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EFFICIENCY OF UKRAINIAN COMMERCIAL BANKS
DURING THE 2014-2018 – DEA APPROACH

Bachelor thesis

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This paper conforms to the requirements for a Bachelor thesis

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I have written this Bachelor thesis independently. Any ideas or data taken from other authors or other sources have been fully referenced.

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(signature of the author and date)

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Introduction

Due to political instability, which was triggered by different factors, including the trade war with Russia, military conflicts in the eastern part of Ukraine, the annexation of Crimea, to name several, during 2014-2016 Ukraine experienced a domestic economic and financial crisis, which was preceded by the worldwide credit crisis of the year 2008 (Adamyk & Skirka, 2016). These crises affected the banking sector of Ukraine and slowed it in terms of efficiency, which also had a negative impact on the economic situation of the country as a whole.

From 2014 to 2016 banking system witnessed massive bank clean-up so that the number of banks sharply shortened by around a half (Rushchishin & Kostak, 2018). Also, this period was marked by a large proportion of non-performing loans and a sharp increase in liquidity risk, credit risk, and other risks. These have led to a number of reforms in the banking sector and its recapitalization (Barisitz & Lahnsteiner, 2017). Banking reforms become the key part of the Comprehensive Development Program for the Ukrainian Financial Sector 2015-2020.

The link between the efficiency of country's banking sector and its economic growth is proved by most of the empirical studies (e.g. Wachtel, 2001; Liang & Reichert, 2007), as well as studies done specifically on cases of transition countries (e.g. Koivu, 2002; Hassan, Sanchez & Yu, 2011). The positive relationship is also confirmed by the neoclassical growth model, developed by Odedokun (1996). As efficient banking system is an important prerequisite for stabilizing the country's economy, it is crucial to understand how efficient its banks are, especially when investigating the case of Ukraine, which economy is still weakened and has not fully recovered from the consequences of latest crises (Karcheva, Bulindin, Klischuk & Starinska, 2018).

Currently, there are very few studies on the efficiency of Ukrainian banks and no research papers that would investigate the efficiency of individual commercial banks during the 2014-2016 crisis and the period of recovery of the banking sector, which forms the research gap that this bachelor thesis strives to fill. Though, Prymostka and Prymostka (2018) compared the efficiency of the Ukrainian whole banking system in 2013-2015 and 2016-2018 intending to examine how liquidation of banks affected the efficiency of the system. Also, there are several studies investigating the macroeconomic and financial indicators (e.g. Dzhonmurodova & Pogorelova, 2017; Gataullina & Marshuk, 2017), but they are not providing a comprehensive picture of the fluctuations in efficiency scores of banks.

This bachelor thesis aims to appraise the technical efficiency levels of commercial banks in Ukraine from 2014 to 2018. The novelty of the current research study is in using Pearson's correlation coefficient for determining the optimal set of input and output variables in combination with applying the Simar and Wilson (2007) two-stage DEA model. One of the key benefits of this methodology is that it allows for obtaining more reliable efficiency scores than the traditional DEA method.

The following research tasks were set up in order to achieve the aim:

- To address the concept of commercial banks' efficiency,
- To introduce the data envelopment analysis method as a tool of efficiency appraisal,
- To summarize the results of previous studies on the measurement of efficiency of commercial banks,
- To provide an overview of the banking sector of Ukraine during 2014-2018,
- To collect data necessary to conduct data envelopment analysis,
- To calculate Ukrainian commercial banks' technical efficiency scores,
- To present and discuss the results.

Understanding the efficiency of banks during the period of 2014-2018 will be helpful for further evaluation of implemented reforms in the banking sector and the determination of the constituents that need to be improved as well as will become a necessary foundation for the development of future reforms. However, investigation of these aspects is an avenue for further research and will not be covered in this thesis.

Notwithstanding in the academic literature the phrase “measurement of efficiency” is most widely used, the author of this work will employ “appraisal of efficiency” collocation because it better reflects the inexact nature of this concept.

The thesis is structured as follows: the first chapter will provide an overview of the theoretical concept of efficiency, types of efficiency as well as the meaning of this concept in terms of the banking system. After that, the author will proceed to a brief overview of methods that are using to appraise the efficiency of banks, explain why the DEA method was chosen, and introduce core ideas of this method. Finally, the summary of previous scientific papers, that investigated the levels of efficiency of banks using the DEA method will be presented.

The second chapter of the paper will start with the analysis of the Ukrainian banking system, following with constructing the DEA model that is suitable for the country and chosen time frame. Then the author will provide the description of data, which will be followed by applying the DEA model to appraise the technical efficiency of Ukrainian banks. Lastly, the results will be analyzed and discussed.

Keywords: Ukrainian commercial banks, technical efficiency, data envelopment analysis, two-stage DEA model

1. Theoretical foundations of appraising banks' efficiency using DEA approach

1.1. Concept of efficiency in the case of commercial banks

The efficiency is one of the central concepts when it comes to measurement of performance of a certain business unit. It was extensively applied in research of all types of business institutions.

In economic science, the term “efficiency” is defined as “the optimize use of resources to generate the best production with the minimum costs” (Jaouadi & Zorgui, 2014, p. 316). One of the first definitions was proposed by Debreu (1951, p. 273) as “a numerical evaluation of the “dead loss” associated with a non-optimal situation (in the Pareto sense) of an economic system”. Another way to define efficiency is “when the marginal productivity per unit of price is equated across all resources that contribute to the firm’s output” (Achabal, Heineke & McIntyre, 1984, p. 111). If compare modern definition with the ones from the early literature, the idea of the concept of efficiency remains the same and can be formulated as *allocation of the available assets when minimizing the costs in order to achieve the maximum amount of output*.

However, the study of Iršová and Havránek (2010) highlights that standard way of considering and measuring the efficiency can be deceptive, when it comes to the banking sector, because of the differences in the set of input and output variables.

Speaking about the definition of efficiency specifically for financial institutions, Berger and Mester (1997) considered three concepts, based on which efficiency should be appraised, as they reflect economic reaction and optimization to changes in market prices and competition. These concepts are cost, standard profit, and alternative profit. Cost efficiency was described as an indicator of how the costs of a given financial institution are close to the costs of a top financial institution if it will have the same production volume and conditions. At the same time, standard profit efficiency estimates whether the bank has the maximum

possible profits taking into account variable costs and variable output prices and how far the bank is to 100% efficiency. Alternative profit efficiency shows how close a given financial institution is from having a maximum level of profits under a particular output level but not output prices.

In economics, the concept of efficiency can be defined by several types of efficiency and it is possible to apply all of them to the context of commercial banks. The most fundamental type is economic efficiency.

The product of technical efficiency and allocative efficiency is called economic efficiency, which means that financial institution is economically efficient if it reached 100% in technical and allocative efficiency at the same time (Bhagavath, 2006).

Technical efficiency can be interpreted from two perspectives, whether it is input-oriented or output-oriented. Input-oriented technical efficiency is the representation of the ability of the decision-making unit (DMU) to have a particular level of outputs with a minimum amount of inputs (Coelli, Rao, O'Donnell & Battese, 2005). The definition of output-oriented is the ability of DMU to have a maximum level of outputs with a particular amount of inputs and under the same technology level (Kumbhakar & Tsionas, 2006). The DMU is considered to be technically efficient if it is operating on the production frontier (Coelli, Rao, O'Donnell & Battese, 2005). Furthermore, it is important to distinguish between pure technical efficiency, which is a measure of how efficiently inputs are utilized, and scale technical efficiency, which shows whether DMU is optimally operated and if it is possible to decrease the number of inputs (Yannick, Hongzhong & Thierry, 2016). The product of pure and scale technical efficiencies is called overall technical efficiency.

Allocative efficiency measures the ability of DMU to optimally use inputs with the established price level in relation to the marginal cost of production (Barros & Mascarenhas,

2005). A bank is allocatively efficient if it is operating on the optimal set of inputs that leads to costs minimization.

Economic, as well as technical and allocative efficiencies, can also be graphically represented (see Figure 1).

