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WINDOW ANALYSIS OF TECHNICAL EFFICIENCY: CASE OF THE SLOVAK BANKING SYSTEM

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Abstract

In the paper, a time-dependent use of data envelopment analysis (DEA) that is known as "window analysis" is applied to a set of banking institutions in Slovakia with an aim to measure their technical efficiency in period 2000 – 2012. It is assumed that the production function remains unchanged and the banking institutions perform activities under variable returns to scale. The non-parametric method of evaluation, based on the input-oriented efficiency slacks-based measure model of data envelopment analysis (SBM) is employed. The paper contributed to so far published literature by addressing the efficiency coefficients variation through window and by term in the scope of the transmission approach to the banking functions. Gained results of the case study applied on the Slovak conditions can be utilized for managerial and regulatory purposes.

Key words: *DEA, window analysis, SBM model, banking, intermediation approach.*

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1. Introduction

As integral part of the financial system, banking sector plays essential role in the targeted economic growth. The banking sector´s efficiency is the cornerstone of the overall productivity in the economy. Due to importance of banking sector efficiency to macroeconomic stability and strong competitive pressure in this sector, a substantial research was done to measure efficiency of banking institutions in developed countries and to benchmark them. As to studies which cover individual banking systems in Visegrad countries, Řepková and Stavárek (2012) analyzed the Czech banking sector and its efficiency over the period of 2000 to 2009, Wozniewska (2008) examined the efficiency of the Polish banking sector over the period of 2000 to 2007, and, eventually, Zemanová (2007) in her analysis of the Slovak banking sector covered the short period of 2002 and 2003. Although the majority of the research relied upon both nonparametric and parametric techniques to evaluate the bank performance in terms of efficiency, they utilized in their quest rudimentary DEA models, the model by Charnes, Cooper and Rhodes (1978) addressed conventionally as the CCR model and the model by Banker, Charnes and Cooper (1984) addressed conventionally as the BCC model. In their papers, Boďa and Zimková (2013a, 2013b) applied a more advanced DEA model, the slacks-based model by Tone (2001) and they focused on selected aspects of technical efficiency of the Slovak banking sector. As to the choice of inputs and outputs, they used the service-oriented approach and the profit approach. This paper extends so far published literature, as it aims to apply the intermediation approach to the

technical efficiency of the banks operating in Slovak Republic and, moreover, it compares the development of efficiency scores through window and the variation of efficiency scores by terms. Economic interpretation of results can be used by the managers and shareholders of commercial banks and by the National bank of Slovakia.

The paper is organized in 4 sections, the first of which is introductory and the last is concluding. The second methodological section is accompanied by the third section which presents the results and includes their interpretation.

2. Methodology and data

The objective of data envelopment analysis (DEA) originated from Farell´s seminal work (1957) and later elaborated on by Charnes et al. (1978) and Banker et al. (1984) is to construct a relative efficiency frontier through the envelopment of the Decision Making Units (DMUs) where the ´best practise´ DMUs form the frontier. In this study, the latest so-called Slacks-Based Model (SBM) introduced by Tone (2001) is utilized. It takes into account inputs and output slacks, and ensures that the slacks are taken into account in the efficiency scores.

In this paper, the assumption of variable returns to scale is formed and combined with a input-oriented SBM model in evaluating the organizational units of the Slovak banking sector on a comparative basis.

In the exact formulation of the SBM model, it is assumed that the data on n production units are available, where any production unit o, $o \in \{1, ..., n\}$, produces s desirable outputs out of m inputs. The values of inputs of production unit o are represented by vector $\mathbf{x}_o = (x_{o1}, ..., x_{om})'$ and the values of outputs by vector $\mathbf{y}_o = (y_{o1}, ..., y_{os})'$. The elements of both vectors are positive. Individual inputs and outputs have corresponding vectors of potential slacks $\mathbf{s}^{\mathbf{x}}{}_o = (s^{\mathbf{x}}{}_{o1}, ..., s^{\mathbf{x}}{}_{om})'$ and $\mathbf{s}^{\mathbf{y}}{}_o = (s^{\mathbf{y}}{}_{o1}, ..., s^{\mathbf{y}}{}_{os})'$, which states how individual inputs and outputs must be improved in order that production unit o become efficient (whereas vector of inputs $\mathbf{x}_o$ need be reduced by $\mathbf{s}^{\mathbf{x}}{}_o$ and vector of outputs $\mathbf{y}_o$ need be increased by $\mathbf{s}^{\mathbf{y}}{}_o$). These slacks are to be identified by the DEA and serve as an exclusive basis of efficiency calculation for respective production unit o.

