“Efficiency assessment of banking systems’ performance”

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ARTICLE INFO	Maxim Korneyev, Ivan Berezhniuk, Volodymyr Dzhyndzhoian, Natalia Nebaba and Sergiy Voytov (2022). Efficiency assessment of banking systems’ performance. *Banks and Bank Systems*, *17*(3), 72-88. doi:10.21511/bbs.17(3).2022.07
DOI	http://dx.doi.org/10.21511/bbs.17(3).2022.07
RELEASED ON	Thursday, 08 September 2022
RECEIVED ON	Monday, 11 July 2022
ACCEPTED ON	Thursday, 18 August 2022
LICENSE	This work is licensed under a Creative Commons Attribution 4.0 International License
JOURNAL	"Banks and Bank Systems"
ISSN PRINT	1816-7403
ISSN ONLINE	1991-7074
PUBLISHER	LLC “Consulting Publishing Company “Business Perspectives”
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
40	14	3

BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10,
Sumy, 40022, Ukraine

www.businessperspectives.org

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EFFICIENCY ASSESSMENT OF BANKING SYSTEMS' PERFORMANCE

Abstract

Globalization processes define the modern trends in world economic development, including both international financial markets and the banking systems of different countries. The study aims to evaluate the efficiency of the banking systems of Ukraine and 17 European countries in order to choose the appropriate measures, concerning its increasing. The Data Envelopment Analysis (DEA) was chosen as a tool for evaluating the efficiency of the banking systems; the calculations were made using the Banxia Frontier Analyst software. Also, the BBC and CCR models of linear programming were used to define the existing relationship between the studied indicators. As a result of the study, the groups of efficient and inefficient banking systems were identified, which allowed determining the existing reserves, possible managerial tools and decisions for improving the inefficient banking systems' performance. Besides, graphical interpretation of the current position (rank) of certain country bank system in relation to other countries' banking systems was presented. The developed approach is aimed at improving bank management at the macro level and enhancing the efficiency of banking systems.

Keywords assessment, banking system, bank management, bank efficiency, Data Envelopment Analysis

JEL Classification G21, G28, M10

Received on: 11th of July, 2022
Accepted on: 18th of August, 2022
Published on: 8th of September, 2022

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Conflict of interest statement:
Author(s) reported no conflict of interest

INTRODUCTION

The financial sector of any country occupies a central place in the process of its economic development. There is a positive relationship between the development of real and financial sectors, especially in terms of financial intermediation, which makes the financial sector very important for the development of any economy. Since banks are key players in the financial market in many countries of the world, the stability and efficiency of the banking system significantly affect the financial system and the economy as a whole.

Given this, ensuring stability and efficiency at the banking system level is impossible without using modern tools and technologies of bank management. In the banking sphere, a failure to formulate a clear concept of development leads to either lack of planning of activity at all or failure to observe logical interrelation between consecutive stages of the management decision-making process – analysis, planning, control, and regulation. The tools for evaluating the current state (efficiency of the analysis unit) and the possibility of comparison of the analysis unit with similar ones are of particular importance, since the absence of full systems of information support of the management process, lack of attention to system analysis, diagnostics and forecasting of activity on macro level can lead to making false managerial decisions.

http://dx.doi.org/10.21511/bbs.17(3).2022.07

The concept of efficiency is measured and can be defined as the relation of useful products to the total cost of the object. Evaluating the efficiency of a banking system allows the top management to control whether it has achieved the planned or rejected development and take appropriate corrective measures to ensure the achievement of the set goals. Besides, the assessment of the efficiency of the banking system and its comparison with the systems of other countries helps the central bank manage and regulate banking activity more efficiently in the country.

1. LITERATURE REVIEW

The concept of the efficiency of any system is complex and multifaceted. The concept of efficiency as a general indicator for all kinds of business was first formulated in the early works of Edgeworth (1881) and Pareto (1927); its empirical realization was implemented in the work of Shepard (1953). Efficiency in economics is interpreted as the maximum potential ratio between input and output of the product development process, which shows the optimal distribution of available resources, which allows for reaching the maximum potential (Cvilikas & Jurkonyte-Dumbliauskiene, 2016; Pimonenko et al., 2017; Prokopenko et al., 2020). Danylyshyn and Bohdan (2022) investigated the efficiency of the financial sector during the wartime. Efficiency of the tax system was investigated by Danylyshyn et al. (2021).

According to Drucker (1963), efficiency can be defined as the ability of an organization to achieve results with minimal input resources. According to Jaouadi and Zorgui (2014), efficiency summarizes the idea of production in the best way, which means that efficiency is focused on using the minimum costs to get the best result. In other words, the optimized use of resources produces the best products at lowest prices. In management, efficiency can be considered a study of the optimized use of internal factors of a firm. On the other hand, the concept of efficiency results in the efficiency of factors and achievement of the goal, not considering the way and optimized use of resources.

Determining the efficiency of banks and banking systems remains a discussion among researchers. To determine bank efficiency, first, it is necessary to decide on the nature of approaches to understanding banking activity. Two basic approaches are widely used in the literature on banking theory, namely production and intermediary (Sealey & Lindley, 1977).

Berger and Humphrey (1997) argue that none of these two approaches is perfect because they cannot fully cover the dual role of financial institutions as providers of account services and financial intermediaries. They note that the production approach may be somewhat better for assessing the efficiency of banking outlets, and the intermediary approach may be more acceptable for evaluating financial institutions as a whole.

Considering the importance of financial institutions, many studies are aimed at assessing the activity of banks in different countries (Buriak et al., 2015; Dao & Nguyen, 2020; Erdkhadifa et al., 2022; Henriques et al., 2018; Irawati et al., 2019; Koziuk, 2017; Kozmenko et al., 2014; Law, 2021; Luong & Nguyen, 2021; Mursalov, 2020; Nguyen et al., 2021; Polyakov et al., 2020; Rekunenko et al., 2022). Among the methods for estimating the efficiency of banks, there are efficiency frontier techniques. For example, Berger and Humphrey (1997) analyzed 130 studies that examined 21 different countries to measure the efficiency of banks using parametric and non-parametric methods, which shows the importance of efficiency studies in this sector. Haralayya (2021) investigated top six implementation challenges of core banking technology.

Morozova et al. (2019) assessed the banking system's efficiency under the influence of the capital concentration factor. The authors have reported the capital efficiency as the dependence of the total income of banks in Ukraine in terms of the volume of their capital and liabilities based on constructing the models of the nonlinear Kobb-Douglas regression for the data of the Ukrainian banks. Besides, bank efficiency was calculated based on actual data and standard values for each factor as a measure in the Euclidean space to the limit of efficiency groups. Kozmenko and Vasyl'yeva (2008) considered the impact of increasing the efficiency of commercial banks on the improve-

ment of the financial and credit mechanism to ensure the innovative development of Ukraine. Also, Kozmenko and Belova (2015) investigated the establishment of systemically important banking institutions as a foundation of stabilization measures of the country's economy. Leonov et al. (2014) analyzed the impact of stock market development as an alternative to households' savings allocation in banks.

Some scientists, such as Kuzmenko and Koibychuk (2018), analyzed the efficiency of the Ukrainian banking system and the efficiency of the banking system in the context of gender policy. The general indicator of the banking system's efficiency was constructed using relative normalization and Harrington's desirability function. The impact of gender policy indicators on the efficiency of the banking system was determined using correlation-regression and factor analysis tools.

Tsegaye (2018) examined the impact of interest rate spread on the banking system's efficiency in South Africa from the 1st quarter of 2000 to the 3rd quarter of 2017 using a non-linear autoregressive system of distributed objectives. The results of the study show that economic growth and real exchange rates are important factors that positively affect the banking system's efficiency, and nonperforming loans impede the efficiency of the banking system in South Africa. Zhuravka et al. (2020) profoundly studied the impact of the banking system on macroeconomic growth in Nigeria, i.e. wages demand, taxes, and entrepreneurship development.

