenance units in U. S. Air Forces," In R. Thompson, and R. M. Thrall (Eds.). *Annals of Operational Research*, vol. 2, pp. 95-112, 1985.
[8] A. Charnes, W. W. Cooper, and E. Rhodes, "Measuring the Efficiency of Decision Making Units," *European Journal of Operational Research*, vol. 2, pp. 429–444, 1978.
[9] A. Charnes, W. W. Cooper, A. Y. Lewin, and L. M. Seiford, *Data Envelopment Analysis: Theory, Methodology and Applications*. New York: Springer-Verlag, 1995.
[10] W. Cooper, L. M. Seiford, and K. Tone, *Data Envelopment Analysis: A Comprehensive Text with Models Applications*. New York: Springer Science, 2007.
[11] W. W. Cooper, L. M. Seiford, and K. Tone, *Data Envelopment Analysis*. Boston: Kluwer Academic Publishers, 2000.
[12] W. W. Cooper, L. M. Seiford, and J. Zhu, *Handbook on Data Envelopment Analysis*. New York: Springer Science+Business Media, 2011.
[13] M. J. Farrell, "The Measurement of Productive Efficiency," *Journal of the Royal Statistical Society (Series A*), vol. 120, no. 2, pp. 253–281, 1957.
[14] S. Fries, and A. Taci, "Cost Efficiency of Banks in Transition: Evidence from 289 Banks in 15 Post-communist Countries," *Journal of Banking and Finance*, vol. 29, pp. 55–81, 2005.
[15] D. Grigorian, and V. Manole, "Determinants of Commercial Bank Performance in Transition: An Appliacation of Data Envelopment Analysis," *Comparative Economic Studies,* vol. 48, no. 3, pp. 497-522, 2006.
[16] H. Gu, and J. Yue, "The Relationship between Bank Efficiency and Stock Returns: Evidence from Chinese Listed Banks," *World Journal of Social Sciences*, vol. 1, no. 4, pp. 95-106, 2011.

[17] Z. Iršová, and T. Havránek, "Bank Efficiency in Transitional Countries: Sensitivity to Stochastic Frontier Design," *Transition Studies Review*, vol. 18, no. 2, pp. 230–270, 2011.
[18] M. Kosak, and P. Zajc, "Determinants of bank efficiency differences in the new EU member countries,"*Financial Stability Report*, Ljubljana: Bank of Slovenia, pp. 27–54, 2006.
[19] E. Mamatzakis, C. Staikouras, and A. Koutsomanoli-Filippaki, "Bank efficiency in the new European Union member states: Is there convergence?,"*InternationalReview of Financial Analysis,* vol. 17, no. 5, pp. 1156–1172, 2008.
[20] R: Matoušek, "Efficiency and scale economies in banking in new EU countries,"*International Journal of Monetary Economics and Finance*, vol. 1, no. 3, pp. 235–249, 2008.
[21] J. C. Paradi, M. Asmild, V. Aggarwall, and C. Schaffnit, "Performance Evaluation in an Oligopoly Environment: Combining DEA Window Analysis with the Malmquist Index Approach – A Study of the Canadian Banking Industry," *Centre for Management of Technology and Entrepreneurship*. Toronto: University of Toronto, pp. 31-47, 2001.
[22] I. Řepková, "Estimation of the cost and profit efficiency of the Slovak banking sector," In *Proceedings of 9thInternation Scientific Conference Financial Management of Firms and Financial Institution.* Ostrava: VŠB – Technickáuniverzita, Ekonomickáfakulta, 2013, pp. 753-762.
[23] I. Řepková, and C. L. Miglietti, "Cost and profit efficiency of the Slovak banking sector," In S. Polouček, and D. Stavárek, (ed.) *Financial Regulation and Supervision in the after - Crisis Period. Proceedings of 13th International Conference on Finance and Banking*. Karviná: Silesian University, 2013, pp. 406-416.
[24] S. P. S. Rossi, M. Schwaiger, and G. Winkler, "Managerial behavior and cost/profit efficiency in the banking sectors of Central and Eastern European countries," *Working paper No. 96*. Wien: Oesterreichische Nationalbank, 2005.
[25] M. Sathye, "Efficiency of Banks in a Developing Economy: the Case of India," *EJOR*, vol. 148, no. 3, pp. 662-671, 2003.
[26] G. Savić, M. Radosavljević, and D. Ilievski, "DEA Window Analysis Approach for Measuring the Efficiency of Serbian Banks Based on Panel Data," *Management Journal for Theory and Practice Management*, vol. 65, pp. 5-14, 2012.
[27] L. M. Seiford, and R. M. Thrall, "Recent developments in DEA: the mathematical programming approach to frontier analysis," *Journal of Econometrics*, vol. 46, pp. 7–38, 1990.
[28] J. K. Sengupta, "Systematic measures of dynamic Farrell Efficiency," *Applied Economics Letters*, vol. 3, pp. 91–94, 1996.
[29] D. Stavárek, *Restrukturalizacebankovníchsektorůaefektivnost bank v zemích Visegrádskéskupiny.*Karviná: Silesian University, 2005.
[30] D. Stavárek, and S. Polouček, Efficiency and Profitability in the Banking Sector. In S. Polouček (Ed.). *Reforming the Financial Sector in Central European Countries*. Hampshire: Palgrave Macmillan Publishers, 2004.
[31] D. Stavárek, and J. Šulganová, "Analýza efektívnosti slovenských bank využitím Stochastic Frontier Approach," *Ekonomická revue – Central European Review of Economic Issues*, vol. 12, no. 1, p. 27–33, 2009.
[32] F. Sufian, "The Efficiency of Islamic Banking Industry: a non-parametric analysis with non-discretionary input variable," *Islamic Economic Studies*, vol. 14, no. 1–2, pp. 53–78, 2007.
[33] H. Tulkens, and P. VandenEeckaut, "Non-parametric efficiency, progress and regress measures for panel data: Methodological aspects," *European Journal of Operational Research,* vol. 80, no. 3, pp. 474-499, 1995.
[34] K. Vincová, "Neefektívnosťzrozsahuv bankovomsektore. Komparácia slovenského a českéhobankovéhosektora," In *International Conference Proceedings: National and Regional Economics VI*. Herľany: Technická Univerzitav Košiciach, 2006, p. 440–445.
[35] H. S. Yildirim, and G. C. Philippatos, "Efficiency of banks: Recent evidence from the transition economies of Europe, 1993–2003," *The European Journal of Finance*, vol. 13, no. 2, pp. 123–143, 2007.
[36] P. Yue, "Data Envelopment Analysis and Commercial Bank Performance: A Primer with Applications to Missouri Banks," *Federal Reserve Bank of St. Louis Review*, vol. 74, no. 1, pp. 31-45, 1992.