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Martin Boďa, Zuzana Piklová
Matej Bel University in Banská Bystrica
e-mails: martin.boda@umb.sk; zuzana.piklova@gmail.com

ON THE COMPARABILITY OF THE PRODUCTION AND INTERMEDIATION APPROACH IN BANKING EFFICIENCY STUDIES

PORÓWNYWALNOŚĆ PODEJŚCIA PRODUKCYJNEGO I INTERMEDIACYJNEGO W BADANIACH DOTYCZĄCYCH EFEKTYWNOŚCI BANKOWEJ

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Abstract: The paper analyses the question of comparability of results that arise from application of the production and intermediation approach in practical efficiency measurement in banking. Its goal is to assess the comparability or congruence of efficiency scores yielded by these two approaches when applied in a case study of Slovak commercial banks for a period of 11 years between 2005 and 2015, using data envelopment analysis (DEA). The paper acknowledges that the chief distinction between the two approaches residing in the treatment of deposits passes into the resulting efficiency scores and troubles their comparability.

Keywords: efficiency, commercial banks, production approach, intermediation approach, comparability.

Streszczenie: Badanie to analizuje kwestię porównywalności wyników po zastosowaniu podejścia produkcyjnego i intermediacyjnego w praktycznym pomiarze efektywności bankowości. Celem jest ocena, za pomocą metody DEA, porównywalności lub spójności przyrostu wydajności uzyskanego dzięki dwóm podejściom stosowanym w studium przypadku słowackich banków komercyjnych w okresie 11 lat w latach 2005-2015. W badaniu stwierdzono, że główna różnica między podejściem produkcyjnym i intermediacyjnym polega na innym rozumieniu roli depozytów bankowych, co znajduje odzwierciedlenie w końcowym wyniku skuteczności.

Słowa kluczowe: efektywność, banki komercyjne, podejście produkcyjne, podejście inermediacyjne, porównywalność.

1. Introduction

Data envelopment analysis (DEA) has risen in importance in banking studies over the past two or three decades as it has become the cornerstone methodology for performance assessment of commercial banks. Owing to the importance of the banking sector to a national economy, it is only natural that banking performance assessment is of interest not only to the banks themselves, but also to the regulators and the academic community. It turns out that simple ratio indicators are not sufficient to capture all aspects of banking operations and traditional ratio analysis fails to recognize all dimensions of performance with which multi-input and multi-output banking operations associate themselves (see e.g. [Paradi et al. 2011]; [Paradi, Zhu 2013]).

Voluminous aspects of banking operations in which commercial banks transmute inputs into outputs are generally well reflected in the level of their technical efficiency as a summary indicator of diverse aspects of their performance. Simply speaking, banking performance is frequently put equal to the banking technical efficiency as one of the most important dimensions of the overall performance. It is possibly thanks to its non-parametric nature, flexibility to handle special situations and understandability, that DEA assumes the position of the primary and leading methodology in banking technical efficiency measurement, as is also testified by the bibliographies of Emrouznejad and Yang [2018] and Liu et al. [2013a, 2013b].

Regardless of a method chosen for efficiency measurement, an inescapable task at the very beginning is to identify and specify the production model of the analysed units, and this is not a pure technical ingredient to the efficiency analysis, but an economic assessment of the situation. The task of choosing the production model, which actually reduces to an enumeration of inputs and outputs of the production process, is imperative for banking applications for no less than three reasons. First, such a detailed description gives an economical outline of what a banking institution does or is at least is expected to do. Second, it is generally required for meaningful application of a DEA methodology (see e.g. [Cook et al. 2014]); and, second, there are two leading competitive approaches in banking literature that interpret the production role of commercial banks in completely different manners (e.g. [Wheelock, Wilson 1995]). By emphasizing different aspects of the banking undertaking, they set up completely diverse input-output sets, and this specification at the initial stage of an efficiency measurement project gravely affects the results of the analysis. It is a long-familiar fact observed in the empirical literature that different input-output sets yield stratified results with different implications for assessment (e.g. [Boďa, Zimková 2015] or [Kenjegalieva et al. 2009]).

There are lively and continuing disputes amongst the practitioners and the debate between the theorists of banking business continues on and off about the validity of one approach over another, which is well readable from summaries of Banerjee [2012, Table 1] or Duygun Fethi and Pasiouras [2010, Table 2]. All this is suggestive that there will scarcely be any reconciliation in a near future. Alarming as it may be, what has been neglected and not properly appreciated is that each of the approaches pre-ordains its own final results and perhaps shows analysed banks in different light. The question to what extent different approaches to banking business lead to identical or comparable results have not been investigated.

In an effort to repair this neglect, the goal of the present study is to provide an assessment of comparability or congruence of efficiency scores yielded by two leading approaches to interpreting banking production, i.e. the production approach and the intermediation approach. Notwithstanding, this task may be grasped only in an empirical context, and therefore the study is footed upon a case study of Slovak commercial banks for a period of 11 years between 2005 and 2015.

More precisely, the study uses production data for several banking institutions of the Slovak banking sector for the specified historical period and examines whether the choice of either the production or the intermediation approach affects the final results so that some guidelines for selection of inputs and outputs can be established. Having in mind that the focus of the study is somewhat limited and specialized to historical Slovak banking conditions, it must be admitted that it is difficult to generalize the findings, although they shed some light on how an input-output set for efficiency measurement in banking based on DEA should be selected. In addition, only technical efficiency, as is customary to most studies, is considered here.

It must be said in defence of the sole focus upon the Slovak banking sector that such an approach has solid methodological grounds. It might be tempting to undertake this sort of analysis in a wider perspective of a cross-country comparison, which is only fictitious and may be appealing merely at face value. The reason is that every economic environment, though possibly falling under a unified framework of global regulation, has particular operating features and is shaped by different political, sociographical, historical and cultural singularities, and the assumption that different banking sectors have identical (or at least similar) conditions is not plausible. It is the conviction of the authors that it is not recommendable to pool the data on commercial banks from a different banking sector and to posit a unified look upon their production process. But such an assumption is what this task would require.

