Efficiency of the banks: the case of the Visegrad countries

Abstract. The purpose of the paper is to measure the technical efficiency of domestic commercial banks in the Visegrad countries (V4) by using non-parametric Data Envelopment Analysis (DEA) and estimate the efficiency change in the banking sector. We apply an input-oriented window DEA model with a constant and variable return to scale to investigate the technical efficiency of commercial banks’ deposits to loan the transformation process. The input-oriented model was evaluated using CCR (a measure of the overall technical efficiency) and BCC (a measure of the pure technical efficiency). The model results provide recommendations for managers in managing banks to increase their effectiveness in the analysed group of banks. The analysis is focused on the 2005-2016 period, since the banking went through massive structural and regulatory changes and was affected by the 2008 financial crisis during this period. To obtain the best research results, we considered three sub-periods (2005-2008; 2009-2012; 2013-2016). The growth of the banking market, as well as the development of the economy, has led to changes in the technical efficiency. Therefore, the last part of this paper is focused on the determinants of the efficiency changes relating to individual sub-periods identified by using the radial Malmquist index under the condition of constant return to scale.

The results point to the fact that the positive efficiency change during the 2005-2008 period was primarily due to the innovation and technological growth, while during the 2009-2012 and 2013-2016 periods it was mostly impacted by progress in the efficiency change due to improved operations of management and return to scale effect.

Taking into account the results of the BCC model, which overcome the assumption that banks operate under the condition of their optimal size, we can see that the leading position was reached by the Hungarian banking sector, whose average pure technical efficiency was 78.83% during the whole analysed period. The Czech Republic ranked second, with the average pure technical efficiency equal to 68.63%, the third one was Poland (60.52%), the last one was the Slovak banking sector (58.32%).

Data relevant to the years 2018 and 2017 were not available at the time of the analysis, therefore the authors present only a trend of future development. Data provided by the European Central Bank which are partially available for 2017 suggest that the development described by the analysis results with the use of the DEA models covering all the three sub-periods will have an increasing trend with digressive slope.

Keywords: Window Data Envelopment Analysis (DEA); Intermediation Approach; Malmquist Index; Commercial Banks; Banking; Return to Scale Effect; Technical Efficiency; CCR; BCC; Visegrad Countries (V4)

JEL Classification: G21; C14

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Effectiveness of bank activity in the Visegrad group.

Abstract. The purpose of this study is to investigate the technical efficiency of commercial banks in the Visegrad countries using a DEA window analysis. The study investigates whether the transformation process (transformation of deposits to loans) in the Visegrad countries was efficient and whether it should bring recommendations for managers in managing banks to increase their efficiency in the analysed group of banks.

1. Introduction

During the global financial crisis, the global banking sector has been facing a series of problems since 2008. The issues that have derailed the overall net profit not only increased both the credit risk and costs in line with the new regulatory framework, but also affected other aspects of banking industry like competition, efficiency and stability. We can see that before the interbank market was very active the year 2008, and banks were lending money with high confidence. The situation has changed since then, and many banks have severe problems when finding resources of liquidity other than deposits. Many countries have faced either a significant decline in their growth rate or even recession (Kiseláková & Kiseľák, 2013).

The financial markets in the Visegrad countries can be characterised as representatives of a bank-oriented financial market where a critical part of financial transactions is carried out through the financial intermediaries. The group of Visegrad countries (V4) includes the Czech Republic (CR), Hungary (HU), Poland (PL) and Slovakia (SR). Using data about the global financial development published by World Bank, we can see that, for example only 30% of financial transactions was carried out through the financial market (debt securities and stock market) in Slovakia in 2015 and 70% was carried out through deposit money banks and other financial institutions. In the case of the Czech Republic, the ratio was approximately 40:60; it was 45:55 for Poland, and it equalled 50:50 for Hungary. In the Visegrad countries, a critical part of financial transactions realised by financial intermediaries is carried out through commercial banks, which play the role of principal or oriented model with a constant and variable return to scale.

The efficiency of the transformation process in the Visegrad countries, whether the efficiency of the transformation process (transformation of the deposits to loans) in the Visegrad countries has changed over the past years, including the determination of the main reason for the positive/negative efficiency change in the Visegrad countries? The answer to these questions may be beneficial to the three main groups. Knowledge of the efficiency score is essential to bank managers since it reflects the quality of daily operations in utilising inputs and outputs. Also, other decisions can be based on that knowledge. Policymakers are the second group that may benefit from the relevant information because they can use it to compare the efficiency of the banking sector before and after the regulation changes took place and, consequently, they can evaluate whether the regulation changes were beneficial to the banking sector. Finally, it is researchers who can also benefit as they can use previous studies in that area to observe the gradual development in the field of multiple efficiency measurement, which can enable them to identify gaps in the research area.