For each production unit o, $o \in \{1, ..., n\}$, it is necessary to solve the following task of linear programming of the non-oriented SBM model under the assumption of variable returns to scale,

$$\rho_o\left(\boldsymbol{\lambda}, \mathbf{s}^{\mathbf{x}}, \mathbf{s}^{\mathbf{y}}\right) = \frac{1 - \frac{1}{m}\sum_{i=1}^{i=m} s^{\mathbf{x}}_{oi} / x_{oi}}{1 + \frac{1}{s}\sum_{j=1}^{j=s} s^{\mathbf{y}}_{oj} / y_{oj}} = !\min$$

with respect to

$$\begin{aligned} \mathbf{s}^{\mathbf{x}} &= \mathbf{x}_o - \sum_{i=1}^{i=n} \{\boldsymbol{\lambda}\}_i \mathbf{x}_i \geq \mathbf{0} \\ \mathbf{s}^{\mathbf{y}} &= \mathbf{y}_o - \sum_{i=1}^{i=n} \{\boldsymbol{\lambda}\}_i \mathbf{y}_i \geq \mathbf{0} \\ \sum_{i=1}^{i=n} \{\boldsymbol{\lambda}\}_i &= 1,\ \boldsymbol{\lambda} \geq \mathbf{0} \end{aligned} \qquad (1)$$

The symbol „≥“ denotes at a vector that respective elements of this vector are non-negative and at least one element is non-zero.

The restrictions of the optimization task constructs the production possibility set with respect to n production units and their observed inputs $\mathbf{x}_1, ..., \mathbf{x}_n$ and outputs $\mathbf{y}_1, ..., \mathbf{y}_n$ as well as their convex linear combinations in $\Re^m$ and $\Re^s$ respectively. The coefficient ρ takes values at interval $[0, 1]$ and it is the SBM score of technical efficiency (in this case of production unit o whose task (1) is subject to optimization. If for some production unit $\rho = 1$ happens to be the case, this production unit is called SBM-efficient, which means that it is technically efficient in the sample of n production units to be evaluated.

A DEA window analysis work on the principle of moving averages (Cooper at al. 2007, pp. 323-329; Asmild et al. 2004, pp. 69-72) and is useful to detect performance trends of a unit over time. Each unit in a different period is treated as if it was a different unit. The performance of a unit in a particular period is contrasted with its own performance in other periods in addition to the perfomance of other unit. This increases the number of data points in the analysis, which can be useful when dealing with small sample size. Varying the window width, that is the number of time periods included in the analysis (in our case 4 years), means covering the spectrum from contemporaneous analysis, which include only observations from one time period, to intertemporal analysis, which includes observations from the whole study period.

There is ongoing controversy over the determination of performance (input and output) indicators in DEA based bank efficiency studies. Bank behavior refers to how bank makes decisions about their operations with respect to a specific goal. Main approaches which have been developed and used both in theory and practice are the intermediation approach, the production approach and their modifications (see e.g. Ahn and Lee, 2014, pp. 1-35). Most often discussed issue is the role of deposits, which have both input and output characteristics. DEA assumes data to be isotonic, that is, efficiency drops as inputs rise, and efficiency rises as outputs increase. Deposits and bad loans were identified by Ahn and Le (2014, p. 2) as the two typical cases of anti-isotonic data where inputs or outputs should not be minimized or maximized, respectively. The most commonly used approach in the European banking industry is the intermediation approach which recognizes intermediation as the core activity of banks. Sealey and Lindley (1977) are considered as the founders of this approach. Deposits (and other selected variables) are treated as inputs and loans and investments are treated as outputs. Despite broad application in bank efficiency studies, the intermediation approach has several shortcomings. Firstly and most clearly seen, the treatment of deposits as inputs fails to justify the importance of deposit services that a bank provides. Secondly, the intermediation approach is neglecting risk indicators and non-interest related services (Ahn and Le, 2014, p. 10). Nevertheless, the intermediation approach is studied as the most common approach. In this paper, two input variables (deposits per one employ and property and equipment per one employ) and one output variable (loans and commercial papers as a proxy for earning assets) are used to measure the technical efficiency of the banks operating in the Slovak Republic stressing assumption that the efficiency frontier does not change over the analyzed period.