The remainder of the paper is organized into three other sections. Section 2 gives a brief summary of the production and intermediation approach in banking and explores their past use in the Slovak banking sector. Section 3 depicts the set-up of the study and presents its results. Eventually, the last section draws useful conclusions and discusses them.

2. Banks as production facilities of financial intermediaries

Conceptual views on efficiency of commercial banks differ and depart in the issue whether commercial banks should be imputed the role of either mere production facilities that utilize traditional, and perhaps banking-specific factors of production in rendering an assortment of banking services, or agents of financial intermediation that act as links between the surplus and deficit economic agents. The authority in these two polar interpretations goes to the production approach and the intermediation approach that are currently two main-stream treatments of the core essence of the banking business. The primary source of difference between them is the treatment of deposits, which have both input and output characteristics.

The production approach fathered by Benston [1965] deems the commercial bank a facility that provides numerous financial products and services to its customers. The philosophy of the production approach thus places on the input side variables such as staff, branch offices, retail floor space of branches or fixed assets that support provision of these products and services. In contrast, on the output side are the variables that measure the volume of products or services rendered, such as the amounts of loans made, deposits taken or amounts of realized cross-selling. There is, however, a habit of considering outputs represented by measures as numbers of loan contracts, numbers of transactions or numbers of deposit accounts (see e.g. [Ahn, Le 2014]). At present, such a definition of banking outputs is not very popular since it takes efficiency considerations down to the level of routine manual activities rather than puts it on the level of monetary considerations where it should be. Under the production approach, efficiency is assessed in relation to the volume of services or products provided (on the input side) and the involvement of resources (on the output side), which is a fact emphasized by Mlima and Hjalmarsson [2002]. The production approach can be further extended and considerations on technical efficiency can be directly linked to considerations on cost efficiency. The main drawback of the production approach is the failure to account for the intermediation function of the commercial bank, which is the aspect highlighted by the intermediation approach.

The intermediation approach was pioneered by Sealey and Lindley [1977] and assumes that the main aim of the commercial bank is to act as a financial intermediary that connects economic agents in excess of funding with units in lack of funding. In this process, the bank collects excess funds in the form of deposits and transforms them into creditory services, such as loans or other investments. This intermediation is facilitated with the help of the bank's employees and fixed assets. Therefore, labour and fixed assets are alongside deposit inputs, whereas loans and other intermediated funds are outputs. There is a tendency to also identify costs associated with intermediation as an input. The crucial deficiency of the intermediation approach is the simplified and sole construal of deposits as inputs only and the imputation of only input characteristics to them. Obviously, it fails to recognize that deposits may have also output features when they arise in securing financial payments.

A solution to the conflict between the production and intermediation approach that arises in the understanding of deposits is perhaps the two-stage interpretation of the banking production, in which the bank first produces deposits using traditional factors of production such as labour and capital, and only then it transforms them into loanable funds. This interpretation recognizes both the production function (stage I) and the intermediation function (stage II) of the commercial bank. A useful description is given by Yang [2012].

Both theoretical concepts have been in the past years applied in technical efficiency measurement of Slovak commercial banks. The production approach was adopted e.g. by Boďa [2015] or Boďa and Zimková [2014, 2015] who select in their efficiency investigations input and output variables that are typical of the production approach. On the contrary, Kočišová [2012] claims that she applies the production approach; yet, her choice of inputs and outputs does not attest to this assertion since deposits are found on the side of inputs. The intermediation approach was applied by far more authors and can be found in the studies of Stavárek, Šulganová [2009], Kočišová [2013], Řepková [2014], Zimková [2014], Boďa, Zimková [2015], Palečková [2015]. A complete listing of the input-output sets considered in these studies is given in Table 1.

Table 1. Input-output set employed in efficiency studies oriented on the Slovak banking sector

Study	PE	D	OC	AS	EM	L	NII	N-II	EA
Studies associated with the production approach									
Boďa 2015		O		I	I	O			
Boďa, Zimková 2014			I				O		
Boďa, Zimková 2015			I	I					
Kočišová 2012		I				O	O		
Studies associated with the intermediation approach									
Boďa, Zimková 2015	I	I	I			O		O	
Kočišová 2013	I	I				O	O		
Palečková 2015	I	I		I		O	O		
Řepková 2014	I	I				O	O		
Stavárek, Šulganová 2009		I	I	I		O		O	
Zimková 2014		I		I	I				O

Note: "I" – input variable, "O" – output variable, "PE" – personal expenses, "D" – deposits, "OC" – operating costs, "AS" – fixed assets, "EM" – averaged number of employees, "L" – loans, "NII" – net interest income, "N-II" – non-interest income, "EA" – earnings assets.

Source: own study.

Truthfully, Table 1 avoids reporting input-output sets that are encountered in other studies as input-output selections become more heterogeneous and grow at sort of an exponential rate. Using the abbreviated notation of Table 1, Ayadi et al. [1998] assign the input status to interest on deposits, PE and D; and the output status to L, NII and N-II, or Chortareas et al. [2012] identify PE, AS and D as inputs and L and EA as outputs. These studies are both examples of the intermediation approach. Similarly, Canhoto and Dermine [2003] specify EM and AS as inputs, whilst L, D, EA and number of branches as outputs, whereas Wu et al [2006] classify EM, total expenses as inputs and D, L and revenues as outputs. Both these studies are examples of an application of the production approach.