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2. Brief Literature Review

I. Štefančian and F. Gold (1985) were the first to apply DEA in the banking sector. They used DEA to evaluate the operating efficiency of 14 saving bank branches. In their study, they not only measured the level of efficiency but also defined how to eliminate inefficiency by adjusting inputs and outputs of inefficient bank branches. J. Pastor et al. (1997) analysed the efficiency of several US and European banks using the value-added approach for comparability to define the inputs and outputs. B. Casu and P. Molyneux (2003) used the intermedation approach to evaluate the efficiency of 750 selected European banks. The results showed relatively low average efficiency scores. Nevertheless, it was possible to detect a slight improvement in efficiency levels through time.

The Malmquist index approach was used in the paper by M. Degli’Innocenti et al. (2017) who estimated productivity growth of commercial banks in the 28 European Union countries and the process of bank integration during the three main stages of the global financial crisis. They analysed the sources of growth in different stages of productivity using a two-stage DEA model. The result showed a productivity growth during 2007-2008, but a consistent decline during 2009-2010. The loss of competitiveness was due to the drop in growth in the performance stage and technical change.

Besides this study, many studies assess the productivity of the European banking industry. S. Bengtsson et al. (1992), G. Battesse et al. (2000), S. Kumbhakar et al. (2001), E. Zimková (2014), I. Palečková (2015), L. Černohorská et al. (2017), I. Řepková (2014), E. Zimková (2014), M. Boďa & E. Zimková (2015), I. Palečková (2017), V. Ponomarenko et al. (2017), M. Toloło et al. (2018) and others. J. Jablonský (2012) estimated the technical efficiency and the super-efficiency of commercial banks in Slovakia in 2012. She found out that more than one half of operations. E. Zimková (2014) estimated the technical efficiency growth in the European banking system due to the liberalisation process.

In the Czech Republic, Hungary, Poland, Slovakia and Ukraine, Data Envelopment Analysis has been used to measure the efficiency of financial institutions in the last years. For example in the works by J. Jablonský (2012), I. Řepková (2014), E. Zimková (2014), M. Bodá & E. Zimková (2015), I. Palečková (2015), L. Černohorská et al. (2017), I. Palečková (2017), V. Ponomarenko et al. (2017), M. Toloło et al. (2018) and others. J. Jablonský (2012) estimated technical efficiency based on the sample of 194 bank branches of one of the Czech commercial banks. He also presented the application of DEA for ranking efficient units. I. Řepková (2014) used DEA to analyse the data of Czech commercial banks and estimated efficiency during the 2003-2012 period. She identified that the average efficiency under the constant return to scale condition reached 70-78%, and under a variable return to scale condition it reached 84-89%. Larger banks scored a lower efficiency than other banks in the banking industry, mostly due to the excess of deposits in balance sheets and inappropriate size of operations. E. Zimková (2014) estimated the technical efficiency and the super-efficiency of commercial banks in Slovakia in 2012. She found out that more than one half of the institutions were found technically efficient by applying a primary input-oriented DEA model under the assumption of a variable return to scale. I. Palečková (2015) also analysed the technical efficiency and noticed an increase in the average technical efficiency of commercial banks in Slovakia between 2004 and 2013. M. Bodá and E. Zimková (2015) used three commonly applied (service-oriented, intermediation, and profit-oriented) approaches to compare the technical efficiency in the Slovak banking market over the 2000-2011 period. The result pointed to the fact that general impression of the efficiency status of individual banks obtained within the three approaches is similar in most cases.

The change of efficiency in Visegrad countries was analysed by L. Černohorská et al. (2017) who found out that changes across all states were relatively stable. Also, they found a substantial decline in the Malmquist index in the 2011-2012 period in Hungary. The Malmquist index remains stable during the 2011-2012 period for Poland and the Czech Republic and slightly declines for Slovakia.

3. Methods

DEA is one of the methods to measure the relative technical efficiency of production units (DMU) that use the same multiple inputs to produce various corresponding outputs. By applying DEA models on the available dataset, we can identify the efficient frontier and the efficiency score of each DMU. Each DMU can be using the DEA method easily visualised on the efficiency frontier and assessed regarding its efficiency. The efficiency calculated by the DEA method easily visualized on the efficiency frontier and assessed regarding its efficiency. The efficiency calculated by the DEA method easily visualised on the efficiency frontier and assessed regarding its efficiency. The efficiency calculated by the DEA method easily visualised on the efficiency frontier and assessed regarding its efficiency.