Table 1. Variables used in the technical efficiency analysis

Variable	Definition	Abbreviation
Inputs		
Deposits	Deposits per employ	DEM
Fixed assets	Property and equipment per employ	FAEM
Outputs		
Earning assets	Loans and commercial papers	EA

Source: the author

In our analysis, the banking sector in the Slovak Republic is represented by 10 banking institutions. All of them have the status of foreign bank licensed in the Slovak Republic (Slovenská sporiteľňa, a. s. – denoted in tables as SLSP; Všeobecná úverová banka, a. s. – denoted as VUB; Tatra banka, a.s. – denoted as Tatra banka; Československá obchodná banka, a. s. – denoted as CSOB; UniCredit Bank Slovakia, a. s. – denoted as UniCredit Bank; Poštová banka, a.s. – denoted as Postova banka; Prima banka Slovensko, a. s. – denoted as Prima banka; OTP Banka Slovensko, a. s. – denoted as OTP banka; VOLKSBANK Slovensko, a. s. since 2013 Sberbank Slovensko, a. s. – denoted as Sberbank; Privatbanka, a. s. – denoted as Privatbanka). This group of the banking institutions concisely represents the banking sector in the Slovak Republic as it covers more than 85 % of the banking assets. Hence the results of this paper can be interpreted as being representative of the total banking sector in Slovakia. To assure consistency of the analysis, building societies and special financial institutions are not under consideration.

The data used in the empirical analysis are the yearly data of balance-sheet items covering period 2000 – 2012 disclosed by the TREND Holding, s.r.o., Bratislava.

3. Results and discussion

All DEA computation were done by DEA-Solver learning version 3.0 and the results are listed in Tables 1-3. The Table 1 presents the technical efficiency scores of the banks operating in the Slovak banking system calculating through window which covered four years. Thus the 10 individual window results are displayed for each bank under consideration. As DEA window analyses works on the principle of moving averages, it is useful to detect performance trends of a unit over a time. In the paper a window with width of 4 years is used. That means that observations are only compared to other observations within a four-year span. The size of span is selected to be as small as possible to minimize the problem of unfair comparison over time. Even though large technological changes have occurred in analyzed period, it is believed that their impacts on the banks were gradual and comparison of the banks efficiency in time span of four years is still reasonable.

Most technically efficient decision making units of the Slovak banking sector in the time span 2000-2012 were Slovenska sporiteľňa and Tatra banka. Their technical efficiency was higher than 90 per cent over all analyzed period. The worst results in the technical efficiency but a good trend over the time experienced the Sberbank Slovensko.

Table 1. Technical efficiency of the banks operating in the Slovak banking system: variation through window

	2000-2003	2001-2004	2002-2005	2003-2006	2004-2007	2005-2008	2006-2009	2007-2010	2008-2011	2009-2012
CSOB	0,77	0,78	0,73	0,69	0,82	0,82	0,94	0,94	0,93	0,91
OTP banka	0,81	0,85	0,80	0,83	0,92	0,90	0,90	0,92	0,93	0,99
Postova banka	0,74	0,81	0,80	0,82	0,90	0,85	0,81	0,77	0,73	0,69
Prima banka	0,62	0,62	0,60	0,60	0,65	0,63	0,64	0,68	0,73	0,76
Privatbanka	0,79	0,87	0,82	0,85	0,88	0,94	1,00	0,94	0,94	0,92
Sberbank Slovensko	0,50	0,57	0,60	0,62	0,75	0,74	0,75	0,81	0,83	0,89
SLSP	0,98	0,97	0,95	0,91	0,93	0,91	0,97	0,96	0,94	0,96
Tatra banka	0,95	0,96	0,98	0,99	0,98	1,00	0,98	0,99	0,98	0,96
UniCredit Bank	0,85	0,81	0,70	0,66	0,73	0,71	0,77	0,74	0,78	0,80
VUB	0,94	0,87	0,85	0,79	0,85	0,82	0,86	0,84	0,86	0,90

Source: the author

The technical efficiency scores of the banks operating in the Slovak banking system calculated in individual years are displayed in Table 2 and Table 3. Most technically efficient is Slovenska sporiteľňa which was found technically efficient in 5 years out of total period followed by Tatra banka which was found technically efficient in 4 years out of total time span from the angle of the intermediation approach. Two banks, OTP banka and UniCredit Bank were technically efficient only at the very beginning of analyzed period and since then they are technically in-efficient in comparison to their benchmarks. Especially the efficiency of the UniCredit Bank ranges in span 63 to 100 per cent. Most volatile performance as to technical efficiency from the intermediation point of view is seen due to efficiency coefficients calculated by term in ČSOB. Since 2006 the Privat banka improved its technical efficiency considerably. Those results are particularly interesting to shareholders and national regulator. Drops in the outputs are significant, but the window analyses coefficients proves the right trend in the development of both banks.