Instead, Svytalkova (2014) and Yarovenko et al. (2021) note that non-parametric methods are more adequate than parametric models for ranking the efficiency of banking institutions. At the same time, according to Wanke et al. (2016), Data Envelopment Analysis (DEA) is the main non-parametric technique presently used for efficiency assessment. This empirical mechanism, developed by Charnes et al. (1978), is based on mathematical methods for measuring the efficiency of a single group of decision-making units that use the same input and output data. By transforming the programming task with endless solutions into an approach to linear programming, DEA identifies the most influential business units and indicates what the inefficient units should do to become efficient. In other words, DEA allows defining the best practices from the point of view of efficiency.

The first study the DEA applied to financial institutions was Sherman and Gold's (1985) study, which assessed 14 bank branches. These authors have confirmed that traditional efficiency measurement methods, such as profitability and transaction costs, have not been so acceptable as they did not take into account the complexity of each branch's operations and did not consider the numerous results generated by multiple inputs. After this research, the banking sector became one of the main areas of interest for DEA application.

Despite the high popularity of DEA in the research aimed at measuring bank efficiency in recent years, there are no scientific works aimed at analyzing the banking system's efficiency in Ukraine by this method. Besides, there are no studies that reflect the effectiveness of the Ukrainian banking system among the bank systems of European countries, which has caused the choice of the research topic.

2. METHODS

To calculate the efficiency of bank systems, it is expedient to use Banxia Frontier Analyst software. This software is a tool that allows making calculations using the Data Development Analysis (DEA) technology. Throughout the world, DEA is used to assess the effectiveness of homogeneous object systems dealing with the same activity types and using the same resources. At the same time, efficiency is understood by the ratio of the value of input parameters to the sum of the values of output parameters.

DEA is based on using linear programming to construct a non-parametric linear surface (production line) based on the existing data. Performance evaluation is then conducted concerning this surface or production line. After the calculations, a comparative peer-to-peer process is undertaken, and future potential for improving the evaluation event for inefficient units is assessed. The following methodological approach is reasonable for assessing the efficiency of the banking system of Ukraine and the European countries (based on DEA analysis), which provides:

http://dx.doi.org/10.21511/bbs.17(3).2022.07

- construction of BCC model of linear programming of conditional input minimization;
- construction of CCR model of linear programming of conditional output maximization.

Mathematical formalization of constructing input-oriented BCC model of linear programming of conditional inputs and output-oriented CCR model of linear programming of the maximal ratio of conditional outputs with constant scale efficiency is as follows:

$$\max\theta = \frac{\sum_i u_i w_i y_i}{\sum_i v_i w_i x_i}, \begin{cases} \dfrac{\sum_i u_i w_i y_i}{\sum_i v_i w_i x_i} \le 1, \\ \min w_i \le w_i \le 100\%, \\ x_i \ge 0, y_i \ge 0 \end{cases} \quad (1)$$

where θ – the level of the country's banking system efficiency; u_i – specification of an econometric model of dependence of the country's banking system's efficiency on the category of conditional outputs; y_i – i-th specification of conditional outputs; v_i – specification of an econometric model of dependence of the country's banking system's efficiency on the category of conditional inputs; x_i – i-th specification of conditional inputs.

Conditional inputs and outputs for DEA analysis should be determined using the main component method, which involves studying the relationships between the investigated indicators. It can reveal hidden indicators (factors) responsible for the existence of linear statistical relations (correlations) between them. Besides, the determination of more influential factors in the conditions of conducting the research of factors among the main chosen indicators, as well as the detection of statistical connection, determine the substantiation of the conclusions concerning the efficiency of certain influences on the investigated system.

3. RESEARCH RESULTS AND DISCUSSION

The combination of selected factors that influence the efficiency of the Ukrainian banking system is given in Appendix A. To identify the relevant values of the indicators, i.e., to determine the practicality of their inclusion in the DEA analysis model, the main component method in the program complex Statistica 8.0 is used.

Implementing the main component method involves selecting variables for analysis and their division into main and auxiliary ones. The main variables in Appendix A are those that directly characterize the banking system: Bank regulatory capital to risk-weighted assets (%), Bank capital to total assets (%), Bank concentration (%), Bank cost to income ratio (%), Bank credit to bank deposits (%), Bank deposits to GDP (%), Bank net interest margin (%), Bank nonperforming loans to gross loans (%), Bank return on assets (%, after tax), Bank return on equity (%, after tax), Bank Z-score, Central bank assets to GDP (%), and Provisions to nonperforming loans (%). Auxiliary factors include macro-environment factors: Broad money (% of GDP), GDP (current USD), billion, GDP per capita (current USD), thousand, Gross domestic savings (% of GDP), Inflation, GDP deflator (annual %), Monetary Sector credit to the private sector (% GDP), Credit to government and state-owned enterprises to GDP (%), Financial system deposits to GDP (%).

According to calculations, the scree plot was obtained (see Figure 1).

Figure 1 shows that of the 13 main components offered by the program, it is advisable to select 5 or 6. To finally determine the number of principal components of final calculations, the values of factors should be analyzed (Table 1).

According to Table 1, only the factors with their own values larger than one should be chosen, i.e., in this case, it is the first five factors. These five selected factors describe the quality of the representation of received data by 88.9%. Having left only five main components in the analysis, a table of coordinates of the initial factors in the space of the new allocated elements will be obtained (Table 2).

According to Table 2, it is necessary to highlight the variables (observations) with the maximum (absolute) value of the factor coordinates for these factors. The total value of the factor load of the variable

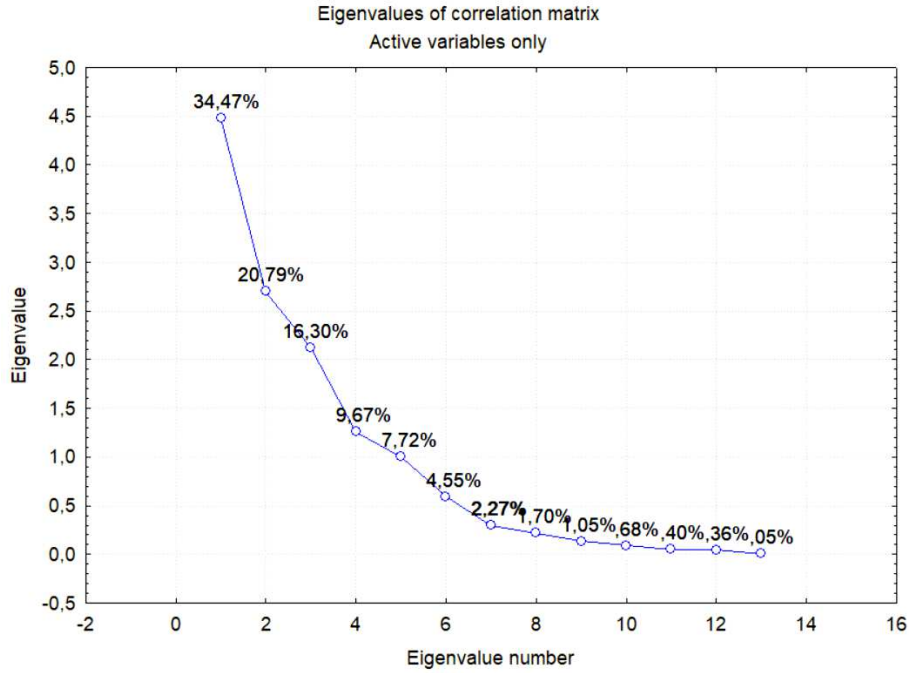

Figure 1. Scree plot based on principal component analysis results

Table 1. Values of factors based on principal component analysis results

Value number	Eigenvalues of correlation matrix and related statistics Active variables only			
	Eigenvalue	% Total variance	Cumulative Eigenvalue	Cumulative %
1	4.480584	34.46603	4.48058	34.4660
2	2.703168	20.79360	7.18375	55.2596
3	2.118740	16.29800	9.30249	71.5576
4	1.256565	9.66589	10.55906	81.2235
5	1.003208	7.71698	11.56226	88.9405
6	0.590979	4.54599	12.15324	93.4865
7	0.295502	2.27309	12.44875	95.7596
8	0.220501	1.69616	12.66925	97.4557
9	0.136453	1.04964	12.80570	98.5054
10	0.088289	0.67915	12.89399	99.1845
11	0.051541	0.39647	12.94553	99.5810
12	0.047387	0.36452	12.99292	99.9455
13	0.007083	0.05448	13 000001	100.0000

with any factor indicates that the variable is more strongly associated with this factor; that is, the larger the value of the factor coordinate of the variable, the better the variables show the structure represented by this factor. The coordinates are displayed for both main and auxiliary variables.