Following M. Asmild et al. (2004) we can consider $N$ DMUs ($n = 1,2,\ldots, N$) observed in $T = 1,2,\ldots, T$ periods using $r$ inputs to produce $s$ outputs. The sample, thus, has $N \times T$ observations, and an observation $n$ in the period $t$, $DMU^t$, represents a $DMU$ in period $t$ with an $r \times s$ dimensional input vector $x^t = \left(x^t_{1}, x^t_{2}, \ldots, x^t_{r}\right)$ and the $s$ dimensional output vector $y^t = \left(y^t_{1}, y^t_{2}, \ldots, y^t_{s}\right)$. The window starting at time $k$, $1 \leq k \leq T$ and with the width $w$, $1 \leq w < T - k$, is denoted by $k$ and has $N \times w$ observations. The matrix of inputs for this window analysis is given by:

$$X^w_{k:n} = \left[\begin{array}{cccc}
x_{1,1} & x_{1,2} & \cdots & x_{1,n} \\
x_{2,1} & x_{2,2} & \cdots & x_{2,n} \\
\vdots & \vdots & \ddots & \vdots \\
x_{k,1} & x_{k,2} & \cdots & x_{k,n}
\end{array}\right].$$

And the matrix of outputs is given by:

$$Y^w_{k:n} = \left[\begin{array}{cccc}
y_{1,1} & y_{1,2} & \cdots & y_{1,n} \\
y_{2,1} & y_{2,2} & \cdots & y_{2,n} \\
\vdots & \vdots & \ddots & \vdots \\
y_{k,1} & y_{k,2} & \cdots & y_{k,n}
\end{array}\right].$$

The following form can give the input-oriented DEA window problem under a constant return to scale assumption:

$$\begin{aligned}
\theta_{j} & = \min_{\theta} \theta \\
& \text{s.t.} \quad X_{j,1} + \delta_{1} \geq 0 \\
& \quad \delta_{1} \geq 0 \\
& \quad \lambda_{j} + \gamma_{j} \geq 0 \\
& \quad \gamma_{j} \geq 0 \\
& \quad (n - 1) \leq \lambda_{j} + \gamma_{j} \leq n \cdot w.
\end{aligned}$$
After the overall technical efficiency and pure technical efficiency estimation, we performed an analysis of factors determining the efficiency change over. For this purpose, we used the Malmquist index with its decomposition into the driving forces of productivity change. The Malmquist index measures total factor productivity change between two data points by calculating the ratio of distances of each data point relative to standard technology (Adeleke et al., 2017). Following R. Shephard (1953), R. Färe et al. (1994) and B. Casu et al. (2004) to define the Malmquist index, it is necessary to determine distance functions concerning two different periods. The Malmquist productivity index evaluates a productivity change of a DMU between two periods as the product of «catch-up» and «frontier shift» terms. The catch-up (recovery or efficiency change) term reflects the degree that a DMU attains for improving its efficiency, while the frontier shift (innovation or technological change) term demonstrates the difference in the efficient frontier surrounding the DMU between the two periods.

The following formula can measure the catch-up effect from period 1 to period 2:

\[
\text{Catch-up} = \frac{\text{Efficiency of } (x_1,y_1) \text{ in period 2 with respect to period 1 frontier}}{\text{Efficiency of } (x_1,y_1) \text{ in period 1 with respect to period 1 frontier}}
\]  

(4)

Next, we use the following notation for the efficiency score of DMU \((x_1,y_1)\) measured by the frontier technology \(\mathcal{f}_2\):

\[
\mathcal{f}_2((x_1,y_1)^*) = \left( t_1, 1, t_2 = 1 \right).
\]  

(5)

Using this notation, we can express the catch-up effect as:

\[
\text{Catch-up} = \frac{\mathcal{f}_2((x_1,y_1)^* t_1, 1, t_2 = 1)}{\mathcal{f}_2((x_1,y_1)^*)}.
\]  

(6)

If the «catch-up» effect value is greater than 1, it interprets the progress in the relative efficiency from period 1 to period 2. The «catch-up» effect value equal to 1 indicates no changes in the relative efficiency, and a value below 1 indicates a regress in relative efficiency.