As stated above, various concepts of efficiency of commercial banks favour the use of different inputs and outputs. The most commonly used approach in the banking industry is probably the intermediation approach (see e.g. [Ahn, Le 2014]). In the published studies applying the same approach, different inputs and outputs can be recognized, which is taken under advisement in the building of the methodological part of the paper.

3. Methodology and results

The present study employs data of a yearly frequency and covers a time frame of 11 years from 2005 to 2015. The data set was compiled by a corporate analytics agency, News and Media Holding, a.s., Bratislava, from annual balance sheet figures and other information disclosed in annual financial statements prepared under IAS/IFRS by organizational units of the Slovak banking sector. The term "organizational unit" is meant to designate a commercial bank *per se*, a branch office of a foreign bank or a special financial institution (a state-owned banking institution assisting in export-import activities). The effective number of organizational units ranges in individual years from 16 to 26 and represents an overwhelming majority of the Slovak banking sector (as the sample in each year amounted to at least 90% of assets in the sector). The effective number of production data points totals 241 bank-years.

The Slovak banking sector is in comparative terms small and the same metric which is applicable to other countries (e.g. Poland) would not hold. The fact that for each year of the investigated period the sample accounted for no less than 90% of assets in the sector is a guarantee that the sample is capable of producing trustworthy results and provides deep insights into the efficiency of Slovak commercial banks.

There are two issues associated therewith. First, the sample cannot be reasonably broken down into subcategories that could be studied separately. It comprises especially commercial banks (seated in the Slovak Republic) and to some exceptions excludes branch offices of foreign banks for the reasons of data unavailability or their negligibility. Second, only annual data was available and they are end-year numbers disclosed by Slovak commercial banks.

The inputs and outputs for the analysis were chosen in step with the normative outlook of both the production and the intermediation approach as discussed before. Whereas the full input-output set under the production approach is as follows: AS + EM + OF [inputs] and D + L [outputs], the full production set under the intermediation approach is made up of these variables: AS + EM + EQ + D [inputs] and L [outputs]. The meaning of the adopted coding is as follows: AS – tangible and intangible fixed assets (in thousands €), EM – average number of employees in full equivalents, OF – number of branch offices, EQ – equity (in thousands €), D – total deposits (without ARDAL and the State Treasury, in thousands €), and L – total loans (in thousands €). Balance sheet production variables (AS, EQ, D, L) and the number of branches were considered at year-ends, whereas the number of employees was expressed as a full-year average.

The purpose of AS and EM is to represent the physical capital and labour force, whereas D and L capture the volumes of services rendered or funds intermediated. In addition, OF captures territorial serviceability of banks and EQ is an additional resource that – from the standpoint of the intermediation approach – facilitates transmutation of the "available" funds into creditory services. As is apparent from Table 1, most of these inputs and outputs are typical of efficiency studies focused on Czecho-Slovak commercial banks (e.g. [Boďa, Zimková 2015]; [Kočišová 2012]; [Palečková 2015]; [Zimková 2014]), but OF as well as AS have not been considered so far, although these two variables are not fairly uncommon (e.g. [Kazan, Baydar 2013]; [Nitoi 2009]).

As prescribed by the conceptual discordance between the approaches, the chief distinction is in the identification of deposits. Under the production approach D is identified as an output, as opposed to the intermediation approach where it constitutes an input. A relatively unusual input recognized in the present examination under the intermediation approach is equity, which has been yet incorporated into the input-output set by none of the cited Czecho-Slovak studies, but the arguments *pro et contra* are aptly discussed by Berger and Mester [1997].

The choice of the production variables outlined earlier answers to the full input-output sets for the production approach (AS + EM + OF [inputs], D + L [outputs]) and the intermediation approach (AS + EM + EQ + D [inputs] and L [outputs]), respectively. Both specifications are most informative for these particular approaches; yet, in practical applications there is a variety of selections (see e.g. [Duygun Fethi, Pasiouras 2010]) and the analyst may come with a modified input-output specification. In recognition of this circumstance, these full (benchmark) input-output selections were expanded into the partial subsets that arise as the combinations of respective inputs and outputs.

It was possible to generate 21 input-output specifications for the production approach and 15 for the intermediation approach. All the possible combinations of inputs and outputs under either of the approaches are declared in Table 2. Individual input-output specifications are listed using the adopted notation, but with additional underscores and plus signs. Whereas an underscore separates inputs from outputs, a summation sign connects variables on a particular side of the production process. For instance, "EM+AS_D" denotes the specification, where there are two inputs (EM and AS) and one output (D).

Other methodological choices were associated with the assumption of scalability of banking operations necessary for DEA and with the models chosen for the study. In respect of the former, the entire analysis was carried out under the assumption of variable returns to scale insomuch as they answer the empirical technology and allows also for benchmarking against the production units that do not operate at their optimum scale size. This also corresponds to the findings of Boďa [2015] who claims that Slovak commercial banks operate prevalently at variable returns to scale. As far as the latter is concerned, a total of 5 DEA models were considered: two BCC models (input and output oriented, BCC-I and BCC-O) and three SBM models (input and output oriented, SBM-I and SBM-O, as well as non-oriented, SBM-N).

The tags of these DEA models are constructed as acronyms of its authors' names (Banker-Charnes-Cooper) or of the underlying efficiency measure (slacks-based-measure). The advantage of the SBM model over the BCC model is that it is non-radial and may be specified both as oriented and non-oriented. The BCC model was devised by Banker et al. [1984], whereas the formulation of the SBM model is ascribed most frequently to Tone [2001]. As forewarned, these models were applied in a framework of technical efficiency measurement, and the allocative component of the overall efficiency is not considered.