As can be seen from Figure 2, the first factor axis, corresponding to its own value 4.48, most closely correlates with the following major variables: x_{15} – Bank return on assets (–0.91); x_{16} – Bank return on equity (–0.84); x_{11} – Bank credit to bank deposits (0.72); x_{17} – Bank Z–score (–0.69); x_{12} – Bank deposits to GDP (0.61); x_{21} – Provisions to non-performing loans (0.57); x_{18} – Central bank assets to GDP (0.55); and the next auxiliary: x_{19} – Credit to government and state-owned enterprises to GDP (0.70); x_7 – Monetary sector credit to private sector (0.65); x_1 – Bank regulatory capital to risk-weighted assets (%); and auxiliary variables: x_2 – Broad money (0.65); x_{20} – Financial system deposits to GDP (0.61); x_5 – Gross domestic savings (–0.54).

Based on the selected factors, a table of source data for all countries of Europe and Ukraine was formed (Appendix C, Figure C4).

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Table 2. Table of coordinates of output factors

Variable	Factor coordinates of variables based on correlations Active and Supplementary variables				
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Bank capital to total assets (%)	–0.652364	–0.591412	–0.300554	0.161193	–0.067110
Bank concentration (%)	–0.493599	–0.538609	0.116360	–0.276755	0.562959
Bank cost to income ratio (%)	–0 366806	–0.581171	–0.489826	–0.213551	–0.311565
Bank credit to bank deposits (%)	0.715404	–0.553446	0.098489	0.203279	0.153286
Bank deposits to GDP (%)	0.611078	–0.225024	0.352513	0.384303	–0.511426
Bank net interest margin (%)	–0.185239	0.333912	–0.118790	0.770960	0.284730
Bank non-performing loans to gross loans (%)	0 040267	0 586773	–0.724964	0.001677	0.231803
Bank return on assets (%, after tax)	–0.908794	–0.034004	0.074676	0.116914	–0.164953
Bank return on equity (%, after tax)	–0.847542	0.336503	0.061087	–0.060210	–0.277524
Bank Z-score	–0.694661	0.603368	0.027443	0.131108	–0.107947
Central bank assets to GDP (%)	0.549991	0.348966	–0.492771	–0.422626	–0.205121
Provisions to nonperforming loans (%)	0.572433	0.022383	–0.672559	0.201473	–0.012253
Bank regulatory capital to risk-weighted assets (%)	–0.314180	–0.558642	–0.629340	0.267030	–0.082125
*Broad money (% of GDP)	0.646483	–0.251523	0.366512	0.333021	–0.485819
*GDP (current USD), billion	0.359547	–0.282276	0.088848	0.498554	–0.477522
*GDP per capita (current USD), thousand	0.387628	–0.219194	0.033196	0.477506	–0.485038
*Gross domestic savings (% of GDP)	–0.543896	–0.051566	0.437129	–0.211253	0.468039
*Inflation, GDP deflator (annual %)	0.287743	0.225950	0.394953	–0.381142	0.242265
*Monetary sector credit to private sector (% GDP)	0.647523	–0.497931	0.375839	0.279474	–0.181646
*Credit to government and state-owned enterprises to GDP	0.702370	0.198613	–0.456175	0.288677	–0.158809
*Financial system deposits to GDP (%)	0.611078	–0.225024	0.352513	0.384303	–0.511426

Note: * Supplementary variable.

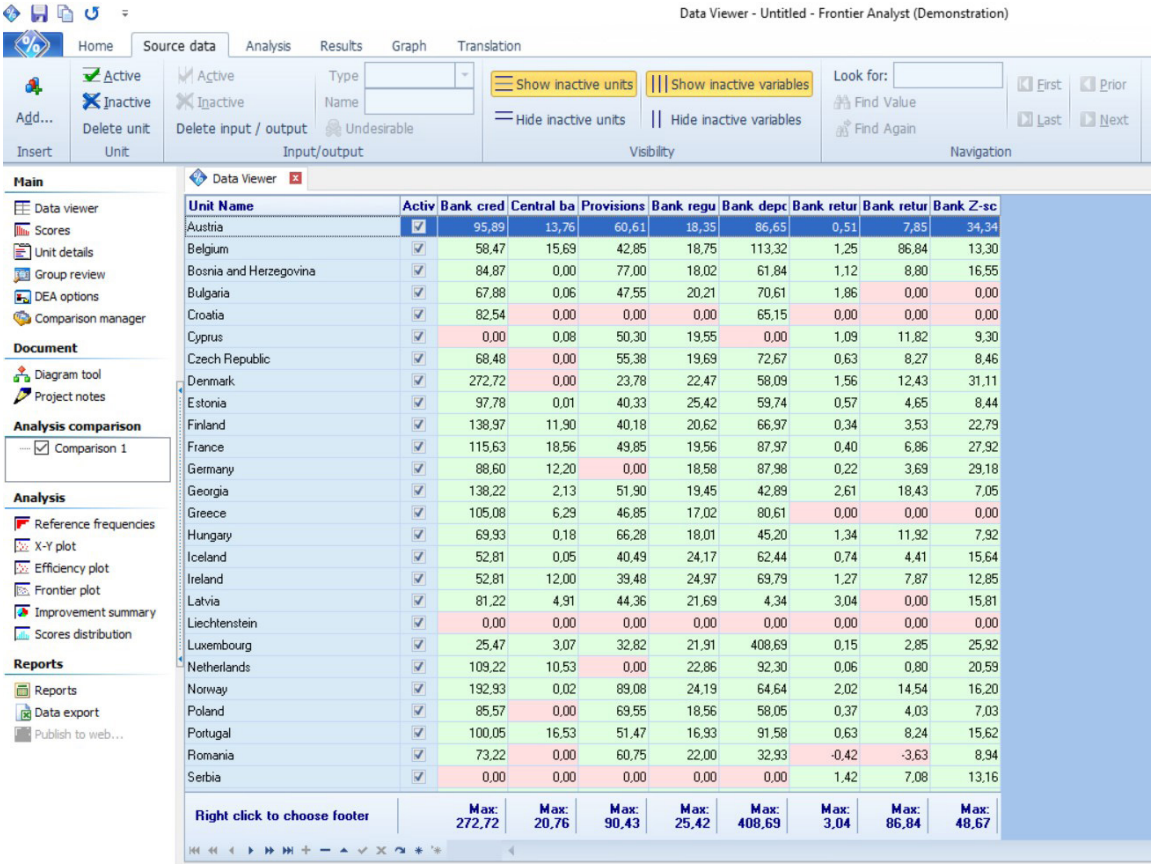


Figure 2. Input of basic data for assessing the efficiency of the banking sector in Europe and Ukraine as of 2020

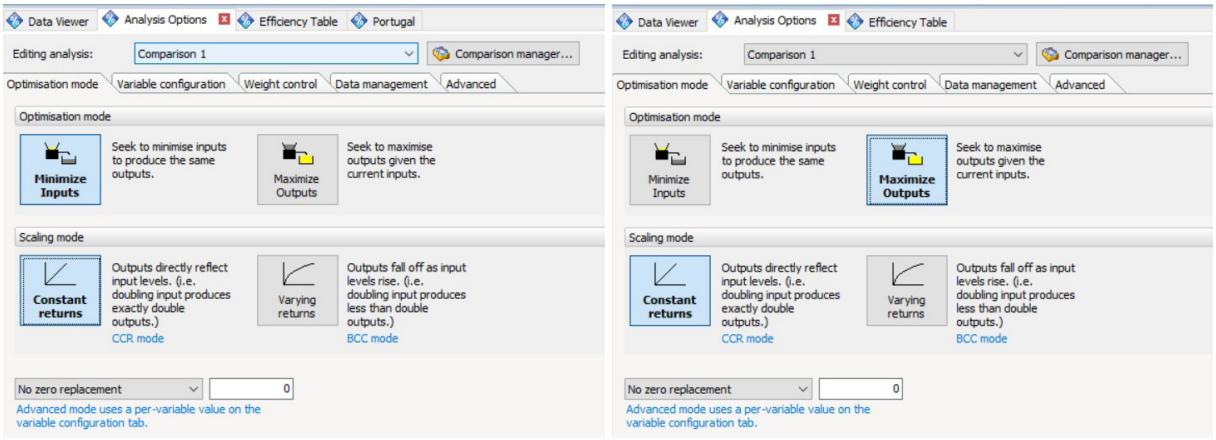


Figure 3. Window for selecting for building an input-oriented BCC model and the output-oriented CCR model

The next step of the proposed methodical approach to evaluating the efficiency of the banking system in Ukraine and the European countries is the direct realization of formula (1).