In addition to the «catch-up» effect, the «frontier-shift» effect must be taken into account to fully evaluate the productivity change, since the «catch-up» effect is determined by the efficiencies being measured as the distances from the respective frontiers. According to W. Cooper et al. (2007), the frontier-shift (or innovation) effect reflects the change in the efficiency frontiers (production frontiers) between two periods. The frontier-shift is defined as follows:

\[
\text{Frontier-shift} = \phi_1 - \phi_2.
\]  

(7)

where \(\phi_1\) and \(\phi_2\) are defined by the following formulas:

\[
\phi_1 = \frac{\text{Efficiency of } (x_1,y_1) \text{ in period 1 with respect to period 1 frontier}}{\text{Efficiency of } (x_1,y_1) \text{ in period 2 with respect to period 2 frontier}}
\]  

(8)

\[
\phi_2 = \frac{\text{Efficiency of } (x_1,y_1) \text{ in period 2 with respect to period 2 frontier}}{\text{Efficiency of } (x_1,y_1) \text{ in period 1 with respect to period 1 frontier}}
\]  

(9)

Using previous notation (5), we can use the following formula representing the frontier-shift effect:

\[
\text{Frontier-shift} = \left[ \frac{\mathcal{f}_2((x_1,y_1)^*)}{\mathcal{f}_2((x_1,y_1)^*)} \right]^{-1}.
\]  

(10)

(10)

The frontier-shift higher than 1 indicates progress in the frontier technology around the evaluated production unit DMU \((x_1,y_1)\), from period 1 to period 2, while frontier-shift equal to 1 and frontier-shift lower than one indicate the status quo and regress in the frontier technology.

The Malmquist index is computed as the product of the catch-up effect and frontier-shift effect. We obtain the following formula for the computation of the Malmquist index:

\[
\text{Malmquist index} = \frac{\mathcal{f}_2((x_1,y_1)^* t_1, 1, t_2 = 1)}{\mathcal{f}_2((x_1,y_1)^*)} \cdot \frac{\mathcal{f}_2((x_2,y_2)^*)}{\mathcal{f}_2((x_2,y_2)^* t_2, 1, t_2 = 1)}.
\]  

(10)

According to W. Cooper et al. (2007), the Malmquist index is a geometric mean of the two efficiency ratios: the one being the efficiency change measured by the period one technology and the other - the efficiency change measured by the period two technology. As can be seen from the formula (10), the Malmquist index consists of four terms: \(\mathcal{f}_2((x_1,y_1)^*)\), \(\mathcal{f}_2((x_1,y_1)^*)\), \(\mathcal{f}_2((x_2,y_2)^*)\), and \(\mathcal{f}_2((x_2,y_2)^* t_2, 1, t_2 = 1)\). The first two are related to the measurements within the same period with \(t_1 = 1\) or \(t_2 = 2\), while the last two are for intertemporal comparison. The Malmquist index higher than 1 indicates progress in the total factor productivity change of the evaluated production unit DMU \((x_1,y_1)\) from period 1 to period 2. The Malmquist index equal to 1 shows a status quo, and the Malmquist index lower than one means deterioration in the total factor productivity.

4. Data, Results and Discussions

In this research, we focus on the overall and pure technical efficiency evaluation of commercial banks in the Visegrad countries between 2005 and 2016. The analysis used banks’ data that cover more than 76% of the total banking assets in case Czech Republic in 2016, more than 46% in the case of Hungary, more than 36% in the case of Poland and more than 80% in the case of Slovakia. We created a panel of 40 universal commercial banks operating in Visegrad countries (twelve from Hungary, eleven from the Czech Republic, six from Poland and eleven from Slovakia’s banking market during the analysed period. The reason for older data exclusion was that the new Basel II rules were implemented in 2004. We use the three sub-periods (windows) DEA analysis, which works on the moving averages principle. The first sub-period (2005-2008) was characterised by the accession of the Czech Republic, Hungary, Poland and the Slovak Republic to the European Union and significant changes in the operation of commercial banks in the structure of their services and the orientation on mortgage banking and asset management. The adoption of the Euro as the national currency in Slovakia characterised the second sub-period (2009-2012). During this period, the banking market in all the V4 countries developed, which was also influenced by the financial crisis that hit banking sectors all around the world in 2008 (Pitóňáková, 2015). The last sub-period (2013-2016) was characterised by non-standard operations of the European Central Bank (ECB), the policy of negative interest rates and the tightening regulation of the national central banks in the V4 countries in the retail lending. The implementers of central banks in the European Union (ECB) and the implementation of Basel III, also characterised this period.