Table 2. All input-output specifications considered

Production approach	Intermediation approach
AS_D AS_L EM_D EM_L OF_D OF_L AS_L+D EM_L+D OF_L+D AS+OF_D AS+OF_L EM+AS_D EM+AS_L EM+OF_D EM+OF_L AS+OF_L+D EM+AS_L+D EM+OF_L+D EM+AS+OF_D EM+AS+OF_L EM+AS+OF_L+D	AS_L D_L EM_L EQ_L AS+EQ_L D+AS_L D+EM_L D+EQ_L EM+AS_L EM+EQ_L D+AS+EQ_L D+EM+AS_L D+EM+EQ_L EM+AS+EQ_L D+EM+AS+EQ_L

Source: own study.

The exposition of the DEA models presupposes that there are n banks in the sample whose production process transmutes m inputs into r desirable outputs. All inputs and outputs are required to be positive. The input vector of a bank o with individual elements is denoted as $\mathbf{x}_o = (x_{o1}, ..., x_{om})'$ and the corresponding output vector as $y_o = (y_{o1}, ..., y_{or})'$. Production may be associated with the excesses in inputs and shortfalls in outputs and such input and output slacks for bank o are denoted here by $\mathbf{s}_o^x = (s_{o1}^x, ..., s_{om}^x)'$ and $\mathbf{s}_o^y = (s_{o1}^y, ..., s_{or}^y)'$, respectively. The efficiency scores of the BCC models for a particular bank o are obtained by solving the linear functions:

$$\theta_o^I = \min\left\{ \theta \geq 0 : \sum_{i=1}^{i=n} \lambda_i \mathbf{x}_i \leq \theta \mathbf{x}_o, \sum_{i=1}^{i=n} \lambda_i \mathbf{y}_i \geq \mathbf{y}_o, \lambda_1 \geq 0, ..., \lambda_n \geq 0, \sum_{i=1}^{i=n} \lambda_i = 1 \right\},$$

$$\eta_o^O = \min\left\{ \eta \geq 0 : \sum_{i=1}^{i=n} \lambda_i \mathbf{x}_i \leq \mathbf{x}_o, \sum_{i=1}^{i=n} \lambda_i \mathbf{y}_i \geq \eta^{-1} \mathbf{y}_o, \lambda_1 \geq 0, ..., \lambda_n \geq 0, \sum_{i=1}^{i=n} \lambda_i = 1 \right\},$$

for BCC-I and BCC-O, respectively. The scalar quantities $\lambda_1, ..., \lambda_n$ are intensity variables that define the benchmark for the bank being assessed. The efficiency scores generated by the SBM models for bank o then ensue from solving the optimization functions:

$$\rho_o^I = \min\left\{ 1 - m^{-1}\sum_i s_{oi}^x / x_{oi} : \sum_{i=1}^{i=n} \lambda_i \mathbf{x}_i = \mathbf{x}_o - \mathbf{s}_o^x, \sum_{i=1}^{i=n} \lambda_i \mathbf{y}_i \geq \mathbf{y}_o, \mathbf{s}_o^x \geq \mathbf{0}, \sum_{i=1}^{i=n} \lambda_i = 1 \right\},$$

$$\rho_o^O = \min\left\{ (1 + s^{-1}\sum_i s_{oi}^y / y_{oi})^{-1} : \sum_{i=1}^{i=n} \lambda_i \mathbf{x}_i \leq \mathbf{x}_o, \sum_{i=1}^{i=n} \lambda_i \mathbf{y}_i \geq \mathbf{y}_o + \mathbf{s}_o^y, \mathbf{s}_o^y \geq \mathbf{0}, \sum_{i=1}^{i=n} \lambda_i = 1 \right\},$$

$$\rho_o^N = \min\left\{ \frac{1 - m^{-1}\sum_i s_{oi}^x / x_{oi}}{1 + s^{-1}\sum_i s_{oi}^y / y_{oi}} : \sum_{i=1}^{i=n} \lambda_i \mathbf{x}_i = \mathbf{x}_o - \mathbf{s}_o^x, \sum_{i=1}^{i=n} \lambda_i \mathbf{y}_i = \mathbf{y}_o + \mathbf{s}_o^y, \mathbf{s}_o^x \geq \mathbf{0}, \mathbf{s}_o^y \geq \mathbf{0}, \sum_{i=1}^{i=n} \lambda_i = 1 \right\},$$

for SBM-I, SBM-O and SBM-N, respectively.

Separately for the production and intermediation approach, all five DEA models (BCC-I, BCC-O, SBM-I, SBM-O and SBM-N) were used in conjunction with all possible input-output sets as enumerated in Table 2. For the production approach, there were as many as $5 \times 21 = 105$ configurations of the model & input-output set, and for the intermediation approach, as many as $5 \times 15 = 75$ such possible configurations emerged. For each configuration of the approach & model & input-output set, DEA programs were run in a usual manner, and technical efficiency scores were computed for the available data set of 241 bank-years. Technical efficiency scores are restricted to the interval (0,1] and a value of one is attained at estimated full technical efficiency.

Comparability and congruence between the approaches was measured and appraised by the means of Pearson correlation. In order to avoid violating the internal logic of technical efficiency measurement that is suggested by a particular model, Pearson correlation coefficients were computed whilst fixing a single DEA model between the technical efficiency scores emerging from all possible input-output sets of the production approach and technical efficiency scores emerging likewise for the intermediation approach. In other words, for each of the 5 DEA models, congruence between the production and intermediation approach was captured by $21 \times 15 = 315$

Table 3. Descriptive summary of the correlation coefficients depicting congruence between the production and the intermediation approach

Model	Minimum	Maximum	Average	St. Dev.	% CC ≤ 0.3	% CC ≤ 0.7
BCC-I	0.144	1,000	0.601	0.152	3.1	76.2
BCC-O	0.190	1,000	0.652	0.179	3.3	54.9
SBM-I	0.147	1,000	0.683	0.153	1.4	48.8
SBM-O	0.182	1,000	0.626	0.196	6.4	58.5
SBM-N	0.305	1,000	0.679	0.151	NA	54.8

Note: "St. Dev." – standard deviation, "% CC ≤ 0.3" – relative frequency of correlation coefficients lower than or equal to 0.3 (frequency of cases of weak correlation), "% CC ≤ 0.7" – relative frequency of correlation coefficients lower than or equal to 0.3 (frequency of cases of moderate correlation), "NA" – datum not available.