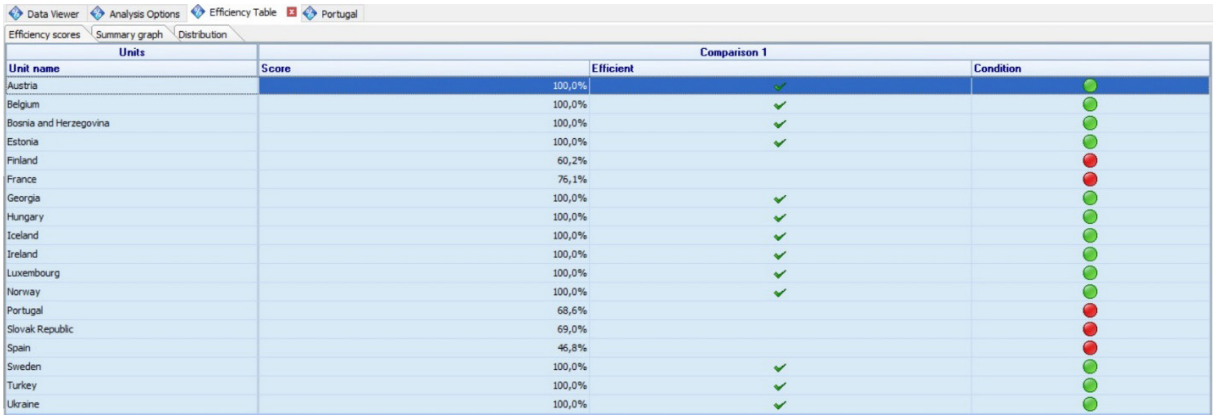
The source data for calculations were given for 32 European countries and Ukraine (Appendix B). Still, based on the fact that not all the indicators were presented for all selected countries as of 2020, Banxia Frontier Analyst program selected only 18 countries (including Ukraine) for calculations.

Figure 4 shows the results of the calculations and determination of the functioning efficiency level for the banking systems of the selected countries.

According to the data received, the banking systems of only five European countries showed their inefficiency: Finland (60.2% of efficiency from the standard banking system), France (76.1%), Portugal (68.6%), Slovakia (69%), and Spain (46.8%). Other countries that participated in the analysis showed 100% efficiency; that is, their effectiveness is either at the same level as the standard or higher than the standard. Ukraine also has an efficient banking system, according to the calculations.

The distribution graph (Figure 5) provides a visual indication of the range of efficiency estimates and the number of countries with their points in each range. Thus, one country is in the range of 41-50, one in 51-60, two in 61-70, 1 in 71-80, and 13 countries in the efficient range, that is, they are 100% efficient.

Having defined efficiently working objects of the research in the range of 17 European countries and Ukraine, according to the input-oriented BCC model of conditional inputs minimization,



Units	Comparison 1		
Unit name	Score	Efficient	Condition
Austria	100,0%	✓	
Belgium	100,0%	✓	
Bosnia and Herzegovina	100,0%	✓	
Estonia	100,0%	✓	
Finland	60,2%		
France	76,1%		
Georgia	100,0%	✓	
Hungary	100,0%	✓	
Iceland	100,0%	✓	
Ireland	100,0%	✓	
Luxembourg	100,0%	✓	
Norway	100,0%	✓	
Portugal	68,6%		
Slovak Republic	69,0%		
Spain	46,8%		
Sweden	100,0%	✓	
Turkey	100,0%	✓	
Ukraine	100,0%	✓	

Figure 4. Functioning efficiency of banking systems of 17 European countries and Ukraine as of 2020, calculated using the DEA BCC model

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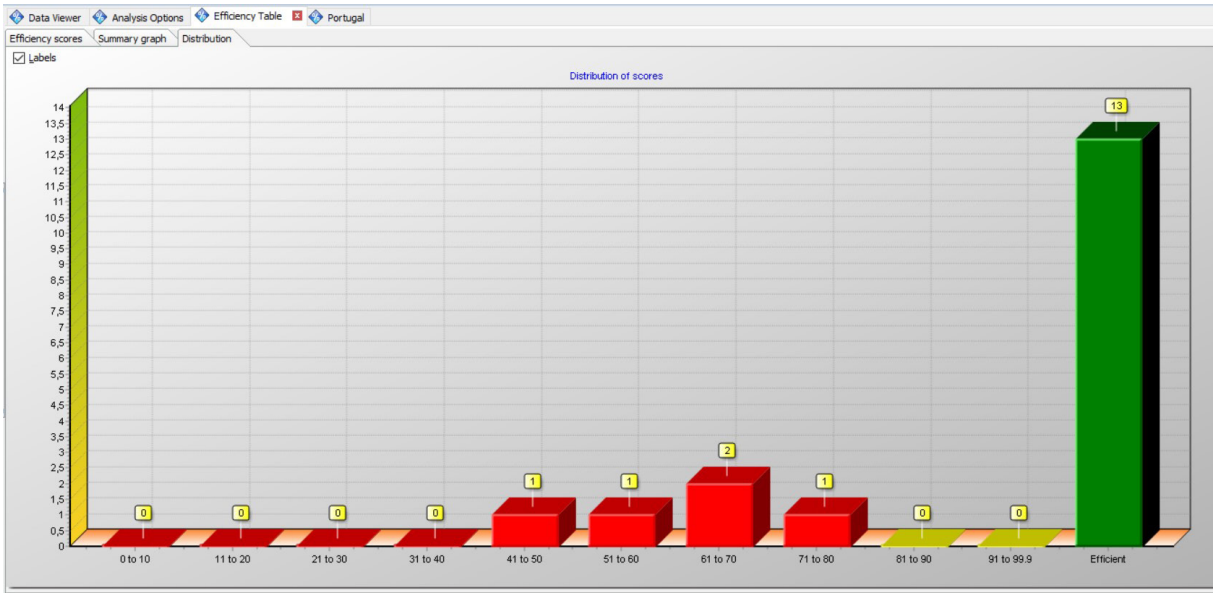

Figure 5. Distribution graph of assessing the efficiency of banking systems of 17 European countries and Ukraine as of 2020 for the DEA BCC model

the available reserve and potential for growth of banking systems' efficiency for the aggregate of analyzed countries will be established (Figure 6).

According to Figure 8, it can be concluded that the reduction of indicators chosen in the analysis as inputs to the model will, in aggregate, lead to improved efficiency of banking systems in the analyzed countries: Reduction of Central bank assets to GDP (%) – by 33.13%; Bank credit to bank deposit (%) – by 22.3%; Provision to nonperformance loans (%) – by 22.29%; Bank regulatory capital to risk-weighted assets (%) – by 17.89%. And the growth of the latest indicators, which are the model outputs, will also contribute to improving the efficiency of the banking systems of selected countries: Bank return on assets (%, after tax) – by 0.56%; Bank Z-score – by 3.84%.