To evaluate the «relative» technical efficiency, the intermediation approach was used, since the main role of commercial banks is the realisation of financial intermediation. The term «relative» refers to the achieved efficiency within the group and under selected criteria (the input and the output variables according to the intermediation approach). In our analysis, we compare the relative technical efficiency of each bank and also the average efficiency of banks in the banking sector according to the banks’ headquarters in one of the four countries of the V4 group. The calculation was done using the DEA Solver-Pro software (http://www.saltech-inc.com/products/prod-dsp.asp) and MS Excel.

As the clients’ deposits are the main source of funds, and loans are the main part of the assets side of the balance sheet, we decided to use deposits as the input and loans as the output variable. We selected the number of employees as an input variable because these employees provide most of the services to the clients. We decided to limit the number of the input and the output variables (accepting the rule that the number of DMUs should be three times the number of the variables) to avoid the unreasonably high-efficiency scores in the estimation. We extracted the data from the Bankscope database (bankscope.bvinfo.com), and we supplemented the missing data from the banks’ annual reports on an unconsolidated basis. We reported all the data in EUR as the...
reference currency. The figures in national currencies (HUF, CZK and PLN) were converted by the official exchange rates of national central banks at the end of the analysed year. Table 1 and Figure 1 give descriptive statistics of the variables used in the analysis.

As can be seen from our sample, the Polish banking sector could be considered as the largest one with the average number of employees equal to 8,285 persons, the average deposit value of EUR 10,938,447 thousand and the average loans amounting to EUR 9,316,478 thousand during the whole analysed period. On the other hand, the banking sector in Slovakia can be considered to be the smallest, with the average number of employees equal to 1,346, the average deposit value of EUR 2,980,393 thousand and the average loans amounting to EUR 2,545,290 thousand during the whole analysed period. The development of input and output average values during the examined period in individual countries in Figure 1 shows that the volume of total loans, deposits and number of employees had significantly risen by 2008. During the first sub-period, the amount of deposits increased by more than 49% in the Czech Republic, more than 54% in Hungary, more than 59% in Poland and more than 91% in Slovakia. The volume of loans increased during the first sub-period by more than 90% in the Czech Republic, more than by 80% in Hungary, more than by 104% in Poland and more than by 58% in Slovakia. In the case of the last variable, a significant increase in the number of employees during the first sub-period can be seen in Hungary (more than 57%) and Poland (more than 28%). The 2009 financial crisis temporarily stopped this growth. Therefore, during the second sub-period (2009-2012) the deposit increased only by 17% in the Czech Republic, by 16% in Poland and by 7% in Slovakia. In the case of Hungary, we can observe a decrease in the deposit value. A similar situation can be seen in case of the second variable, where the total amount of loans increased only by 23% in the Czech Republic and Poland, by 10% in Slovakia, and decreased by 11% in Hungary. In the case of the number of employees, an increase can be observed in the Czech Republic (3%) and Hungary (4%), whereas the number of employees decreased in Poland (4%) and Slovakia (3%). During the last sub-period the renewal of growth can be seen in the Czech Republic (an increase in deposits by 21%, loans by 16% and the number of employees by 3%), Poland (an increase of deposits by 25%, loans by 25% and the number of employees by 2%), and Slovakia (an increase of deposits by 17%, loans by 25% and the number of employees by 4%). On the other hand, in Hungary, the renewal of growth can be seen only in terms of deposits (by 5%), while for loans and the number of employees the downward trend continued.

Data from 2018 and 2017 were not available at the time of this analysis. Therefore, only a trend of future development is presented by the authors. Data partially available for 2017 by the European Central Bank, suggest that the development described by the analysis results using the DEA models in all the three sub-periods would have an increasing trend with digressive slope. In 2017, the volume of total loans have increased in all the V4 countries, especially in the Czech Republic (by 43%), followed by Slovakia (by 11%), Poland (by 10%) and Hungary (by 6.9%). From the point of view of deposits, the highest increase was in Czech Republic (27%), followed by Hungary (10.9%), Poland (9.5%) and Slovakia (5.2%). An increase in the number of employees was recorded in the case of the Czech Republic (0.84%) and Hungary (0.32%). Slovakia and Poland recorded a decrease by 4.6% and 2.5%, respectively.