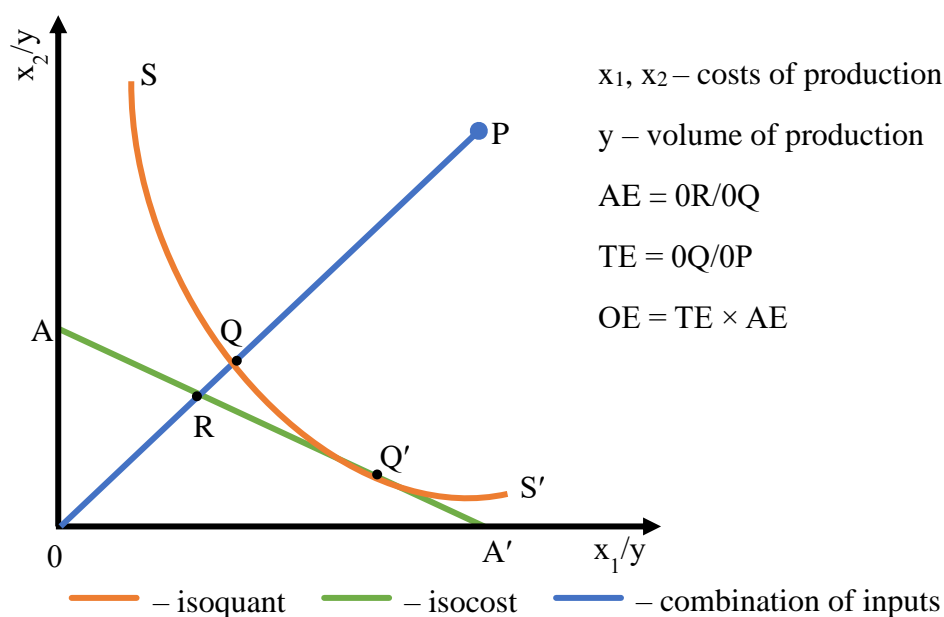


Figure 1. Overall efficiency (OE), allocative efficiency (AE), and technical efficiency (TE) (input-oriented model).

Source: Coelli, Prasada & Battese (1998, p. 135)

The constructed model in Figure 1 has two inputs x_1 and x_2 to produce one output y at point P. Points on the isoquant SS' represent combinations of inputs needed to produce a unit of output in case the DMU is perfectly efficient. Isocost line AA' shows price information, the combination of inputs that costs the same amount. Technical efficiency (TE) in this situation will be calculated as ratio OQ/OP , allocative efficiency (AE) is the ratio OR/OQ . In order to calculate economic efficiency, which can be also called overall efficiency (OE), $OE = TE \times AE = (OQ/OP) \times (OR/OQ)$.

Despite this, other types of efficiency can be defined. The short summary of some of the other types of efficiency, that are used within economic science and are relevant to the banks' scope is provided in Table 1.

Table 1

Types of efficiency

Type of efficiency	Description
Productive	Bank's ability to produce the maximum output on its production possibility frontier using minimum costs (Kopp, 1981).
Dynamic	It can be defined as productive efficiency over a time frame focused on cost minimization by implementing new technology (Silva & Stefanou, 2007).
X-efficiency	The concept was introduced by Leibenstein (1966) and can be expressed as the ratio of minimum costs used by the bank if it has the same efficiency as the most efficient bank in the sample under the same bundle of independent variables to actual costs. This concept takes into account the competition in the market phenomena.

Source: composed by the author

In order to access the efficiency scores and define the best-performing entities in the industry, the usual practice is to apply benchmarking techniques. Generally speaking, benchmarking is the process of identifying the best practices in the industry, by comparison, their performance, implementation of which will help an organization to increase its performance (Camp, 1989).

There are three main groups of methods, which allow to compute the efficiency of commercial banks and are considered as benchmarking tools. They are traditional, parametric, and non-parametric. Traditional methods include analysis of such financial ratios as ROA, ROE, net interest margin, and others. These methods are not widely used for appraising the efficiency because, even though they can very easily and quickly calculated, the results do not reflect the whole situation, they do not allow to distinguish between

productivity and efficiency and do not capable to have multiple output variables

(Wozniowska, 2009).

In order to overcome these limitations when calculating efficiency scores of commercial banks, synthesized methods are used. They can be categorized as parametric and non-parametric and each of them has their own strengths and shortcomings (see Table 2).

Table 2

Quantitative techniques for efficiency appraisal

Method	Advantages	Disadvantages
Parametric approach		
SFA (stochastic frontier approach)	<ul style="list-style-type: none"> - accounts for random noises and systematic differences - it is possible to compare individual relative efficiency scores - can handle unbalanced panel data 	<ul style="list-style-type: none"> - needs functional form specification - requires a large number of DMUs
DFA (deterministic frontier analysis)	<ul style="list-style-type: none"> - combines production function with non-stochastic error 	<ul style="list-style-type: none"> - requires several years of data
TFA (thick frontier approach)	<ul style="list-style-type: none"> - allows computing the efficiency of lowest cost quartile 	<ul style="list-style-type: none"> - does not provide individual efficiency scores, only general - does not measure cost efficiency
COLS (corrected ordinary least square)	<ul style="list-style-type: none"> - allows computing unbiased estimator of the intercept parameter 	<ul style="list-style-type: none"> - fails to handle complex models
Non-parametric approach		
DEA (data envelopment analysis)	<ul style="list-style-type: none"> - does not require specification of functional form - can have multiple inputs and outputs - does not require prior weights of variables 	<ul style="list-style-type: none"> - does not account for random and stochastic errors - neglects slack variables - sensitive to outliers - sensitive to the number of variables
FDH (free disposal hull)	<ul style="list-style-type: none"> - does not have convexity assumption 	<ul style="list-style-type: none"> - needs large dataset
Index numbers	<ul style="list-style-type: none"> - measures efficiency over time 	<ul style="list-style-type: none"> - requires computing of distance function

Source: composed by the author based on Bauer, Berger, Ferrier & Humphrey, 1998; Mokhtar, Abdullah & Al-Habshi, 2006; Bezat, 2009; Ahmed, 2015; Asmare & Begashaw, 2018; Dzemydaitė & Galinienė, 2013; Campbell, Rogers & Rezek, 2008; Agahi, Zarafshani & Behjat, 2008; Caves, Christensen & Diewert, 1982

In order to appraise the efficiency of commercial banks, most of the scholars apply one or both of the following methods: data envelopment analysis (e.g. Titko, Stankevičienė & Lāce, 2014; Ahn & Le, 2015), stochastic frontier analysis (e.g. Mohamad, Hassan & Bader, 2008; Kallel, Hamad & Triki, 2019). EBSCO Discovery database gives 4819 search results of works investigating bank efficiency using the DEA, and 1131 – using the SFA approach; Google Scholar provides 46900 search results with DEA, and 15500 – with SFA method, which indicates that DEA is a prevailing method for measuring the efficiency of banks.

If briefly compare these methods, the DEA allows using small sample sizes (Taib, Ashraf & Razimi, 2018), does not require to specify a functional form (Qaisar & Hayat, 2015), and can accommodate multiple inputs and outputs. At the same time, the DEA method does not account for noise and random error (Matousek & Taci, 2004), which SFA does. The most dangerous characteristic of DEA is that it is very sensitive to the number of DMUs, inputs, and outputs (Sun & Chang, 2011).

In this bachelor thesis, the DEA method will be applied because of the relatively small sample size and need to have multiple inputs and output variables.