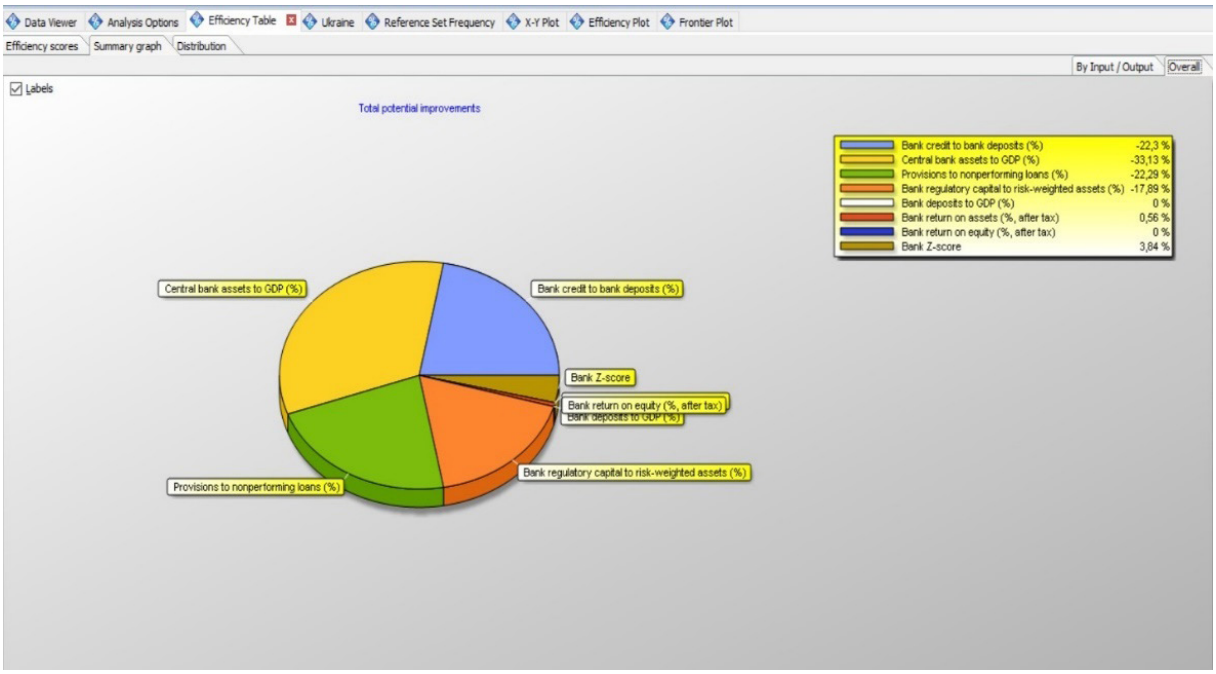

Figure 6. Potential for improving the efficiency of banking systems in 17 European countries and Ukraine as of 2020 for the DEA BCC model

Data Viewer | Analysis Options | Efficiency Table

Efficiency scores | Summary graph | Distribution

Units	Comparison 1		
Unit name	Score	Efficient	Condition
Austria	100,0%	✓	
Belgium	100,0%	✓	
Bosnia and Herzegovina	100,0%	✓	
Estonia	100,0%	✓	
Finland	60,2%		
France	76,1%		
Georgia	100,0%	✓	
Hungary	100,0%	✓	
Iceland	100,0%	✓	
Ireland	100,0%	✓	
Luxembourg	100,0%	✓	
Norway	100,0%	✓	
Portugal	68,6%		
Slovak Republic	69,0%		
Spain	46,8%		
Sweden	100,0%	✓	
Turkey	100,0%	✓	
Ukraine	100,0%	✓	

Figure 7. Efficiency of banking systems in 17 European countries and Ukraine as of 2020 calculated based on the DEA CCR model

Let us discuss in detail the analysis of inefficient banking systems using the information contained in the banking systems concerning the potential improvement of their operation, standard comparison, reference materials, and incoming or outgoing data on separate banking systems (Appendix C). The data in Appendix C for countries with inefficient banking systems show that each country should reduce the value of input indicators, and only Spain should increase the value of Bank Z-score.

Let us make similar calculations for the output-oriented CCR model of linear programming maximization of the ratio of conditional outputs with constant scale efficiency (Figure 7).

The calculation data for the output-oriented CCR model confirms the results of the settlements on the BCC model of DEA analysis, since the same countries have an inefficient banking system and the exact significance of this inefficiency. The distribution graph of assessing the efficiency of banking systems of 17 European countries and Ukraine as of 2020 for the CCR model of DEA (Figure 8) also confirms the data obtained in the calculation for the first model.

Figure 9 shows the possible ways of improving the efficiency of banking systems in those countries where banking systems were identified as inefficient.

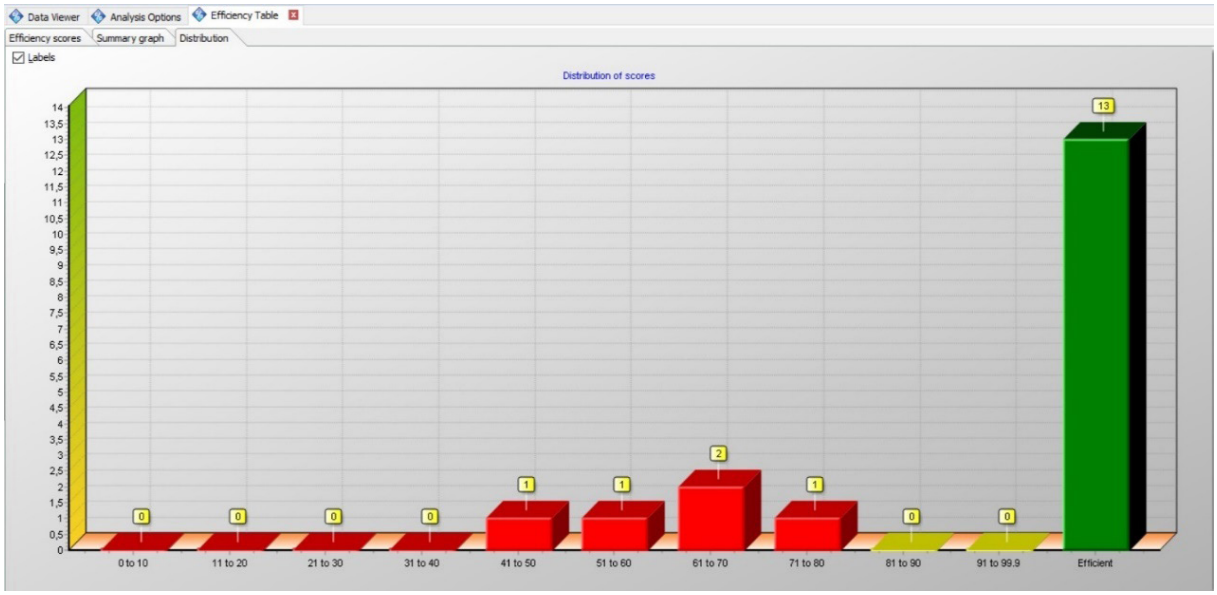

Figure 8. Distribution of assessments of the banking system's effectiveness in 17 European countries and Ukraine as of 2020 for the DEA CCR model