In general, this development trend is in line with trends within the third analysed sub-period. Following the described methodology, the efficiency of all banks in the three sub-periods (2005-2008; 2009-2012; 2013-2016) using CCR (a measure of the overall technical efficiency)
The CCR model reported an increase of the overall technical efficiency medians from the first to the second period (by 17.7%) with an increase (21.04%) towards the third one (the median values of 38.48% were within the first period, 45.29% within the second period and 54.83% within the third period). A slower increase in the median values between the first and second sub-period can also be explained by the financial crisis that hit the banking sectors all around the world in 2008. The CCR overall technical efficiency can be decomposed into the BCC pure technical efficiency and the scale efficiency. We used the BCC model due to the other than the optimal size operation of the banks. The pure technical efficiencies were higher during all the analysed periods (the median values of 57.23% were within the first period, 66.71% within the second period, and 75.56% within the third period) due to the existence of scale inefficiency and the non-optimal size of banks. Based on the above sample, we can say that most banks operated under the conditions of variable return to scale, mostly decreasing return to scale. In view of the results presented in Figure 2, a higher variability can be seen under the CCR model, especially for the second sub-period.

We calculated the level of average efficiency separately for each state to observe differences in the average efficiency among the V4 countries. Table 2 presents the results.

Taking into account the results of the BCC model, which overcome the assumption that banks operate under the condition of their optimal size, we can see that the leading position was reached by the Hungarian banking sector, whose average pure technical efficiency was 78.86% during the whole analysed period. The Czech Republic ranked second, with the average pure technical efficiency equal to 68.63%. The third one was the banking sector in Poland, where the average pure technical efficiency gains value of 60.52%. The last was the Slovak banking sector, where the average pure technical efficiency of only 58.32%. Hungarian banks reached the highest efficiency during the 2005-2014 period. In 2015 and 2016, Polish banks were the most efficient. The Polish banking sector reached the highest improvement of efficiency between the first and last year of the analysed period, where the average pure technical efficiency increased by 138%. The slowest increase can be seen in Hungary, where the average efficiency increased only by 10%. According to the CCR model, the most efficient was the banking sector in Hungary, the second was in the Czech Republic, the third was in Slovakia and the last was the Polish banking sector. The highest improvement can also be seen in the case of Poland (126%), in Slovakia (94%), the Czech Republic (86%), and the last one is the Hungarian banking sector (16%).

One of the significant advantages of DEA is the ability to identify potential areas for the improvement of inefficient banks. The input-oriented model brings recommendations for inefficient bank how to become efficient by reducing inputs side. The identification of the sources of inefficiency may help to remove some barriers on the way to catch up with more efficient banks in the money lending business. We can see (Table 3) that, in order to improve the efficiency, it was necessary to reduce the value of inputs by 40% on average in the model with constant return to scale assumption, and by 22% in the model with a variable return to scale assumption. The highest reduction rate was required at the beginning of the analysed period when the average efficiency score was the lowest one. If we look at the reduction rates separately according to the examined countries, we find that the highest reduction was required in the case of Polish banks (45.5%) in the model with constant return to scale assumption, and in the case of Slovak banks (26.18%) in the model with variable return to scale assumption.

In the next part, we analyse the relationship between pure technical efficiency (BCC) and the bank size, using the total deposit and total loans amount as the proxy of its size. As the value of total deposit (TD) and total loans (TL) has relatively high volatility (as is evident in Table 1), we have decided to transform it to a logarithmic form. In Figure 3, we plot the BCC efficiency against the bank size during the whole analysed period. In each case, we consider both linear and nonlinear fitted values. We obtained the R-square by finding a linear or quadratic function. We can see a relatively weak linear relationship between the pure technical efficiency and the bank size. More importantly, scatter plots reported in Figure 3 indicate a potential nonlinear link between the pure technical efficiency and the bank size. Following the theoretical results from D. Martinez-Miera and R. Repullo (2010), such a nonlinear investigation of nonlinear relationship can
be useful from a policy point of view, as it allows identifying an optimal threshold beyond which the bank size becomes dangerous for the performance and of the whole banking sector. For the relationship between the total deposits, total loans and pure technical efficiency, we report the turning point (i.e. the optimal threshold). As we can see in the figure, the results show the U-shaped relationship between the bank size and efficiency (convex curve). The turning points in the logarithmic form vary between 5.9005 and 6.0961, which is equivalent to EUR 1,247,564 thousand in the case of deposits and EUR 795,180 thousand in the case of loans. The value of the turning point suggests that in terms of this relationship, the growth was in Slovakia during the first sub-period which is equivalent to EUR 1,247,564 thousand in the case of loans, which is higher than 13%. During the second sub-period the relationship becomes weaker, and we can again see the reinforcement of the relationship between the variables within the last sub-period. The threshold value was approximately the same during each of the sub-periods. The U-shape, the relationship between variables, indicates that the smallest and largest banks tend to be the most efficient. It can also be seen according to the average value of the pure technical efficiency for the fifth percentile of smallest and largest banks in the sample. If we look at the situation from the point of view of total deposits, we can see that the fifth percentile of the smallest banks reached the average pure technical efficiency of 93.32%, the fifth percentile of the largest banks reached the average efficiency of 72.99%, while the rest of the sample reached the average efficiency of only 65.92%. If we look at the situation from the point of view of total loans, we can see that the fifth percentile of the smallest banks reached the average pure technical efficiency of 70.95%, the fifth percentile of the largest banks reached the average efficiency of 90.71%, while the rest of the sample reached average efficiency of only 66.17%. We can conclude that the most efficient were banks with the lowest values of deposits and the highest value of loans. It indicates that the most efficient were banks which were able to either transform their level of deposits to the highest level of loans or which provide their level of loans from the lowest level of deposit. We can suppose that for the commercial bank it is more appropriate to choose the strategy of specialisation if it does not belong to the group of the largest banks in the market. From our analysis, the riskiest were medium-sized banks, suggesting that these banks should also be subject to regulatory oversight.