Source: own study.

correlation coefficients that were closely examined and described. Table 3 provides a descriptive overview of these correlation coefficients (315 coefficients per model).

The analysis was performed using DEA Solver ProTM, version 12.0, and the functionalities and scripts of the R environment, version 3.2.2 [R Core Team 2014].

Table 3 reports firstly for each model the range of correlation coefficients, their average value and standard deviation and then shows the percentages of the correlation coefficients with values of 0.3 and 0.7 at most, respectively. Since all the correlation coefficients measured are positive, these percentages coincide with the relative frequencies of cases when weak and moderate correlation was detected, respectively.

First thing to note is that the correlation coefficients in Table 3 are positive and so only positive correlation was detected between the production and intermediation approach. Of course, in some relatively rare cases, the degree of comparability or congruence is extremely faint as is readable from the minimum values of the correlation coefficients and as is attested by the percentages of cases in which the correlation coefficients are lower than or equal to 0.3. For the 5 DEA models considered, minimal correlation coefficients vary between 0.144 and 0.305 and weak correlation is found for 1.4 to 6.4% cases.

It is apparent at first glance that there are marked differences between the production and intermediation approach, which inevitably comes from the economic underpinning of these approaches that is translated into the specification of the input-output set. Moreover, the results for different models are much alike. The minimum value of correlation for the SBM-N model might be suggestive that this model might, perhaps owing to its non-orientedness (in combination with non-radiality), help best preserve the compatibility between the approaches, but this impression disappears when inspecting the average value or calculating the relative frequency of cases when strong correlation was found, i.e. 100% – 54.8% = 45.2%.

It escapes the reporting capability of Table 3, but a detailed check of the correlation coefficient reveals that the smallest values of the correlation coefficient between the approaches occur when deposits D are present as both an output under the production approach and an input under the intermediation approach. If it is not present in one of the approaches (on the opposite side of the production process), correlation coefficients tend to be overall higher. The smallest correlation coefficients are observed when the inputs and outputs sets are completely different and they have no overlap of variables on the input or output side and when D appear on the opposite sides. Such cases are reported in Table 4. These results are just confirmative of insurmountable economic differences of these two approaches that primarily sprout form the manner they treat deposits.

On the other hand, with each DEA model there are input-output pairs when correlation coefficients are one and when these approaches concur ideally. At any rate, such situations are rare and happen with identical input-output specifications shared by both approaches. There are only three such situations, AS_L, EM_L, EM+AS_L. Of course, it is then unnecessary to point out which theoretical approach is put to use in describing bank production.

Table 4. Input-output specifications with the weakest congruence between the production and intermediation approach

Input-output set for an approach		Correlation coefficient				
production	intermediation	BCC-I	BCC-O	SBM-I	SBM-O	SMB-N
OF_D	D_L	0.165	0.430	0.147	0.418	0.448
AS+OF_D	D_L	0.144	0.328	0.195	0.182	0.305
OF_D	D+EM+EQ_L	0.396	0.270	0.459	0.212	0.431
OF_D	D+EQ_L	0.353	0.251	0.389	0.203	0.383

Source: own study.

A graphically more instructive representation of the (absent/present) relationship between the technical efficiency scores yielded by the two opposing methodological approaches is the visualization that results from multidimensional scaling (MDS). The MDS was accomplished in IBM SPSS Statistics version 20.0 by running the PROXSCAL algorithm. The scaling maps are organized in Fig. 1 and display – for the four oriented DEA models considered (BCC-I, BCC-O, SBM-I, SBM-O) – in a two-dimensional coordinate system to what degree are different input-output configurations similar or discordant. Insofar as the maps are very similar and the map for the last model, the non-oriented SBM model (SBM-N), would add no information, it is not presented.

The maps show the relative positions of different input-output configurations for BCC-I, BCC-O, SBM-I, SMB-O as they are dictated and suggested by the set of efficiency scores. In other words, each configuration of inputs and outputs led to certain values of 241 efficiency scores (one score per one bank-year) and was reduced via MDS into a pair of representative values (for dimension 1 and dimension 2), and finally plotted. This reduction of dimension of size 241 into dimension of size 2 was accomplished by PROXSCAL so that the minimum of the information would be lost. The quality of fit is assessed by the stress penalty criterion (Stress-I according to Kruskal [1964]), which is displayed as part of the heading of each map.

Following the recommendation and assessment scale of Kruskal [1964], the quality of fit for each map is fair. A configuration for the production approach is identified with the starting letter "P", whereas a configuration for the intermediation approach is shown with the starting letter "I". The second letter identifies the model, i.e. "B" for the BCC model and "S" for the SBM model. Eventually, the third letter is somewhat redundant as it represents the orientation of a DEA model, i.e. "I" and "O" representing an input and output orientation, respectively. Individual configurations are marked and labelled by different numbers following the order of Table 2.