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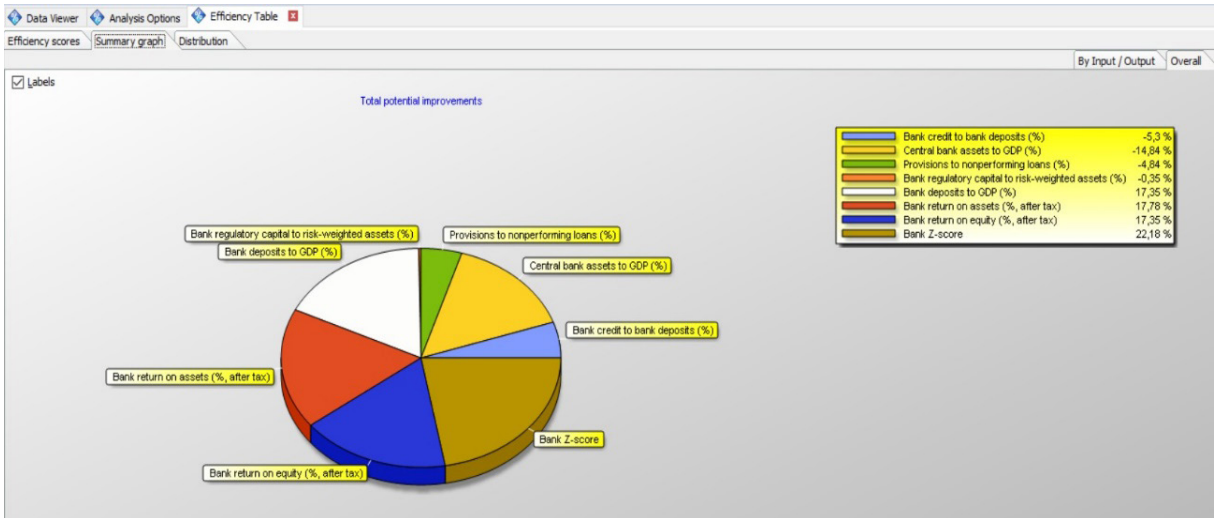

Figure 9. Potential for improving the efficiency of banking systems in 17 European countries and Ukraine as of 2020 for the DEA CCA model

The analysis data for the CCR model show the need to change both input and output indicators of the model. As for the input indicators, it is necessary to reduce the indicator of Bank credit to bank deposits (%) to 5.3% (in general in the countries with inefficient banking systems), Central bank assets to GDP (%) to 14.84%, provisions to non-performing loans (%) to 4.84%, Bank regulatory capital to risk-weighted assets (%) – only to 0.35%. Instead, output indicators need to grow (since the model was aimed at output maximization): The indicator bank deposit to GDP (%) to 17.35%, Bank return on assets (%, after tax) to 17.78%, Bank return on equity (%, after tax) to 17.35%, and Bank Z-score to 22.18%.

A comparison of the available reserves and the potential growth in the efficiency of banking systems in the countries whose banking systems were found to be inefficient according to the analysis results under both DEA analysis models are presented in Table D1 of Appendix D. The table presents an in-depth interpretation of the feasibility of activating certain areas of strategic banking systems for countries with inefficient banking systems as a result of the analysis.

CONCLUSION

The aim of the study was to assess the efficiency of the banking systems of Ukraine and 17 different European countries in order to select appropriate measures and tools to improve it. The DEA was utilized as the efficiency assessment instrument of the banking systems and the computations were made using the Banxia Frontier Analyst software.

As a result of the study, an input-oriented BCC model and output-oriented CCR model were constructed. At the same time, conditional inputs and outputs were calculated based on the administrative fold of the efficiency parameters of the functioning of banking systems. During the study, the groups of efficient and inefficient bank systems were defined, existing reserves and the potential for efficiency improvement for countries with inefficient bank systems were identified. The graphic interpretation of the current position of distinct bank systems relative to similar systems of other countries was further illustrated. The results can be used to improve the bank supervision based on assessing bank systems efficiency of different countries and their comparison, as the proposed method is aimed at improving bank management at the macro level. This approach allows for a comparative analysis of efficiency; building a visualization of weights for further information activity; carrying out the more effective distribution of available resources; finding the information needed for developing a planning strategy, etc. All of the above can be used by the top management of a bank in the process of developing and implementing strategic and tactic management decisions.

AUTHOR CONTRIBUTIONS

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APPENDIX A

Table A1. Factors of influence on the efficiency of the Ukrainian banking system for 2000–2020

Ukraine	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	x_{18}	x_{19}	x_{20}	x_{21}
2000	15.50	17.95	32.38	658.34	24.66	27.50	10.78	16.20	92.94	67.95	80.93	11.02	6.72	29.60	2.10	13.36	7.15	12.37	1.60	11.02	38.40
2001	20.70	21.67	39.31	807.80	23.19	10.20	12.60	15.60	83.56	75.00	88.99	12.53	5.28	25.10	1.11	8.86	5.90	10.13	2.10	12.53	39.20
2002	18.00	27.82	43.96	911.91	24.43	5.25	17.03	14.70	76.16	62.95	87.06	16.70	6.49	21.90	1.15	8.54	7.34	8.81	2.81	16.70	37.00
2003	15.20	34.37	52.01	1087.79	24.44	8.16	23.70	12.30	54.66	53.50	85.30	22.95	8.05	28.30	2.67	17.83	8.08	7.22	3.16	22.95	22.30
2004	16.80	35.16	67.22	1416.60	28.51	15.31	24.29	13.80	63.00	48.34	90.41	24.04	8.27	30.00	1.90	11.16	9.19	5.29	2.67	24.04	21.10
2005	15.00	42.44	89.24	1894.47	23.32	24.10	31.08	12.40	61.91	47.95	86.09	30.07	7.63	5.60	2.04	13.18	7.27	2.39	2.49	30.07	8.50
2006	14.20	46.20	111.88	2391.32	21.80	14.85	42.72	13.30	56.56	49.60	102.00	33.86	6.38	4.00	1.54	10.63	7.48	1.83	2.56	33.86	7.00
2007	13.90	52.74	148.73	3197.93	22.31	22.84	55.82	11.60	73.84	60.32	113.95	38.81	6.69	3.00	1.33	11.42	5.44	1.30	2.83	38.81	7.00
2008	14.00	52.05	188.11	4066.55	19.74	29.02	70.69	12.90	78.61	45.82	158.16	37.68	5.33	3.90	–0.01	–0.09	5.71	2.56	5.95	37.68	64.40
2009	18.10	51.45	121.55	2639.39	15.45	12.63	70.82	13.10	73.26	58.20	214.46	35.73	6.71	13.70	–5.71	–45.64	3.10	6.31	8.02	35.73	65.10
2010	20.83	53.35	141.21	3078.43	15.56	13.67	60.30	14.63	71.45	56.06	164.26	38.22	6.93	15.27	1.98	–14.19	5.38	6.67	11.43	38.22	66.63
2011	18.90	50.81	169.33	3704.82	14.45	14.18	54.52	14.76	84.86	64.06	146.95	37.53	5.87	14.73	0.75	6.64	5.52	6.93	10.51	37.53	68.29
2012	18.06	52.99	182.59	4004.80	11.76	7.98	51.82	15.03	26.99	65.85	131.84	40.32	10.57	16.54	0.14	2.48	6.64	8.39	10.34	40.32	64.88
2013	18.26	59.70	190.50	4187.74	8.22	4.31	56.51	15.06	28.71	65.62	120.83	45.52	5.71	12.89	–0.13	–0.91	6.40	10.22	11.77	45.52	61.73
2014	15.60	60.29	133.50	3104.64	9.89	15.90	59.85	11.23	30.11	60.92	134.60	42.30	4.17	18.98	–4.54	–9.77	5.00	21.34	12.97	42.30	64.04
2015	12.31	49.99	91.03	2124.66	13.32	38.88	47.04	8.02	31.34	45.37	149.71	35.74	4.47	28.03	–2.86	–11.24	6.40	20.82	9.82	35.74	64.61
2016	12.69	46.23	93.36	2187.73	14.80	17.10	38.61	9.78	37.10	41.55	117.58	33.02	9.13	30.47	–6.50	–17.18	5.57	16.91	16.42	33.02	72.68
2017	16.10	40.55	112.09	2638.33	12.18	22.10	31.15	11.90	44.91	54.72	106.65	29.36	7.63	54.54	–0.98	–1.81	6.24	12.69	17.05	29.36	81.15
2018	16.18	35.89	130.89	3096.56	9.86	15.40	27.74	10.77	44.84	50.32	105.43	25.57	7.60	52.85	–2.21	–2.91	6.21	10.30	14.32	25.57	86.03
2019	19.66	36.16	153.88	3661.46	6.84	8.25	22.82	13.51	47.77	55.49	91.28	26.41	8.03	48.36	3.03	21.37	8.12	8.76	11.13	26.41	90.43
2020	16.50	44.13	155.50	3724.94	6.41	9.79	21.03	13.03	48.23	60.37	66.82	31.74	5.62	22.89	1.44	11.10	6.16	8.04	8.00	31.74	51.52