In the last part, we examine changes within individual sub-periods using the radial Malmquist index under the condition of constant return to scale. Table 4 records the results of this analysis.

The average progress of 46.37% in the total factor productivity is recorded in the first time window. The progress in the frontier technology positively determined this productivity growth of the analysed banks by 52.44% and a decline in the technical efficiency by 1.78%. In the second time window, we observe the Malmquist index (MI) indicating a slower improvement in the total factor productivity with an annual increase rate of 2.26%. This more gradual increase was supported by a decline in the technical progress (which should be influenced by the financial crisis) by 9.21%, and even the positive catch-up effect (12.49%) could not tip the scales in the total factor productivity. In the third time window, the MI index recorded a 1.26% increase in the total factor productivity with growth in the relative technical efficiency (6.87%) and the adverse innovation effect (4.84%). The frontier shift effect representing the impact of innovation was positive only during the first sub-period. However, the source for this effect can be latent and of any type like technological change or progress, macroeconomic development central bank policies or even government regulations. All these issues, together with information technologies, influenced the banks’ ability to offer more sophisticated products and services, enabling them to take their products closer to clients and so increase their efficiency. The catch-up effect was more critical during the second and third sub-periods, which represents an improvement in the technical efficiency due to improved operations and management of commercial banks and optimisation of the bank optimal size.

If we look at the results according to the countries shown in Table 5, we see that the average Malmquist index was above 1 in the Czech, Polish and Slovak banking sectors. This result shows a positive efficiency change in the mentioned banking sectors. The highest productivity growth was in Slovakia during the first sub-period which illustrated the most top performance change (an increase...
to scale assumption. If we look at the reduction rates by country, we find that the highest reduction was required in the case of Polish banks in the model with constant return to scale assumption, and in the case of Slovak banks - in a model with a variable return to scale assumption.

When looking at the development of the whole banking industry according to the data published by the European Central bank, it can be seen that the volume of deposits slightly increased in Poland (9.5%), and Slovakia (5.2%) in 2017, while the number of employees decreased (by 4.6% in Slovakia and by 2.5% in Poland). This development is in line with the trends corresponding to the third sub-period. When considering the last analysed period of 62.24%). Hungary reached the worst performance in the second sub-period, as its average Malmquist index was the lowest, indicating regress by 14.04%. The technological change, observed by positive growth in all two countries only during the first sub-period. Therefore, we can suppose that the entrance of the Visegrad countries into the European Union had a positive impact on innovation which was developed, adapted or absorbed by players within the banking systems of all the states. The highest regress in the technological change can be seen in all the states during the second sub-period which was impacted during the crisis period. Therefore, the level of innovations was not so high as during the first sub-period. The regress in the technological change can also be seen in the last sub-period where the rate of decline is not so high. The difference in the technical efficiency in the form of the positive catch-up effect can be seen during all the sub-periods in the case of Poland and Slovakia. It indicates that the progress in the pure technical efficiency in these countries was primarily impacted by the growth in the efficiency change due to improved operations and management and the return to scale effect. Managers were able to manage the process of deposit-to-loan transformations more effectively, which led to an increase in their efficiency.