1.2. Data Envelopment Analysis method

Data envelopment analysis (DEA) is a linear programming-based method, which was developed by Charnes, Cooper, and Rhodes (1978), but originally was introduced in the paper of Farrell (1957). The essence of the DEA is to measure the relative technical efficiency of decision-making units (DMU) using multiple input and output variables. The original DEA model, also known as the CCR model, measures the efficiency of each DMU as the ratio of the weighted sum of outputs to the weighted sum of inputs. The results of the ratio lie between 0 and 1, where 1 is the “perfect situation” of 100% efficiency, which means that DMU does not waste inputs in order to have a particular amount of outputs. CCR model was developed based on the assumption of constant returns to scale (CRS), which states that

there is a positive relationship between the inputs and outputs. This model can be expressed as follows (see Model 1):

$$\begin{aligned}
 & \text{maximize} \quad \frac{\sum_{r=1}^s u_r y_{r0}}{\sum_{i=1}^m v_i x_{i0}} \\
 & \text{subject to} \quad \frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}} \leq 1, \quad j = 1, 2, \dots, n \\
 & \quad \quad \quad u_r \geq \varepsilon, \quad r = 1, 2, \dots, s \\
 & \quad \quad \quad v_i \geq \varepsilon, \quad i = 1, 2, \dots, m,
 \end{aligned} \tag{Model 1}$$

where x_{ij} – the observed amount of the i input from the DMU j , y_{rj} – the observed amount of the r output from the DMU j , n – productive units, s – outputs, m – inputs, u_r – the weight given to the output r , v_i – the weight given to the input i , ε – non-Archimedean number (a sufficiently small positive number).

Source: Charnes, Cooper, and Rhodes, 1978

This fractional model can be expressed as a linear programming model (see Model 2):

$$\begin{aligned}
 & \text{maximize} \quad \sum_{r=1}^s u_r y_{r0} \\
 & \text{subject to} \quad \sum_{r=1}^s u_r y_{rj} - \sum_{i=1}^m v_i x_{ij} \leq 0, \\
 & \quad \quad \quad \sum_{i=1}^m v_i x_{i0} = 1, \quad j = 1, 2, \dots, n \\
 & \quad \quad \quad u_r \geq \varepsilon, \quad r = 1, 2, \dots, s \\
 & \quad \quad \quad v_i \geq \varepsilon, \quad i = 1, 2, \dots, m
 \end{aligned} \tag{Model 2}$$

Source: Charnes, Cooper, and Rhodes, 1978

As the CRS assumption may be accepted only if DMU operating at an optimal scale, Banker, Charnes, and Cooper (1984) proposed a modified DEA model, known as the BCC model (which stands for the first letters of authors' surnames), in order to overcome this limitation. BCC model is based on a variable return to scale assumption (VRS), which claims that an increase in inputs does not lead to a proportional increase in outputs. BCC model can be represented as follows (see Model 3):

$$\begin{aligned}
& \text{maximize} \quad \frac{\sum_{r=1}^s u_r y_{r0} - u_0}{\sum_{i=1}^m v_i x_{i0}} \\
& \text{subject to} \quad \sum_{r=1}^s u_r y_{rj} - u_0 - \sum_{i=1}^m v_i x_{ij} \leq 0, \quad j = 1, 2, \dots, n \quad (\text{Model 3}) \\
& \quad \quad \quad u_r \geq \varepsilon, \quad r = 1, 2, \dots, s \\
& \quad \quad \quad v_i \geq \varepsilon, \quad i = 1, 2, \dots, m \\
& \quad \quad \quad u_0: \text{unrestricted in sign,}
\end{aligned}$$

Source: Banker, Charnes, and Cooper, 1984

This equation can be transformed into a linear programming model as well (see Model 4):

$$\begin{aligned}
& \text{maximize} \quad \sum_{r=1}^s u_r y_{r0} - u_0 \\
& \text{subject to} \quad \sum_{r=1}^s u_r y_{rj} - \sum_{i=1}^m v_i x_{ij} - u_0 \leq 0, \\
& \quad \quad \quad \sum_{i=1}^m v_i x_{i0} = 1, \quad j = 1, 2, \dots, n \quad (\text{Model 4}) \\
& \quad \quad \quad u_r \geq \varepsilon, \quad r = 1, 2, \dots, s \\
& \quad \quad \quad v_i \geq \varepsilon, \quad i = 1, 2, \dots, m \\
& \quad \quad \quad u_0: \text{unrestricted in sign}
\end{aligned}$$

Source: Banker, Charnes, and Cooper, 1984

Also, DEA models can be categorized as input-oriented and output-oriented, so that the input-oriented model aims to maximize outputs and output-oriented – minimize inputs. All of the models provided above are input-oriented.

CRS and VSR frontiers can be graphically represented (see Figure 2). According to the figure, *C* and *G* DMUs are considered to be efficient under CRS assumption and *A*, *B*, *C*, *D*, and *E* DMUs – under the VRS assumption. Here *C* DMU can be described as purely efficient. Speaking about *F* DMU, it is inefficient under both assumptions. To calculate the technical efficiency of this DMU under the CRS assumption, the following ratio should be used HG/HF , and under VRS – HB/HF .

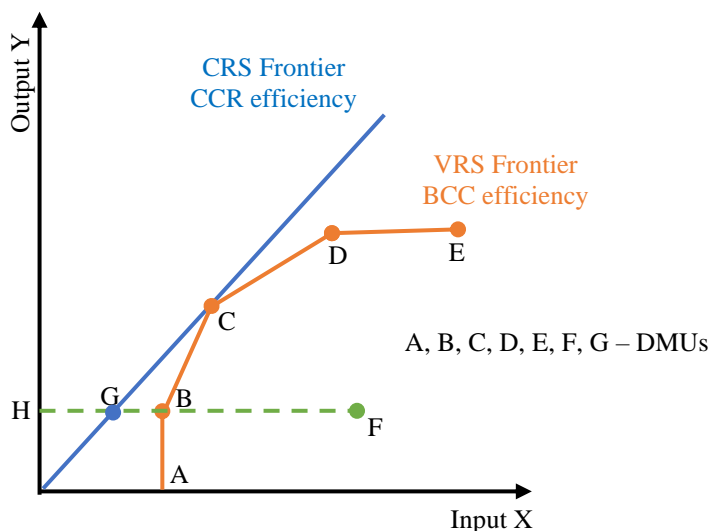


Figure 2. Constant return to scale (CRS) frontier and variable return to scale (VRS)

frontier

Source: Coelli, Rao, O'Donnell & Battese, (2005, p. 174)

Traditional DEA models have a range of limitations making DEA not a perfect tool for all of the types of efficiency analysis. That is why several extensions to the original model were developed during the years.

One of such extensions is Network DEA, developed by Färe and Grosskopf (1996). This model overcomes the limitation of traditional DEA that it does not take into account the time dimension of the dataset, Network DEA allows investigating inner processes of the production. Another modification is slack based measure (SBM) DEA, developed by Tone (2001), which measures efficiency based directly on input excesses and output shortfalls simultaneously, and gives it an advantage over other methods. Fuzzy-DEA extension was firstly introduced by Sengupta (1992) and later applied to banks by Wu, Yang, and Liang (2006). This model allows measuring the efficiency of DMUs that belong to different operating environments, which is the limitation of the original DEA. Originally, Fuzzy-DEA was developed to overcome the need to use imprecise data for the analysis. Another modification is Bayesian DEA suggested by Mitropoulos, Talias, and Mitropoulos (2015),

which aims to enhance statistical inference in DEA. Later this model was modified by Tsionas (2020), who proposed a coherent approach to Bayesian DEA, which allows obtaining coherent posterior distributions of efficiency levels and claims that this technique does not need solving a linear programming problem for each observation. PCA-DEA is one more model, which is based on the idea of Zhu (1988) to combine principal component analysis (PCA) and DEA, which allows dealing with the problems that arise when there is an extreme number of input and output variables in relation to the number of DMUs in the model. Later the algorithm of how to perform PCA-DEA was developed by Adler and Golany (2002). To overcome the problem with noise in data and sampling error, which leads to biased results, Bootstrap DEA was introduced by Simar and Wilson (1998). More recently they proposed a 2-stage DEA model (Simar & Wilson, 2007) that also takes into account environmental variables.

The systematization of the aforementioned DEA models is presented in Figure 3. The choice of concrete model largely depends on the aims of the research, the combination of available variables, sample size, and other factors.