Note: x_1 – Bank regulatory capital to risk-weighted assets (%); x_2 – Broad money (% of GDP); x_3 – GDP (current USD), billion); x_4 – GDP per capita (current USD), thousand; x_5 – Gross domestic savings (% of GDP); x_6 – Inflation, GDP deflator (annual %); x_7 – Monetary Sector credit to private sector (% GDP); x_8 – Bank capital to total assets (%); x_9 – Bank concentration (%); x_{10} – Bank cost to income ratio (%); x_{11} – Bank credit to bank deposits (%); x_{12} – Bank deposits to GDP (%); x_{13} – Bank net interest margin (%); x_{14} – Bank non-performing loans to gross loans (%); x_{15} – Bank return on assets (%, after tax); x_{16} – Bank return on equity (%, after tax); x_{17} – Bank Z-score; x_{18} – Central bank assets to GDP (%); x_{19} – Credit to government and state-owned enterprises to GDP (%); x_{20} – Financial system deposits to GDP (%); x_{21} – Provisions to nonperforming loans (%).

http://dx.doi.org/10.21511/bbs.17(3).2022.07

APPENDIX B

Table B1. Data for calculations based on the DEA method in the European countries as of 2020

Countries	Bank credit to bank deposits (%)	Central bank assets to GDP (%)	Provisions to nonperforming loans (%)	Bank regulatory capital to risk-weighted assets (%)	Bank deposits to GDP (%)	Bank return on assets (% after tax)	Bank return on equity (% after tax)	Bank Z-score
Austria	95.89	13.76	60.61	18.35	86.65	0.51	7.85	34.34
Belgium	58.47	15.69	42.85	18.75	113.32	1.25	86.84	13.3
Bosnia and Herzegovina	84.87	0.001	77	18.02	61.84	1.12	8.8	16.55
Bulgaria	67.88	0.06	47.55	20.21	70.61	1.86	n/a	n/a
Croatia	82.54	n/a	n/a	n/a	65.15	n/a	n/a	n/a
Cyprus	n/a	0.08	50.3	19.55	n/a	1.09	11.82	9.3
Czech Republic	68.48	0.00	55.38	19.69	72.67	0.63	8.27	8.46
Denmark	272.72	–	23.78	22.47	58.09	1.56	12.43	31.11
Estonia	97.78	0.01	40.33	25.42	59.74	0.57	4.65	8.44
Finland	138.97	11.9	40.18	20.62	66.97	0.34	3.53	22.79
France	115.63	18.56	49.85	19.56	87.97	0.4	6.86	27.92
Germany	88.6	12.2	n/a	18.58	87.98	0.22	3.69	29.18
Georgia	138.22	2.13	51.9	19.45	42.89	2.61	18.43	7.05
Greece	105.08	6.29	46.85	17.02	80.61	n/a	n/a	n/a
Hungary	69.93	0.18	66.28	18.01	45.20	1.34	11.92	7.92
Iceland	52.81	0.05	40.49	24.17	62.44	0.74	4.41	15.64
Ireland	52.81	12	39.48	24.97	69.79	1.27	7.87	12.85
Latvia	81.22	4.91	44.36	21.69	4.34	3.04	n/a	15.81
Liechtenstein	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Luxembourg	25.47	3.07	32.82	21.91	408.69	0.15	2.85	25.92
Netherlands	109.22	10.53	n/a	22.86	92.3	0.06	0.8	20.59
Norway	192.93	0.02	89.08	24.19	64.64	2.02	14.54	16.2
Poland	85.57	0	69.55	18.56	58.05	0.37	4.03	7.03
Portugal	100.05	16.53	51.47	16.93	91.58	0.63	8.24	15.62
Romania	73.22	n/a	60.75	22.00	32.93	–0.42	–3.63	8.94
Serbia	n/a	n/a	n/a	n/a	n/a	1.42	7.08	13.16
Slovak Republic	107.02	10.15	65.45	18.21	57.48	0.56	6.22	21.81
Slovenia	72.46	15.75	77.42	18.54	57.84	0.72	7.97	n/a
Spain	94.21	20.76	64.84	15.91	99.9	0.35	5.68	5.12
Sweden	177.04	7.49	49.71	22.78	72.75	0.73	6.85	48.67
Switzerland	n/a	n/a	37.83	19.34	n/a	0.43	7.2	13.98
Turkey	107.45	0.61	65.14	18.4	54.46	1.7	11.83	14.43
Ukraine	91.28	8.76	90.43	19.66	26.41	3.03	21.37	8.12

APPENDIX C

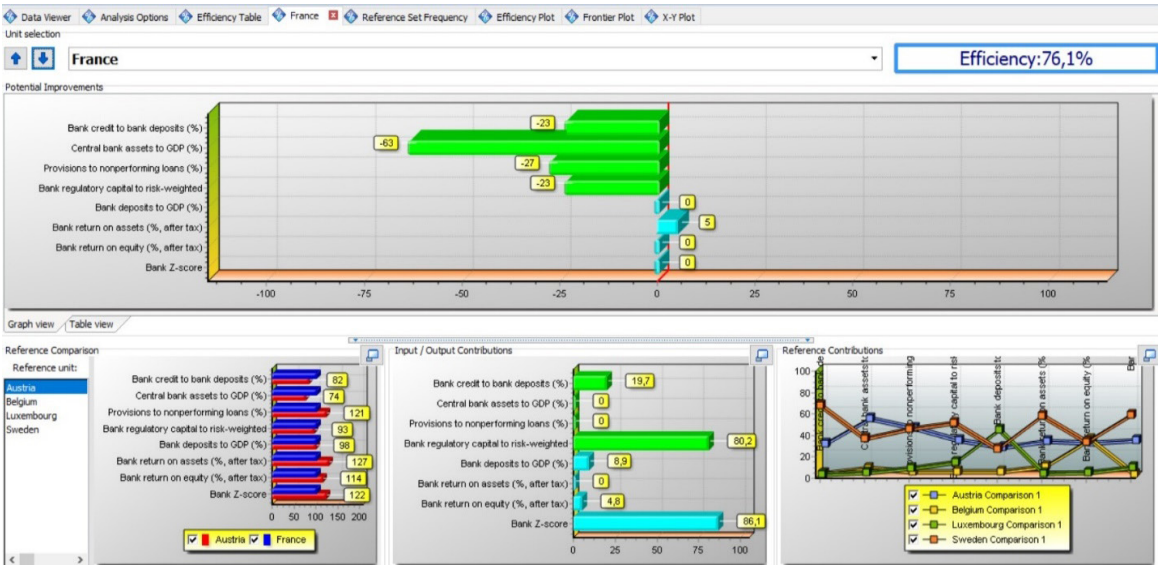

Figure C1. Analysis of the results and potential for improving the efficiency of the French banking system as of 2020 for the BCC model