Each map helps assess similarity or disparity of input-output configurations as configurations with similar efficiency scores are clustered together and configurations with contrasting efficiency scores are positioned some distance apart. With most configurations of input and output variables the maps in Fig. 1 point to the existence of three groups of objects marked by different colours. The dark-coloured

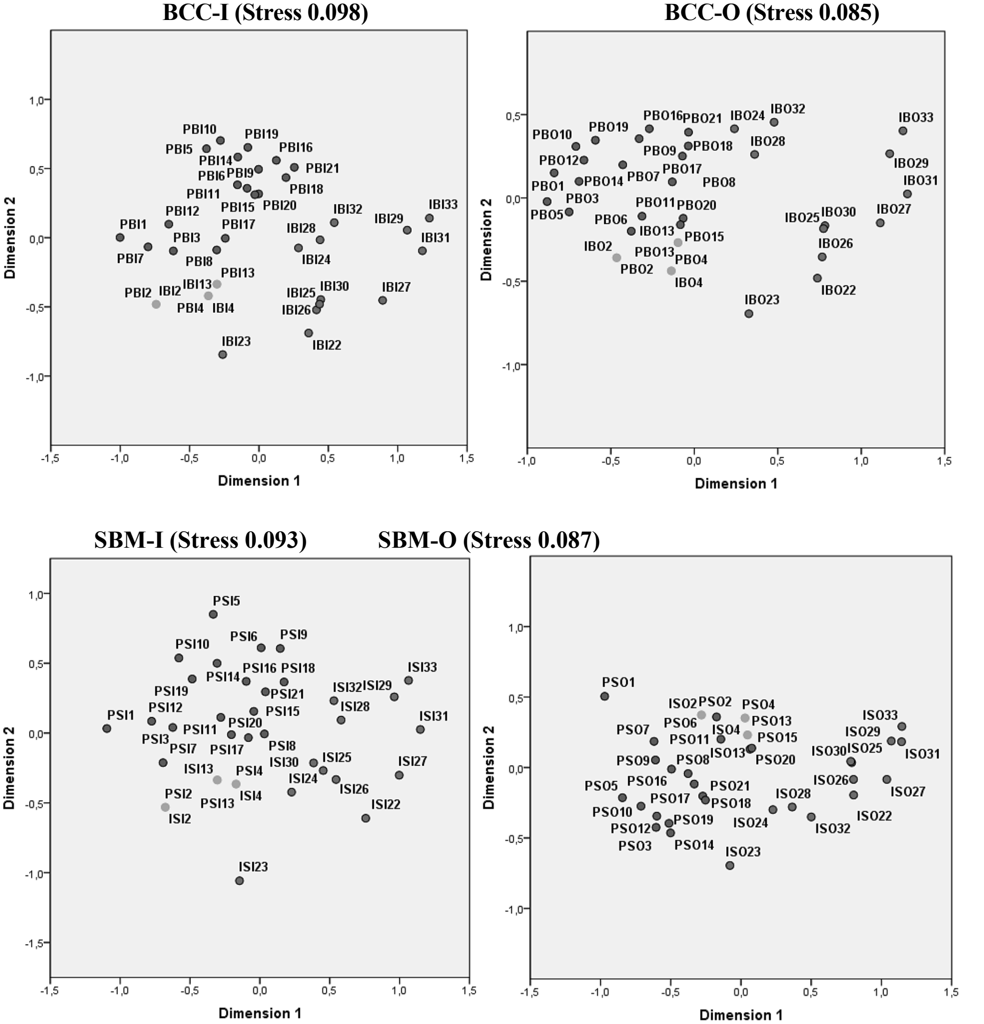

Fig. 1. Coordinate similarity between the production and intermediation approach

Source: own study.

group is formed by combinations of inputs and outputs of the production approach. The medium-coloured group consists of combinations of inputs and outputs of the intermediation approach. The last group, the group of light-coloured configurations, encompasses the configurations in which the same sets of efficiency scores were obtained, which is a consequence of the fact that for input--output configurations of both approaches are identical. In such a case, a trivial case of match arises. The largest distances communicated by the scaling maps are between the different configurations of the production and intermediation approach that place deposits on the opposite sides of the transformation process. The values of stress answer to a fair fit, which is a testimony that the results achieved are trustworthy and may be interpreted in this manner.

4. Discussion and concluding remarks

Since the philosophies of the production and intermediation approaches impute banking institutions different primary roles and imply different input-output sets, there should be a difference between these approaches in how they measure and assess technical efficiency in a practical situation. The said discord also arises in the present situation, in which a case study focusing on Slovak commercial banks is conducted and their technical efficiency scores as yielded by both approaches on a yearly basis for each year of the 11-year period between 2005 and 2015 are drawn for comparison. The differences were clearly detected not only by the undertaken correlation analysis, but are optically readable in the scaling maps produced by multidimensional scaling. The differences in efficiency scores are understandable if different input-output configurations are selected, but it is confirmed that the most severe source of these differences is in the treatment of deposits: it thus matters whether they are located on the input or output side of banking production.

There are contexts in which either the production approach or the intermediation approach should be preferred and put to exclusive use, perhaps depending on whether the study emphasizes the importance of providing banking services as such (a micro-economic perspective) or the significance of financial intermediation to a national economy (a macro-economic treatment). Yet, commercial banks do not fulfil the sole roles of deposit makers or financial intermediation agents, but they are posited into both roles simultaneously. Therefore, the decision to favour one approach over the other is difficult to make. Of course, there exist almost data-mining approaches that help decide whether a production variable with uncertain characteristics should be treated as input or output to a production process (see [Cook, Zhu 2007] or [Toloo et al. 2018]), but these defy the economic rationale of a technical efficiency measurement undertaking.

Basically, there are two possible options to solve this problem. One option is the inclusion of deposits into both sides of the production process at the same time, i.e. the consideration of deposits simultaneously as an input and output. Naturally, these would necessitate the utilization of two different measures of deposits. In this regard, it is not straightforward to state which metric of deposits should be used on the input side and which metric should be employed on the output side. The input side should be most appropriately represented by the deposits that are available to commercial banks in active operations, whereas the output side should be represented by the deposits that are reported in the balance sheets of commercial banks as these are the result of the banking production.