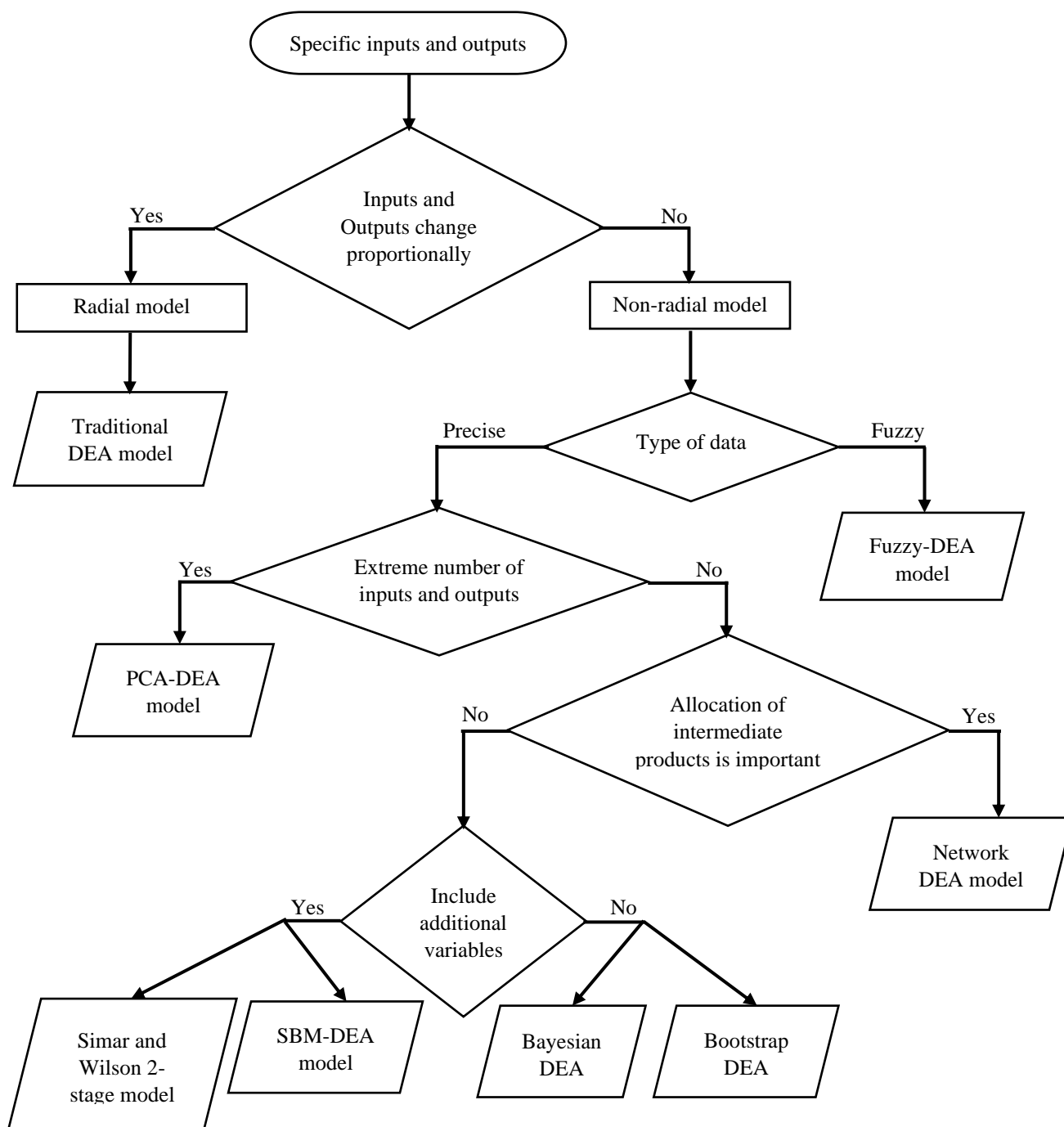


Figure 3. Algorithm of selecting appropriate DEA model

Source: composed by the author

To sum up, traditional DEA has two models, that are based on CRS and VSR frontiers. Because of the limitations of traditional models and the need to apprise efficiency from different datasets, a number of modified DEA models were developed, and they are applicable to the banks' scope.

1.3. Appraising of banks efficiency using DEA method – results of previous studies

The DEA method is a widely used technique for appraising efficiency in the banking sector. There are a lot of research papers that apply DEA for commercial banks, but most of them were done in developed countries. Although in recent years a lot of studies were conducted in developing countries in order to fill this gap, investigating emerging countries is still an avenue for further research.

To the author's knowledge, there are very few research studies done on appraising the efficiency of commercial banks of Ukraine using the DEA method, and there is no study that is focused on calculating the efficiency of banks during the whole 2014-2018 period, which still forms a research gap.

Speaking about studies that investigated the efficiency of Ukrainian banks during the 2014-2018 period, to the best of the author's knowledge, there was not any study conducted that would focus on measuring the efficiency of commercial banks separately using any method and considering the effect of implemented reforms. However, the paper of Prymostka and Prymostka (2018) assessed the efficiency of the Ukrainian banking system as a whole in two periods 2013-2015 and 2016-2018 using the model of dynamics norm. The study aimed to compare the efficiency of the whole banking system before and after the massive liquidation of banks. The authors found that there was an increase in efficiency between two periods (in 2013-2015 the efficiency was 0.285 pp and in 2016-2018 – more than 0.5 pp). Also, the study proved that the efficiency of the banking system is determined by the financial indicators and not the number of active banks.

Moreover, there are research papers that consider different macroeconomic or financial indicators that have an effect on the efficiency of the whole banking sector, as most

of the studies do not focus on separate banks. Analysis of these studies is also important for the thesis because they provide general tendencies of the sector.

Zmurko and Mylyanyk (2015) made an analysis of the resource potential of commercial banks which is considered to be one of the components of banks' efficiency. Authors state that due to the crisis that began in 2014 and provoked the procedure of banks' liquidation, a resource base for active operations increased by 3.03% and total capital decreased by 23.14%. One more problem is the lack of long-term resources, which should be solved on the macroeconomic level.

Dzhonmurodova and Pogorelova (2017) researched the efficiency of the banking sector during 2012-2016 using such indicators as profit, banks' recourses, liabilities, and equity. Authors concluded that 2014 became the worst year in terms of all indicators, in 2015 the situation a bit stabilized but in 2016 banking sector faced record level of loss, which was explained by the procedure of nationalization of PrivatBank. Moreover, during 2014-2016 was found a clear trend of decreasing of efficiency of banks.

Gataullina and Marshuk (2017) analyzed the main performance indicators of commercial banks during 2014-2016. There was an increase in banks' assets due to the devaluation of hryvnia as well as an increase in banks' liabilities. Also, the authors noticed that in 2017 began the phase of stabilization of the banking sector.

To sum up, all of the studies confirm that period of 2014-2016 caused a drop in the level of efficiency of banks.

In the frame of this bachelor thesis, it is also important to investigate the studies done specifically using the DEA method because when building a DEA model several aspects should be considered and the reliability of the results will highly depend on them.

First of all, it is worth mentioning that among the researchers there is no consensus when it comes to what type of DEA method should be applied to commercial banks, input- or

output-oriented. There are plenty of studies that use an input-oriented DEA model (e.g. Tanna, Pasiouras & Nnadi, 2011; Nigmonov, 2010), as well as a lot of studies use output-oriented (e.g. Kumar & Gulati, 2010; Depren & Depren, 2016).

Secondly, the choice of input and output variables is extremely important, because the results of the model will mostly depend on that. There are plenty of works, that investigates the issue of DEA model misspecification (e.g. Olesen & Petersen, 1996; Galagedera, 2004; Adler & Yazhensky, 2010; Luo, Bi & Liang, 2012), putting an emphasis on the choice of variables issue, stating that wrong set of inputs and outputs, as well as their amount, can lead to distortion of the reliability of the results. Unfortunately, there is no statistic test, which will serve as a “golden rule” and give an optimal needed amount of input and output variables.