Table 2. Technical efficiency of the banks operating in the Slovak banking system: variation by term (till an effect of the financial crisis)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CSOB	0,77	0,74	0,81	0,80	0,83	0,57	0,74	0,97	1,00	0,97
OTP banka	1,00	0,89	0,93	0,79	0,73	0,91	0,91	0,90	0,91	0,89
Postova banka	0,79	0,80	0,77	0,80	0,87	0,87	0,86	0,84	0,83	0,69
Prima banka	0,71	0,66	0,59	0,63	0,58	0,66	0,65	0,60	0,69	0,64
Privatbanka	0,70	0,82	0,84	0,99	0,72	0,72	1,00	1,00	0,99	1,00
Sberbank Slovensko	0,48	0,49	0,53	0,59	0,67	0,73	0,73	0,76	0,72	0,82
SLSP	0,92	1,00	1,00	1,00	0,94	0,92	0,88	0,98	0,91	1,00
Tatra banka	0,96	0,91	0,92	0,99	1,00	1,00	0,98	0,98	0,98	1,00
UniCredit Bank	1,00	0,96	0,82	0,73	0,70	0,63	0,84	0,66	0,71	0,83
VUB	0,97	1,00	0,98	0,83	0,78	0,85	0,81	0,87	0,73	0,90

Source: the author

Table 3. Technical efficiency of the banks operating in the Slovak banking system: variation by term (after an effect of the financial crisis)

	2010	2011	2012
CSOB	0,83	0,87	0,88
OTP banka	0,92	0,96	0,97
Postova banka	0,64	0,65	0,71
Prima banka	0,75	0,77	0,76
Privatbanka	0,79	1,00	0,88
Sberbank Slovensko	0,89	0,86	0,80
SLSP	0,90	0,90	1,00
Tatra banka	1,00	0,91	0,92
UniCredit Bank	0,71	0,80	0,74
VUB	0,91	0,85	0,83

Source: the author

Overall we can state that in the period 2002 – 2012 the most technically efficient bank from the intermediation point of view in Slovakia was Slovenská sporiteľňa followed by Tatra banka comparing them to the rest of analyzed banks providing services in Slovakia. On the contrary the worst efficiency scores calculated by window analyses has reached Sberbank Slovensko, although the bank is steadily increasing its technical efficiency compared to the best performers from the level of 50 to 89 per cent over analyzed period. Other banks under research were steadily increasing their technical efficiency although ČSOB experienced volatile performance.

Results displayed in Tables 1-3 allow individual commercial banks and the national regulatory body to identify the qualitative aspects of the banking operations from the intermediation point of view.

4. Conclusion

The paper present results of a longitudinal performance analysis of the 10 banking institutions providing their services in the Slovak Republic over the period from 2000 till 2012. The banks included into analyzes are Slovenská sporiteľňa, a. s. – denoted as SLSP; Všeobecná úverová banka, a. s. – denoted as VUB; Tatra banka, a.s. – denoted as Tatra banka; Československá obchodná banka, a. s. – denoted as CSOB; UniCredit Bank Slovakia, a. s. – denoted as UniCredit Bank; Poštová banka, a.s. – denoted as Postova banka; Prima banka Slovensko, a. s. – denoted as Prima banka; OTP Banka Slovensko, a. s. – denoted as OTP banka; VOLKSBANK Slovensko, a. s. since 2013 Sberbank Slovensko, a. s. – denoted as Sberbank; Privatbanka, a. s. – denoted as Privatbanka. The DEA window analyzes combined with the intermediation approach to functions of banking industry obviously showed that the coefficients of the technical effiency of the decision making units under research resulted from the window analyses are more stable in time framework then coefficients of the technical effiency of decision making units gained by term (each year individualy). Thus the window analyses results contribute in analysing trend of the efficiency performance. The original contribution of the paper is a dynamic measure of the technical efficiency of banking institutions in Slovakia based on the intermediation approach, which covers efficiency of transmission of the inputs (deposits per employ, fixed assets per employ) to outputs (earning assets including loans and investments into commercial papers). According the window analyses the best performance in the technical efficiency was reached by Slovenská sporiteľna and Tatra banka. As the window span in our analyses represents 4 years, ten technical efficiency scores presenting an average of "efficiency scores identified in the window" over analyzed period are higher then 0,9. According to variation by term, the largest Slovak bank by asset size, Slovenska sporiteľňa, was found technically efficient in a total of 5 years and Tatra banka in a total of 4 years from the angle of the intermediation approach. On the contrary the worst efficiency scores calculated by window analyses has reached Sberbank Slovensko, although the bank is steadily increasing its technical efficiency compared to the best performers from the level of 50 to 89 per cent over analyzed period. Most volatile performance as to technical efficiency from the intermediation point of view is seen in ČSOB. Those results are particularly important for shareholders and national regulator. Drops in the outputs are significant, but the window analyses coefficients proves the right trend in the development of both banks.

As it is stated in the contribution, the window analyses assume that the production frontier of the decision making units is constant over the whole analyzed period. This assumption is in the banking industry particularly strong taking into account the new technologies which range

from the internet banking based services to the possibility of the on-line credits, etc. Therefore the future research should include the productivity changes using the Malmquist index approach (an inspiration for which may be the paper by Řepková (2012)).

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