An alternative option is the application of a two-stage DEA modelling approach that would better describe the characteristic features of both theoretical approaches of the banking business and would make it possible to handle both financial intermediation and banking production as separate processes and decompose them into interconnected stages. A good description of a two-stage DEA method is provided by Yang [2012] who models banking production as the first stage that is connected to financial intermediation as the second stage.

As suggested by the results, deposits have an undeniable role in the entire process of technical efficiency measurement. Input is a production characteristic that serves production of outputs, that is used in or throughout production, and that is reduced (depleted) or impaired (worn-out). Simultaneously, an input should be a desired minimum and in portrayals of efficiency its minimum value should be visualized as suitable.

Nonetheless, with deposits, it is not clear whether commercial banks should minimize or maximize them. If a bank aspires at deposit maximization, this suggests that it posits itself as a producer of deposits, but by the same token, if it strives after deposit minimization, the bank sees its primary role as a financial intermediary. To decide which of these two orientations is more appropriate remains a topic for further research. At any rate, the findings of the present study are relevant in full for both applied and academic research and for both the banks themselves and the regulators. Commercial banks have a competitive interest to measure their performance in comparison to the performance of other banks and regulators need this information in assessment of the stability and resilience of the banking sector. The legacy of the findings formulated in this study is that utmost care must be exercised in defining the model of banking production with a special emphasis on deposits.

It might be tempting to associate the accomplished analysis with efficiency drivers that continue to be sought in empirical research (e.g. [Andries 2011], [Casu, Molyneux 2003] and [Drake 2001]), but this would demand that the analysis be issued with a different set-up and pushed along a different line of inquiry. The adopted configuration serves the purpose of confronting diverse input-output selections without making judgements concerning the effect that any particular selection has or can have upon drivers of efficiency which emanate from that selection. Without an extension in the spirit of a second-stage regression analysis using either truncated regression or classical least squares regression (see [Simar, Wilson 2011]), such an effort is not possible.

It remains to remark that a judicious and rational attitude to modelling is to attempt several specifications of the input-output set at a time and to compare the results generated by different choices. Of course, this requires that firstly some important decisions should be made regarding the purpose the technical efficiency assessment seeks to fulfil, as well as the designated role of the deposits in banking production. It goes then without saying that specifications of inputs and outputs cannot be capricious, but every specification must have a good economic rationale and be justifiable. Aside from serving as a robustness check, differences in the results are then an impetus for further analysis: whether a discrepancy may emerge and what brings it about. Such a procedure is not for its own sake, but is parallel to practice of considering different modelling choices and juxtaposing the results that is common to statistics, yet not proliferated in data envelopment analysis.

Another interpretation of the discord potentially present between the intermediation and production approach may be rendered in terms of the macroeconomic desirability and microeconomic competitiveness. Since financial intermediation is the key function of a financial and banking sector and *per se* fosters economic development and growth (see e.g. [Levine 1997]), good performance in financial intermediation is desirable to the economy and praiseworthy from a purely macroeconomic point of view. In contrast, good performance in production of deposits equips a bank with a competitive edge as it means that the bank concerned is capable of attracting deposits in a technically efficient way. Even so, it naturally does not mean that the bank would control a dominant portion of the deposit market, it merely implies that it serves a fraction of the market it can efficiently provide with depository facilities.

Table 5 shows the matrix of all combinations that may arise with respect to poor or good performance under the intermediation and production approach and gives their interpretation for the economy and for the bank itself.

Table 1. Links between performance in technical efficiency under the intermediation and production approaches and macroeconomic and microeconomic desirability

Result of the efficiency assessment	Underperformance in the production of deposits	Outperformance in the production of deposits
Underperformance in the financial intermediation	Poor service to the economy, weak competitive position	Poor service to the economy, competitive advantage
Outperformance in financial intermediation	Good service to the economy, weak competitive position	Good service to the economy, competitive advantage

Source: own study.

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References

Ahn H., Le M.H., 2014, *An insight into the specification of the input-output set for DEA-based bank efficiency measurement*, Management Review Quarterly, vol. 64, no. 1, p. 3-37.

Andries A.M., 2011, *The determinants of bank efficiency and productivity growth in the Central and Eastern European banking systems*, Eastern European Economics, vol. 49, no. 6, p. 35-59.

Ayadi F., Adebayo A., Omolehinwa E., 1998, *Bank performance measurement in a developing country: an application of data envelopment analysis*, Managerial Finance, vol. 24, p. 5-16.

Banker R.D., Charnes A., Cooper W.W., 1984, *Some models for estimating technical and scale inefficiencies in data envelopment analysis*, Management Science, vol. 30, no. 9, p. 1078-1092.

Banerjee B., 2012, *Banking sector efficiency in new EU member states: a survey*, Prikazi in analize, vol. 18, no. 3, p. 1-38.

Benston G., 1965, *Branch banking and economies of scale*, Journal of Finance, vol. 20, no. 2, p. 312--331.

Berger A.N., Mester L.J., 1997, *Inside the black box: what explains differences in the efficiencies of financial institutions?*, Journal of Banking and Finance, vol. 21, no. 7, p. 895-947.

Boďa M., 2015, *A slacks-based measure DEA methodology for identification of returns to scale in the Slovak banking sector*, Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, vol. 63, no. 6, p. 1847-1858.

Boďa M., Zimková E., 2014, *An insight into SBM efficiency of Slovak commercial banks*, Financial Assets and Investing, vol. 5, no. 2, p. 7-25.

Boďa M., Zimková E., 2015, *Efficiency in the Slovak banking industry: a comparison of three approaches*, Prague Economic Papers, vol. 24, no. 4, p. 434-451.

Canhoto A., Dermine J., 2003, *A note on banking efficiency in Portugal, new vs old banks*, Journal of Banking and Finance, vol. 27, p. 2087-2098.