However, researchers identified three approaches that can be used when selecting variables: intermediation, production, and profitability approaches. Intermediation approach states that the main function of banks is raising funds and use them for credits, this approach treats input variables as loans and securities, and output variables as loans and capital (Yannick, Hongzhong & Thierry, 2016; Sealey & Lindley, 1977). Production approach defines the primary aim of banks as providing services and states that capital and labor should be denoted as input variables, whereas loans and deposits – as output variables (Heffernan, 2005). The profitability approach follows a similar logic as production one, but output variables are more focused on profit, for example, interest income (Thagunna & Poudel, 2013).

Based on the aforementioned notes, when analyzing previous works, attention should be paid not only on the results but also on methodology and choice of variables.

Because of the lack of studies on the efficiency of Ukrainian banks and the fact that DEA is sensible to different country- and industry-related factors method, for the analysis of previous works, the author focuses only on studies done in Eastern Europe and with

longitudinal datasets, which is close to the frame of the current research and will allow building a better DEA model for efficiency analysis of Ukrainian banks.

Řepková (2014) investigated the technical efficiency (CRS), pure technical efficiency (VRS), and scale efficiency scores of Czech commercial banks using the dynamic DEA method. The author found that on average Czech banks are, in general, efficient. Another finding is that large banks are usually operating with lower technical efficiency.

Bod'a and Zimková (2015) examined Slovakian commercial banks by applying DEA slack-based model (SBM) to three different theoretical approaches: the service-oriented approach, the intermediation approach, and the profit-oriented approach. The aim of the paper was not only to measure the efficiency under these three approaches but also to analyze which one is better in terms of the banking system. Authors found that the choice of approach depends on the objectives of the research, for example, if a researcher is interested in how regulations affect the efficiency of the banks than the intermediation approach should be followed.

Yadav (2015) estimated the technical efficiency of Russian commercial banks. In the paper, the author used DEA in order to measure total technical efficiency, pure technical efficiency, and scale efficiency. The study found that most of the banks underperform in the use of total expenses and deposits to create net investments and loans.

The research study that was conducted by Nițoi and Spulbăr (2016) applied the CCR output-oriented DEA model to Romanian banks. After finding the DEA scores, in order to improve the robustness of results and identify the determinants of Romanian banks' efficiency, 3 models were applied: Tobit model, Simar and Wilson (2007) model, and fractional logit model developed by Papke and Wooldridge (1996). The results of these three models appeared to be similar.

Speaking about the studies that used the DEA method for investigating the efficiency of Ukrainian commercial banks, in recent years there were conducted two such pieces of research. Grebeniuk (2017) investigated Ukrainian banks during the period 2013-2016 using output-oriented CCR DEA model, but due to the fact that 6 input and 7 output variables were used in one model and this choice was not reasoned, a very high number of banks with 100% efficiency was found, which indicates that the accuracy of the research is low, this paper cannot be used as a benchmark for the future research. Kyshakevych and Mazharov (2018) examined the efficiency of Ukrainian banks in 2017 using both CCR and BCC input-oriented DEA models. For the research 6 input and 5 output variables were chosen and split into 8 models (5 based on intermediation approach and 3 – on profitability approach) with 3-4 input and 2 output variables in each. The most efficient banks (100% efficient) under the CCR DEA model in 2017 were Raiffeisen Bank Aval, Financial Initiative, CIB Bank, VERNUM Bank, Settlement Center, Ukrainian Bank for Reconstruction and Development and Alpari Bank.

The summary of previous research papers that investigated the efficiency of commercial banks using the DEA method is provided in Table 3. Interestingly, most of the papers are using extended DEA models and prove the accuracy of the obtained results. Also, the majority of studies are input-oriented, which can be explained by the fact that bank managers have more control over input variables and can more easily influence them. Moreover, most of the papers used panel data for analysis, in order to ensure more accurate results.

Table 3

Summary of literature overview: banks efficiency measurement using DEA method

Author(s)	Target country	Research period	Method	Results
Řepková (2014)	Czech Republic	2001-2011	Dynamic DEA model, input-oriented	average CRS efficiency diverge from 80% to 92%; average VRS efficiency – 90-98%
Bod'a & Zimková (2015)	Slovakia	2002-2011	DEA SBM model, input-oriented	three theoretical approaches, used in the research paper, appeared to be complementary and gave almost the same results in terms of technical efficiency; the range of results is from 52% to 100% of efficiency
Yadav (2015)	Russia	2007-2014	CCR and BCC DEA models, input-oriented	banks are operating at decreasing returns to scale; CRS efficiency ranges from 6% to 53%, VRS efficiency – 39-63% during the years
Nițoi & Spulbăr (2016)	Romania	2005-2011	CCR DEA model, output-oriented; Tobit model, Simar and Wilson model, fractional logit model	high level of bank concentration leads to lower cost efficiency levels; technical efficiency ranges from 78% to 91%
Kyshakevych & Mazharov (2018)	Ukraine	2017	CCR and BCC DEA models, input-oriented	large banks (most of them are state-owned) have considerably higher VRS technical efficiency than other groups of banks; CRS efficiency ranges from 36% to 100%

Source: composed by the author

Analyzing chosen input and output variables (see Table 4), “total deposits” is the input variable used in most of the studies, the input variable “total expenses” was used in two studies; “total loans” and “interest income” are common output variables. All of the variables chosen are more from a macroeconomics perspective, instead of “total personnel costs”, which is more about the bank’s level and internal factor. When it comes to the number of

inputs and outputs, based on reviewed research papers, the optimal amount is two input variables and two output ones.

Table 4

Summary of literature overview: inputs and outputs

Variables \ Authors	Řepková (2014)	Boďa & Zimková (2015)	Yadav (2015)	Nițoi & Spulbăr (2016)	Kyshakevych & Mazharov (2018)
Input variables					
Total deposits	✓	✓	✓	✓	
Personnel costs	✓				✓
Operating expenses		✓			✓
Fixed assets				✓	✓
Interest expenses					✓
Output variables					
Total loans	✓	✓	✓	✓	✓
Interest income	✓	✓			✓
Other assets				✓	✓
Other income					✓
Net investments			✓		

Source: composed by the author

Taking into account previous scientific papers on the efficiency of Ukrainian and other Eastern European countries' banks, the current study implements the input oriented-oriented two-stage DEA-BCC model developed by Simar and Wilson (2007), which allows getting more accurate and reliable results.

2. The efficiency of Ukrainian commercial banks – an empirical analysis

2.1. An analytical overview of the Ukrainian banking sector

When considering the efficiency of banks in a certain country, it is highly important to understand the context in which these banks were forming and developing because the events that happen in the banking sector directly influence the activities of banks and lead to changes in efficiency indicators. That is why, in the frame of this bachelor thesis, an overview of the banking sector of Ukraine will be considered.

Despite the fact that the Ukrainian banking sector is relatively young, it has undergone a considerable amount of challenges and has its own ups and downs.

The Ukrainian banking sector was formed in 1991 based on the inadequate Soviet Union base. In the first years, it experienced a rapid increase in the number of banks, from 96 in 1991 to 230 in 1995, which was explained by low capital requirements and easiness to entry. (Davydenko, 2011)

Later, the banking sector has experienced four major crises: in 1998, in 2004, in 2008 and 2014-2016. The main factors that triggered these crises are both external and internal processes. (Rylova & Khmaryuk, 2014)

In general, the history of the Ukrainian banking sector can be divided into several phases (compiled by the author):

1. 1991-1998 – Formation phase

- 1991-1992 – re-registration of commercial banks from the USSR into Ukrainian
- 1992-1995 – the rapid increase in the number of commercial banks
- 1996 – monetary reform (introduction of hryvnia)
- 1998 – financial crisis

2. 1999-2008 – Improvement of regulatory mechanisms phase

- 2001 – the adoption of laws that regulate banking activities
- 2006-2007 – increase in banks with foreign capital
- 2008 – global financial crisis

3. 2009-2013 – Anti-crisis activities phase

4. 2014-2020 – Reformation phase

- 2014-2016 – the wave of banks bankruptcy and liquidation

- 2016 – nationalization of PrivatBank (the largest commercial private bank)
- 2016-2020 – activities that are focused on the stabilization of the banking system

The latest phase is the most relevant to the frame of current research, it needs more detailed considerations.