5. Conclusions

The aim of the article was to measure the technical efficiency in the Czech, Hungarian, Polish and Slovak banking sectors by using the non-parametric input-oriented DEA model with a constant and variable return to scale. We used the intermedialation approach to define the input and output variables. The results bring the answer to the first research question: «Does the banking sector of the V4 countries perform efficiently?». We can see that the efficiency of the banking sector in the Visegrad countries increased during the analysed period except for the 2009-2011 period, when a slowdown was recorded due to the financial crisis and subsequent changes in the regulatory requirements or banks’ loan assessment behaviour. The results showed that the banking sector in Hungary was the most efficient, followed by the Czech, Slovak and Polish banking sectors respectively.

The second research question was «What are the main sources of inefficiency, and is there any way how the managers of commercial banks can improve the efficiency of the transformation process in the V4 countries?». The identification of the factors of inefficiency may help to remove some barriers on the way to catch up with more efficient banks in the money lending business. The results showed that to improve efficiency it was required to reduce the value of inputs by 40% on average in the model with constant return to scale assumption, and by 22% in the model with a variable return (2013-2016), where the increase can be seen in the case of Poland (an increase in deposits - by 25%, loans - by 25% and the number of employees - by 2%) and Slovakia (an increase in deposits by 17%, loans - by 25% and the number of employees - by 4%), we can conclude that the development of the input variables is more positive, as the growth rate is slowing down with the current slowdown of loans (an increase by 11% in Slovakia and by 10% in Poland). Therefore, we can suppose that it will have a positive effect on the efficiency of the abovementioned banking sectors.

The analysis of the efficiency of the deposit-to-loan transformation process in the V4 countries has changed over the past years, which means that the relative technical efficiency changed during the three sub-periods. The CCR model recorded increasing median values of the overall technical efficiency during the three periods (38.48%, 45.29% and 54.83%). The BCC model showed more clustered results of the pure technical efficiency with the median increase of 16.56% between the first and second periods and an increase of 13.26% between the last two periods. The slowdown of the average technical efficiency in the second sub-period could be the result of the financial crisis in 2008. The comparison of the bank size and the pure technical efficiency showed the U-shaped relationship between the bank size and efficiency (the convex curve). The turning points vary between EUR 1,247,564 thousand in the case of deposits and EUR 795,180 thousand in the case of loans. The value of the turning point suggests that the growing bank size tends to decrease the efficiency within the threshold, whereas beyond this threshold the growing bank size tends to increase the efficiency of the analysed commercial banks.

Basing on the Malmquist index, it can be generally concluded that the frontier shift effect, representing the effect of innovation, was positive only during the first sub-period. During this sub-period, banks in the Visegrad countries increased their productivity mainly due to technical progress. The banking sector took advantages mostly of information technologies and reached a higher production frontier. During the second and third sub-periods, the catch-up effect was more critical, which represents an improvement in technical efficiency due to improved operations and management of commercial banks and also optimization of the bank size. The development of the innovation effect was slower than the increase in the relative efficiency, which can be caused by negative impacts relating to restrictive regulatory requirements, the 2008 financial crisis, and more gradual economic growth. The factors mentioned above can be considered to be the answer to our last research question: «What is the main reason for the positive/negative change in efficiency in the Visegrad countries?»

Tab. 5: Productivity change indexes in individual countries

| Country | Years | Number of banks | Catch-up effect | Frontier-shift effect | Malmquist index |
|---------|-------|-----------------|----------------|----------------------|-----------------|
| CR      | 2005-2008 | 11              | 0.9385         | 1.0583              | 1.0434          |
|         | 2009-2012 | 11              | 1.0236         | 1.0918              | 1.1092          |
|         | 2013-2016 | 11              | 1.0813         | 0.9582              | 1.0327          |
| HU      | 2005-2008 | 12              | 0.9596         | 1.4159              | 1.3261          |
|         | 2009-2012 | 12              | 0.9658         | 0.8906              | 0.8566          |
|         | 2013-2016 | 12              | 0.9438         | 0.9511              | 0.8876          |
| PL      | 2005-2008 | 6               | 1.0390         | 1.4331              | 1.4852          |
|         | 2009-2012 | 6               | 1.2618         | 0.8980              | 1.1315          |
|         | 2013-2016 | 6               | 1.1070         | 0.9420              | 1.0424          |
| SR      | 2005-2008 | 11              | 1.1095         | 1.5966              | 1.6224          |
|         | 2009-2012 | 11              | 1.1453         | 0.9223              | 1.0545          |
|         | 2013-2016 | 11              | 1.1717         | 0.9506              | 1.1126          |

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