Casu B., Molyneux P., 2003, *A comparative study of efficiency in European banking*, Applied Economics, vol. 35, no. 17, p. 1865-1876.

Chortareas G.E., Girardone C., Ventouri A., 2012. *Bank supervision, regulation, and efficiency: evidence from the European Union*, Journal of Financial Stability, vol. 8, no. 4, p. 292-302.

Cook W.D., Tone K., Zhu J., 2014, *Data envelopment analysis: prior to choosing a model*, Omega, vol. 44, p. 1-4.

Cook W.D., Zhu J., 2007, *Classifying inputs and outputs in data envelopment analysis,* European Journal of Operational Research, vol. 180, no. 2, p. 692-699.

Drake L., 2001, *Efficiency and productivity change in UK banking*, Applied Financial Economics, vol. 11, no. 5, p. 557-571.

Duygun Fethi M., Pasiouras F., 2010, *Assessing bank efficiency and performance with operational research and artificial intelligence techniques: a survey*, European Journal of Operational Research, vol. 204, no. 2, p. 189-198.

Emrouznejad A., Yang G.I., 2018, *A survey and analysis of the first 40 years of scholarly literature in DEA: 1978–2016*, Socio-Economic Planning Sciences, vol. 61, p. 4-8.

Kazan H., Baydar M., 2013, *Performance measurement with data envelopment analysis in service industry: Banking application*, Business Management Dynamics, vol. 3, no. 5, p. 37-50.

Kenjegalieva K., Simper R., Weyman-Jones T., Zelenyuk V., 2009, *Comparative analysis of banking production frameworks in Eastern European financial markets*, European Journal of Operational Research, vol. 198, no. 1, p. 189-198.

Kočišová K., 2012, *Aplikácia DEA modelov pri analýze technickej efektívnosti pobočiek komerčnej banky*, Ekonomicky Casopis, vol. 60, no. 2, p. 169-186.

Kočišová K., 2013, *An analysis of bank efficiency in the Slovak and the Czech Republic by data envelopment analysis*, Quaere 2013: recenzovaný sborník příspevků vědecké interdisciplinární mezinárodní vědecké conference doktorandů a odborných asistentů, vol. 3, p. 912-921.

Kruskal J.B., 1964, *Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis*, Psychometrika, vol. 29, no. 1, p. 1-27.

Levine R., 1997, *Financial development and economic growth*, Journal of Economic Literature, vol. 35, no. 2, p. 688-726.

Liu J.S., Lu L.Y.Y., Lu W.M., Lin B.J.Y., 2013a, *A survey of DEA applications*, Omega, vol. 41, no. 5, p. 893-902.

Liu J.S., Lu L.Y.Y., Lu W.M., Lin B.J.Y., 2013b, *Data envelopment analysis 1978–2010: a citation-based literature survey*, Omega, vol. 41, no. 1, p. 3-15.

Mlima A.P., Hjalmarsson L., 2002, *Measurement of inputs and outputs in the banking industry*, Tanzanet Journal, vol. 3, no. 1, p. 12-22.

Nitoi M., 2009, *Efficiency in the Romanian banking system: an application of data envelopment analysis*, Romanian Journal of Economics, vol. 29, no. 2, p. 162-176.

Palečková I., 2015, *Banking efficiency in Visegrad countries: a dynamic data envelopment analysis*, Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, vol. 63, no. 6, p. 2085--2091.

Paradi J.C., Zhu H., 2013, *A survey on bank branch efficiency and performance research with data envelopment analysis*, Omega, vol. 41, no. 1, p. 61-79.

Paradi J.C., Yang Z., Zhu H., 2011, *Assessing bank and bank branch performance: modelling considerations and approaches*, [in:] Cooper W.W., Seiford L.M., Zhu, J. (eds), *Handbook on data envelopment analysis, international series in operations research & management science*, 164, Springer, New York, p. 315-361.

R Core Team, 2014, R: a language and environment for statistical computing, R Foundation for Statistical Computing, Vienna, https://www.r-project.org (14.05.2017).

Řepková I., 2014, *Efficiency of the Czech Banking Sector Employing the DEA Window Analysis Approach*, Procedia Economics and Finance, vol. 12, p. 587-596.

Sealey C.W., Lindley J.T., 1977, *Inputs, outputs and a theory of production and cost at depository financial institutions*, Journal of Finance, vol. 32, no. 8, p. 1251-1266.

Simar L., Wilson P.W., 2011, *Two-stage DEA: caveat emptor*, Journal of Productivity Analysis, vol. 36, p. 205-218.

Stavárek D., Šulganová J., 2009, *Analýza efektívnosti slovenských bank využitím Stochastic Frontier Approach,* Ekonomická revue – CEREI, vol. 12, no. 1, p. 27-34.

Toloo M., Allahyar M., Hančlová J., 2018, *A non-radial directional distance method on classifying inputs and outputs in DEA: application to banking industry*, Expert Systems with Applications, vol. 92, p. 495-506.

Tone K., 2001, *A slacks-based measure of efficiency in data envelopment analysis*, European Journal of Operational Research, vol. 130, no. 3, p. 498-509.

Wheelock D.C., Wilson P.W., 1995, *Evaluating the efficiency of commercial banks: does our view of what banks do matter*?, Review of Federal Reserve Bank of St Louis, vol. 77, no. 4, p. 39-52.

Wu D., Yang Z., Liang, L., 2006, *Using DEA – neural network approach to evaluate branch efficiency of a large Canadian bank*, Expert Systems with Applications, vol. 31, p. 108-115.

Yang C-C., 2012, *Service, investment, and risk management performance in commercial banks*, Service Industries Journal, vol. 32, no. 12, p. 2005-2025.

Zimková E., 2014, *Technical efficiency and super-efficiency of the banking sector in Slovakia,* Procedia Economics and Finance, vol. 12, p. 780-787.