As a result of the tense political situation in 2014, Ukraine's economy has declined, and the national currency has devalued. This has become a big challenge for most banks in Ukraine, many of them have not been able to cope with the problems, so within a few years, almost half of the banks were liquidated by the National Bank of Ukraine (see Table 5).

(Rushchishin & Kostak, 2018)

Table 5

Main indicators of activity of Ukrainian banks during the period 2013-2018

Indicator	2013	2014	2015	2016	2017	2018
Number of active banks	180	163	117	96	82	76
<i>including</i> banks with foreign capital	49	51	41	38	38	37
<i>including</i> banks with 100% foreign capital	19	19	17	17	18	23
Banks' branches and other structural units	19290	15082	11871	10316	9489	8509
Assets (bln. hryvnya)	1278	1317	1254	1256	1334	1360
Banks' capital (equity) (bln. hryvnya)	193	148	104	124	161	155
ROA (%)	0.12	-4.07	-5.46	-12.6	-1.93	1.69
ROE (%)	0.81	-30.46	-51.91	-116.74	-15.84	14.67

Source: National Bank of Ukraine, 2019

Speaking about the ROA and ROE, which are also indicators of efficiency of usage of assets and equity of banks, the sharp and constant decrease in both measurements can be seen from the beginning of 2014 to the end of 2016. Starting from 2017 recovery can be noticed,

which exactly corresponds to the time frame of investigated crises. Improvements are also seen in assets and banks' capital.

During the 2014-2016 period for many commercial banks experienced a significant decrease in the quality of services such as banks delayed the time to pay off deposits or were doing it in parts, asked customers to extend their deposit account, etc. (Mudra, 2018). Also, during this period Ukrainian banking sector was challenged by distrust of banks among the citizens, devaluation of Ukrainian hryvnia against the US dollar for more than three times, inefficient way of refinancing of banks, after which a number of banks could not repay the debt and went bankrupt, poor risk management of commercial banks (Zolotar'ova & Halaganov, 2017).

The peaky point of this period becomes the process of nationalization and recapitalization of PrivatBank, which is the biggest commercial bank in the country and the most attractive to the citizens of Ukraine. The procedure was initialized at the end of 2016 and the main reason was the fact that the bank is not able to meet capital requirements (Barisitz & Lahnsteiner, 2017). Nationalization was conducted in order to protect the money of depositors, stabilize the bank as well as to prevent the whole banking system from collapsing (Horbal, Hoshovska & Poltavtseva, 2017).

During 2015 Oschadbank and Ukreximbank, which were the main state-owned banks, initiated the Eurobond restructuring procedure and experienced internal restructuring that involved changes in management structure (Ash, Gunn, Lough, Lutsevych, Nixey, Sherr & Wolczuk, 2017).

In 2015 happened the financial sector reform under which the Comprehensive Development Program for the Ukrainian Financial Sector until 2020 has been initiated. This program is aimed at closer EU integration, strengthening the transparency of disclosure

among the financial sector participants, improving the protection of rights of creditors, consumers, and investors. (Savchenko & Kovács, 2017)

During the program, the National Bank of Ukraine managed to achieve improvements in providing banks with conditions for free competition, implemented risk-oriented supervision, intensified the financial monitoring procedures, eased the foreign exchange restrictions, created conditions for the development of fintech. (*Zvit pro vykonannya Kompleksnoyi prohramy rozvytku finansovoho sektoru Ukrayiny do 2020 roku*, 2020)

The period of 2014-2018 was extremely tense to the banking sector of Ukraine. Under the influence of internal and external factors, a number of reforms were implemented focused on the stabilization of the situation and the creation of conditions for further development of the sector. They led to fluctuations in efficiency scores of commercial banks, which will be further investigated.

2.2. Data and methodology

To start with the data description, in order to overcome the selection bias, banks that were liquidated during the investigated period should also be included. The list of banks, the efficiency of which will be researched was formed based on the top 25 banks rankings on the total assets each year. This study will use unbalanced panel data of 26 Ukrainian commercial banks over the 5-year period, from 2014 to 2018. Chosen banks represented more than 70% of the total assets in each year from the investigated period. All the data were manually collected from the annual reports of chosen banks, taken on the banks' official websites. Annual reports are subject to an independent audit, which proves the reliability of data.

For the efficiency analysis, the DEA method will be applied. For the specifications of the DEA model, the input-oriented model was chosen, the author assumes that bank managers have much more abilities to control their inputs, rather than outputs. This approach was confirmed by many scholars (e.g. Nigmonov, 2010; Titko, Stankevičienė & Lāce, 2014;

Fethi & Pasiouras, 2010). BCC model will be used because the CCR model is based on the CRS assumption, which claims that DMUs should operate on the optimal scale, which is not applicable to the banking sector, where we can notice imperfect competition and banking regulations (Titko, Stankevičienė & Lāce, 2014).

For the purpose of illustrating the principle of the DEA BCC model, the following hypothetical example will be considered (see Table 6):

Table 6

Data for the DEA BCC hypothetical example (in mln. euros)

Decision-making unit (DMU)	Input variables		Output variables	
	Personnel expenses	Interest expenses	Total loans	Interest income
DMU ₁	5	24	125	16
DMU ₂	2	10	97	7
DMU ₃	11	53	210	10
DMU ₄	8	36	166	12

Source: compiled by the author

In the example, data about four DMUs (assume banks, in this case) are presented. Using the formula of input-oriented DEA BCC model, the linear programming model for accessing the efficiency of DMU₁ will be (see Model 5):

$$\text{Maximize: } 125u_1 + 16u_2 - u_0$$

$$\text{Subject to: } 5v_1 + 24v_2 = 1$$

$$125u_1 + 16u_2 - 5v_1 - 24v_2 - u_0 \leq 0 \quad (\text{Model 5})$$

$$97u_1 + 7u_2 - 2v_1 - 10v_2 - u_0 \leq 0$$

$$210u_1 + 10u_2 - 11v_1 - 53v_2 - u_0 \leq 0$$

$$166u_1 + 12u_2 - 8v_1 - 36v_2 - u_0 \leq 0$$

$$u_r, v_i \geq \varepsilon$$

By solving this linear programming model, the efficiency of DMU₁ is 100%.

As DEA is originally a tool for cross-sectional data, DEA efficiency scores will be computed year by year, to see the dynamics over the years. With regard to obtaining the average score for the period, such techniques as Window Analysis and Malmquist Productivity Index may be applied for efficiency scores, but as the average score for the period is not an objective of this study, they will not be calculated.

Speaking about the choice of input and output variables, there is no consensus among researchers about the best technique to identify the optimal set. As the DEA method is highly sensitive to the variables, and different combinations of variables lead to different efficiency scores, the step of choosing the variables is highly important and will mostly influence the final results. Most of the currently existing algorithms for defining the best combination are based on classical statistical concepts. Among the most frequently used are procedures that are based on Pearson correlation coefficient, partial correlation coefficients, principal component analysis (PCA), regression analysis, Kruskal-Wallis test, efficiency contribution measure (ECM), bootstrapping. Some of these methods propose forward stepwise variable selection and some – backward.

Among the research studies done particularly about the efficiency of commercial banks, the most popular techniques are based on Pearson's correlation coefficient (e.g. Titko, Stankevičienė & Lāce, 2014) and principal component analysis (e.g. Adler & Yazhemsky, 2010). Most of the recent papers start with a relatively large set of variables (around 5-7 for input and 5-7 for output), and by applying the aforementioned techniques, eliminate variables that will bias results.

In the current study, the Pearson's correlation coefficient approach will be used, because of several reasons. Firstly, as after calculating efficiency scores, additional manipulating techniques will be applied, it is recommended to keep primary variables, which will not be possible in the case of principal component analysis, which transforms variables

into principal components (PCs) as well as others methods for dimension reduction.

Secondly, this method easy in implementation and has a small run time. The essence of Pearson's correlation coefficient approach is in eliminating the highly correlated variables from the model one by one. Because repeating this method for each year separately will lead to a unique list of variables for each time point, all of the data will be merged for this analysis in order to minimize possible bias.