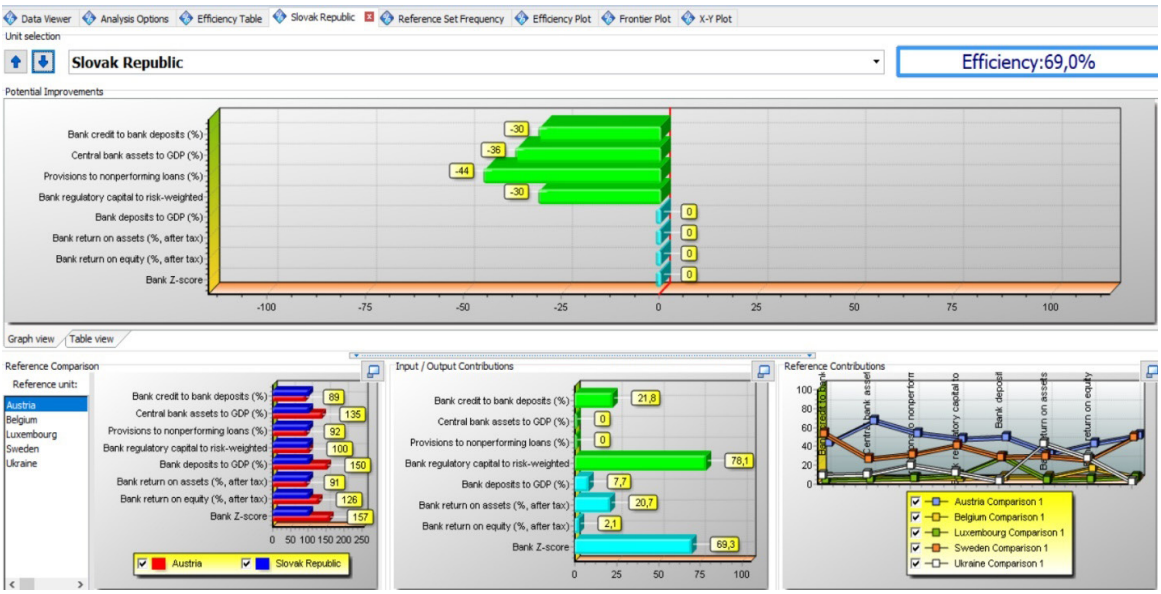

Figure C2. Analysis of the results and potential for improving the efficiency of the banking system of the Slovak Republic as of 2020 for the BCC model

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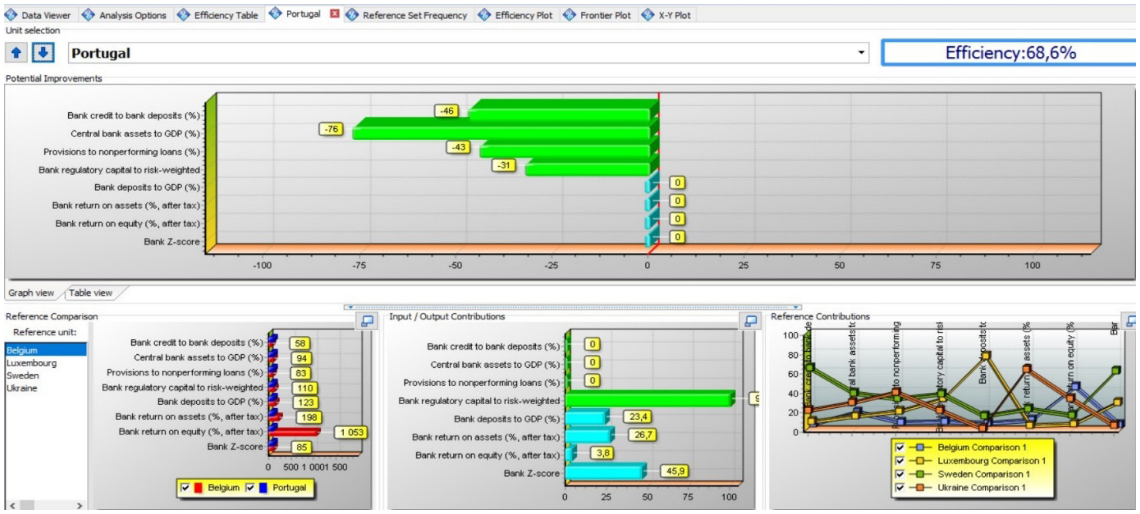

Figure C3. Analysis of the results and potential for improving the efficiency of the Portuguese banking system as of 2020 for the BCC model

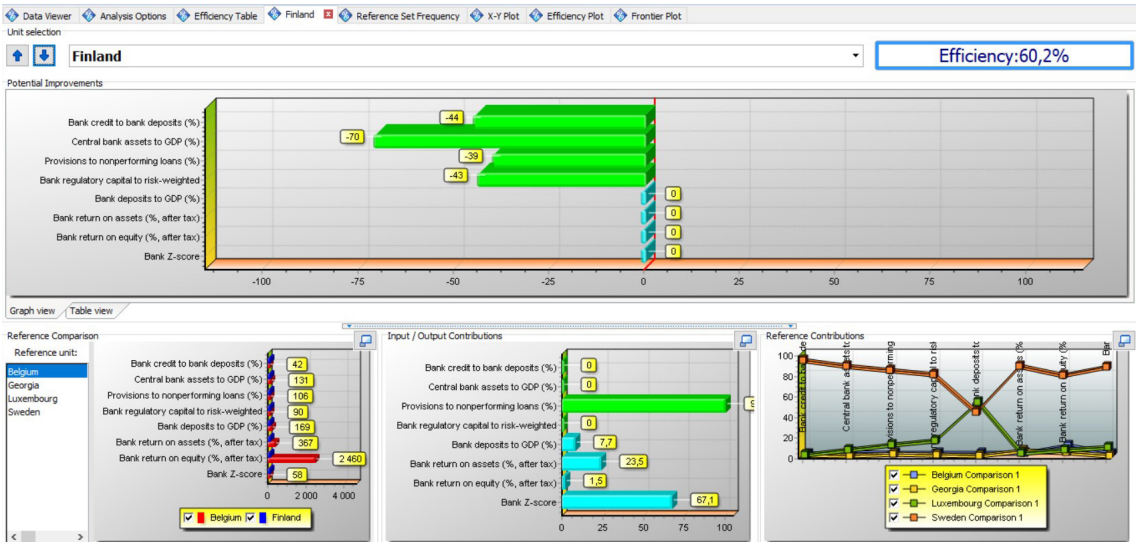

Figure C4. Analysis of the results and potential for improving the efficiency of the Finnish banking system as of 2020 for the BCC model

Figure C5. Analysis of the results and potential for improving the efficiency of the Spanish banking system as of 2020 for the BCC model

APPENDIX D

Table D1. Efficiency upside potential of banks for some European countries, calculated based on the BCC model and the CCR model of DEA

Country	BCC model	CCR model
Finland		
Bank credit to bank deposits (%)	–44	–7
Central bank assets to GDP (%)	–70	–51
Provisions to nonperforming loans (%)	–39	0
Bank regulatory capital to risk-weighted assets (%)	–43	–6
Bank deposits to GDP (%)	0	65
Bank return on assets (%, after tax)	0	65
Bank return on equity (%, after tax)	0	65
Bank Z-score	0	65
France		
Bank credit to bank deposits (%)	–23	0
Central bank assets to GDP (%)	–63	–52
Provisions to nonperforming loans (%)	–27	–4
Bank regulatory capital to risk-weighted assets (%)	–23	0
Bank deposits to GDP (%)	0	31
Bank return on assets (%, after tax)	5	38
Bank return on equity (%, after tax)	0	31
Bank Z-score	0	31
Portugal		
Bank credit to bank deposits (%)	–46	–21
Central bank assets to GDP (%)	–76	–66
Provisions to nonperforming loans (%)	–43	–16
Bank regulatory capital to risk-weighted assets (%)	–31	0
Bank deposits to GDP (%)	0	45
Bank return on assets (%, after tax)	0	45
Bank return on equity (%, after tax)	0	45
Bank Z-score	0	45
Slovak Republic		
Bank credit to bank deposits (%)	–30	0
Central bank assets to GDP (%)	–36	–8
Provisions to nonperforming loans (%)	–44	–19
Bank regulatory capital to risk-weighted assets (%)	–30	0
Bank deposits to GDP (%)	0	44
Bank return on assets (%, after tax)	0	44
Bank return on equity (%, after tax)	0	44
Bank Z-score	0	44
Spain		
Bank credit to bank deposits (%)	–82	–63
Central bank assets to GDP (%)	–90	–78
Provisions to non-performing loans (%)	–73	–43
Bank regulatory capital to risk-weighted assets (%)	–53	0
Bank deposits to GDP (%)	0	113
Bank return on assets (%, after tax)	0	113
Bank return on equity (%, after tax)	0	113
Bank Z-score	39	197

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