In Table 7 the author presents the list of potential input and output variables. The list was formed based on variables used in previous research papers taking into account the availability of data provided in annual reports. Even though some variables may be treated both as input and output ones, in this bachelor thesis this issue will not be considered.

Table 7

The initial list of input and output variables

Input variables		Output variables	
Input 1	Total deposits	Output 1	Loans
Input 2	Operating expenses	Output 2	Securities
Input 3	Fixed assets	Output 3	Interest income
Input 4	Interest expenses	Output 4	Other income
Input 5	Personnel costs	Output 5	Total assets

Source: compiled by the author

Descriptive statistics of the initial set of input and output variables are provided in Table 8. It is interesting to notice that the standard deviation of all of the variables is high which indicates large variation in data.

Table 8

Descriptive statistics (in bln. hryvnya)

	Mean	Median	Minimum	Maximum	Std. Deviation
Total deposits	31.25	12.98	1.65	212.98	44.51
Operating expenses	1.55	0.7	0.06	14.97	2.56
Fixed assets	1.11	0.44	0.01	7.61	1.45
Interest expenses	2.93	0.84	0.03	29.36	5.33
Personnel costs	0.67	0.36	0.03	4.56	0.87
Loans	21.03	11.99	0.005	195.34	28.95
Securities	7.29	0.67	0	90.35	17.22
Interest income	4.6	2.07	0.008	31.36	6.56
Commission income	0.99	0.3	0.003	13.21	1.94
Total assets	42.59	19.46	2.96	274.93	60.2

Source: composed by the author

In order to find the optimal set of variables, the correlation analysis was conducted separately for the list of input and output variables (see Table 9, Table 10).

Table 9

Correlation matrix for input variables

	Total deposits	Operating expenses	Fixed assets	Interest expenses	Personnel costs
Total deposits	1				
Operating expenses	0.75*	1			
Fixed assets	0.8*	0.71*	1		
Interest expenses	0.94*	0.74*	0.73*	1	
Personnel costs	0.91*	0.8*	0.79*	0.86*	1

Note: * correlation is significant at 0.01 level

Source: compiled by the author

Table 10

Correlation matrix for output variables

	Loans	Securities	Interest income	Commission income	Total assets
Loans	1				
Securities	0.42*	1			
Interest income	0.82*	0.72*	1		
Commission income	0.57*	0.65*	0.8*	1	
Total assets	0.86*	0.8*	0.94*	0.79*	1

Note: * correlation is significant at 0.01 level

Source: compiled by the author

From the correlation analysis of input as well as output variables, it is seen that the correlation between most of the variables is highly significant. After omitting strongly correlated variables one by one, the final list of input variables is operating expenses, fixed assets; and for the output variables: loans, securities. These variables will be used for computing efficiency scores using DEA.

Diving deeper into the methodology, it is important to mention that the traditional DEA method might provide biased results because of omitting several factors that may have a favorable or unfavorable impact on the efficiency score. That is why in the literature are widespread methods that propose two-stage DEA models that include so-called environmental variables. Typically, under the first stage is meant calculating classical DEA scores and under the second one – regressing these scores.

One of the relatively recent methods is one developed by Simar and Wilson (2007). The efficiency of this method was approved by many researchers and it is applicable to the study on banks (e.g. Stewart, Matousek & Nguyen, 2016).

Simar and Wilson (2007) proposed an algorithm that utilizes a bootstrapped truncated regression model as a second stage. In the frame of this bachelor thesis, this method will be used, that is why it requires more detailed consideration.

In original work authors propose two algorithms of implementation, both of them aim at improving the inference, but the second one is taking into account the bias term and considered to be preferred to use, according to the authors. That is why the second algorithm will be implemented.

The developed procedure can be described as follows (Simar & Wilson, 2007):

- Calculate the DEA efficiency score based on original data of inputs and outputs,
- With the help of the method of maximum likelihood, estimate $\hat{\beta}$ and $\hat{\sigma}_\varepsilon$,
- Compute a set of bootstrap estimates of n times $A = \{(\hat{\beta}^*, \hat{\sigma}_\varepsilon^*)_{n=1}^n$,
- Find a bias-corrected estimator $\widehat{\hat{\beta}}$ and original $\hat{\delta}$,
- Run the truncated regression,
- Compute set bootstrap estimates of n times $K = \{(\hat{\beta}^*, \hat{\sigma}_\varepsilon^*)_{n=1}^n$,
- Using bootstrapped values K and original estimates $\widehat{\hat{\beta}}$ and $\widehat{\hat{\delta}}$ to construct confidence intervals.

Based on suggestions of a research paper written by Berger and Mester (1997), as environmental variables were chosen the following ones: ROA (net profit/loss of the bank divided by total assets), ROE (net profit/loss of the bank divided by total equity), liquidity ratio (highly liquid assets divided by total deposits), the natural logarithm of total assets, the natural logarithm of the total number of branches, the natural logarithm of the age of the bank expressed as the number of years it existed till 2018 or year of liquidation.

2.3. Results and discussion

The analysis was performed in the RStudio environment using the “rDEA” package developed by Simm and Besstremyannaya (2020). In order to assure that Simar and Wilson (2007) algorithm gives more precise and reliable results, two models with the same specifications were run: traditional DEA and Simar and Wilson (2007) two-stage DEA.

The results of the efficiency scores of Ukrainian commercial banks in the period 2014-2018, that are calculated using the traditional input-oriented DEA-BCC model, are shown in Table 11. When analyzing obtained scores, it is important to highlight that several

banks demonstrate a 100% efficiency, which may be a signal that results are biased especially when considering the context of the banking sector of Ukraine in this period.

Table 11

Efficiency scores, computed with traditional DEA

Bank	2014	2015	2016	2017	2018
PrivatBank	1	1	1	1	1
Ukreximbank	1	1	1	1	1
Delta Bank	1	N/A	N/A	N/A	N/A
ING Bank Ukraine	1	1	1	1	1
Rodovid Bank	1	1	1	N/A	N/A
Oschadbank	0.8237	0.6171	1	1	1
Citibank	0.2867	0.7243	1	1	1
OTP Bank	0.4395	0.4684	0.8129	0.9359	1
Alfa Bank	0.5756	0.6265	0.7164	0.4668	1
Ukrgasbank	0.3306	0.6394	0.6322	0.5878	1
Raiffeisen Bank Aval	0.6928	0.3824	0.3704	0.4079	1
ProCredit Bank	0.2742	0.3198	0.3672	0.7932	1
Crédit Agricole	0.4435	0.4449	0.5127	0.6264	0.6792
Prominvestbank	1	0.638	0.5294	0.275	0.1643
First Ukrainian International Bank	0.6055	0.4069	0.41	0.3598	0.4156
Tascombank	0.6653	0.4954	0.2894	0.3262	0.26
Bank Vostok	0.4388	0.3862	0.3429	0.3187	0.5107
UKRSIBBANK	0.207	0.4635	0.4253	0.3613	0.4669
Megabank	0.3837	0.4063	0.41	0.4738	0.2155
Diamantbank	0.3372	0.3372	0.2976	N/A	N/A
BANK CREDIT DNEPR	0.2821	0.3044	0.2805	0.3028	0.3228
Universal Bank	0.2062	0.2535	0.2606	0.4223	0.2842
Ukrsotsbank	0.5098	0.3066	0.1008	0.1171	0.1017
Platinum Bank	0.1759	0.2504	N/A	N/A	N/A
KredoBank	0.2073	0.1881	0.1768	0.2071	0.2166
Fidobank	0.1224	0.1021	N/A	N/A	N/A

Note: N/A – no data, efficiency score is not available because the bank was in the phase of liquidation

Source: compiled by the author

After computing the efficiency scores under the two-stage Simar and Wilson DEA model taking into account environmental variables, new scores were obtained (see Table 12).

As it was recommended by the authors of the method, in the first loop 100 bootstrap iterations were done and in the second – 2000.

Table 12

Efficiency scores, computed with Simar and Wilson 2-stage DEA model

Bank	2014	2015	2016	2017	2018
Rodovid Bank	0.7915	0.7391	0.8704	N/A	N/A
ING Bank Ukraine	0.7528	0.7526	0.8702	0.8604	0.5634
PrivatBank	0.6391	0.7317	0.9555	0.5215	0.853
Ukreximbank	0.7648	0.7307	0.8242	0.725	0.6441
Delta Bank	0.6328	N/A	N/A	N/A	N/A
Oschadbank	0.5954	0.4826	0.6525	0.5256	0.8852
Citibank	0.2203	0.5977	0.8847	0.8587	0.5361
OTP Bank	0.3332	0.41	0.7169	0.82	0.6656
Alfa Bank	0.4451	0.4941	0.6203	0.3732	0.6788
Ukrgasbank	0.2592	0.5141	0.53	0.4667	0.748
Raiffeisen Bank Aval	0.5461	0.3023	0.3114	0.3079	0.812
Crédit Agricole	0.3425	0.3883	0.4446	0.5245	0.5155
ProCredit Bank	0.2191	0.2584	0.3071	0.6683	0.7616
Prominvestbank	0.6894	0.4989	0.4467	0.2312	0.1033
First Ukrainian International Bank	0.4813	0.3176	0.3563	0.2953	0.3077
Tascombank	0.5523	0.4084	0.2357	0.2692	0.1798
Bank Vostok	0.3474	0.3057	0.2436	0.2731	0.4061
UKRSIBBANK	0.1612	0.3981	0.3617	0.2742	0.3495
Megabank	0.3037	0.3183	0.3466	0.4137	0.1332
Diamantbank	0.2755	0.2758	0.2141	N/A	N/A
BANK CREDIT DNEPR	0.2234	0.2452	0.2042	0.2629	0.2212
Universal Bank	0.1624	0.1996	0.1812	0.365	0.1628
Platinum Bank	0.1478	0.2352	N/A	N/A	N/A
Ukrsotsbank	0.3905	0.2406	0.0876	0.0901	0.0631
KredoBank	0.1674	0.1508	0.1415	0.1738	0.1317
Fidobank	0.0916	0.0825	N/A	N/A	N/A

Notes: N/A – no data, efficiency score is not available because the bank was in the phase of liquidation; confidence interval for the efficiency scores is 0.05

Source: compiled by the author

The banks in Table 11 and Table 12 are ranked by the average efficiency score during the observed period. Due to the specifications of the DEA method, scores computed with arithmetic mean cannot be used as a metric for drawing conclusions, but they can show a general trend. As it can be noticed from the quick analysis of results from the Traditional DEA model and Simar and Wilson (2007) model, the rank positions of the banks, in general, remained the same.

Analyzing the obtained results of Simar and Wilson (2007) model several findings should be highlighted. First of all, as there are no previous studies that assessed the efficiency of individual Ukrainian commercial banks during 2014-2018, it is not possible to compare the results. But analyzing obtained scores in general, the downward trend during 2014-2016 can be seen, which is in line with previous research studies that investigated financial indicators of the banking sector's activities in this period. It is also approving the findings of Prymostka and Prymostka (2018) that in the period 2016-2018 there was a growth of efficiency.

Secondly, there is a large diversion between the highest and the lowest score, for example in 2018 the scores ranged from 6% to 89%. Taking the whole observed period, the range of efficiency scores was from 8% to 85%, which is an extremely high difference. Referring to the previous studies measuring banks' efficiency in Eastern European countries, none of the overviewed papers reported such difference between banks' efficiency.

Thirdly, assessing the technical efficiency scores allows defining the best-practice and worst-practice banks during the observed period. For example, in 2018 the bank with the highest efficiency was Oschadbank and with lowest – Ukrsotsbank. Noteworthy that banks with the highest and lowest scores changed their positions during the period. It is also interesting to notice that none of the banks achieved 100% technical efficiency.

In 2018 most of the banks demonstrate the highest efficiency scores. So, generally, it is possible to state that implemented policies of the National Bank of Ukraine contributed to

the stabilization of the technical efficiency of banks. But despite this, there are still many banks that operate on low efficiency and need improvements in their activities.

Speaking about PrivatBank that was nationalized in 2016, during 2017 was a rapid decrease in the efficiency, which was recovered to its previous values in 2018. In 2018 the Systemically important banks were PrivatBank, Oschadbank, and Ukreximbank. These banks demonstrated one of the highest efficiency scores in the investigated period, which is a positive factor.

Most of the banks that undergone liquidation had extremely low scores of efficiency, which may be evidence of the right policies of the National Bank of Ukraine. However, such banks as Delta Bank and Rodovid Bank started the procedure of liquidation with relatively high scores of efficiency. This may indicate that other factors contributed to the decision of the National Bank of Ukraine (e.g. cases of money laundering, fraudulent transactions).

To summarize, during 2014-2018, Ukrainian commercial banks experienced fluctuations in the technical efficiency, but, in general, a positive trend can be noticed during the years. Also, none of the banks was operating at a 100% level of technical efficiency.

Talking about the limitations of this work, the efficiency scores were calculated with only one set of variables. In order to optimize the results several sets of variables that will represent separate models should be considered (for example, models that follow intermediation, production, and profitability approaches). Moreover, the model built utilizes only 2 inputs and 2 outputs, which are perfect numbers for the current sample size, but increasing the number of variables while widening the list of banks analyzed will lead to more reliable results. Also, the thesis focused only on calculating technical efficiency, while measuring scale efficiency would allow analyzing the impact of the scale size on the efficiency of banks.

Conclusion

During the 2014-2016 years, the Ukrainian banking sector was affected by a financial crisis that significantly weakened it. The National Bank of Ukraine implemented a bunch of reforms aiming at stabilization of the situation. This bachelor thesis endeavors to appraise the technical efficiency levels of Ukrainian commercial banks during the period of crisis and the recovery phase.

The contribution of the thesis is twofold. From the theoretical perspective, the contribution is in developing an algorithm for choosing the most appropriate DEA model for the research of banks' efficiency, which includes extended DEA models that were developed during the recent years. Moreover, the author summarizes the studies about assessing the efficiency of banks in Eastern European countries using the DEA method, in terms of the methodology used as well as presents the list of most frequently applied input and output variables.

From the practical perspective, the author calculates the technical efficiency scores of the largest Ukrainian banks during the 5-years period, and in this way enriching the current set of studies. As was mentioned earlier, there are only a few academic papers that investigate the efficiency of individual Ukrainian banks using the DEA method. Also, the author applies the recently developed DEA model in combination with the technique for defining the optimal set of variables, at the time when none of the studies about the efficiency of Ukrainian banks used any of the extended DEA models.

In an attempt to cover the existing research gap that was formed due to the lack of studies about the efficiency of Ukrainian commercial banks, technical efficiency scores of 26 Ukrainian commercial banks during 2014-2018 were appraised using the Simar and Wilson (2007) two-stage DEA model. To sum up the empirical findings, generally, the analysis confirmed the influence of the 2014-2016 crisis on the efficiency of commercial banks. At

the same time, the activities that the National Bank of Ukraine implemented to stabilize the situation, positively affected the efficiency of banks during 2017-2018. The obtained results are in line with the findings of previous research papers.

The study has several limitations that should be taken into consideration. Firstly, the efficiency scores are calculated only with one set of variables. To optimize the results several sets of variables might be considered. Secondly, the thesis focused only on calculating technical efficiency, assessing scale efficiency will also allow analyzing the impact of the scale size on the efficiency of banks.

Although this bachelor thesis has several limitations, the provided results are reliable and presented findings, as well as considerations, can be used by the management of banks, policymakers or other parties that aim to understand the situation in the banking sector of Ukraine in terms of efficiency during 2014-2018 as well as to have an indicator for evaluation of the reforms implemented for stabilization of the situation in the banking sector.

Among the proposals for further study is the investigation of the relationships between banks' efficiency and their size, their ownership structure, the presence of foreign capital in their structure. Also, the recommendation is to identify the reasons for the large dispersion of technical efficiency scores between the banks. Lastly, the analysis that focuses on answering in what way the reforms influenced the efficiency scores can be done.

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