Comparison Of The Efficient Of Domestic And Foreign Banks With Data Envelopment Analysis: In The Case Of The Poland Banking System (2016-2022 Period)[1]

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Abstract

The main reason for this research is to analyze the Polish banking systems with Data Envelopment analysis and its sub-models, to measure efficiency, and then to compare the banks of both countries separately and together, according to the results of the analysis. In this study, the measurement of the efficiency of all 19 banks operating in Poland between 2016-2022 was investigated with CCR and BCC models of an input-oriented the Data Envelopment Analysis. According to the analysis result, efficient and inefficient banks were identified and compared, and potential improvement suggestions were developed for inefficient banks. It has been observed that the efficiency of the banking system has estimated to increase linearly over the years. Results of efficient banks of Poland have been compared and recommended as benchmarks and potential improvement suggestions for inefficient banks.

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1. Introduction

 The banking sector is particularly important for the stability of financial systems. The main role of a financial system is the efficient allocation of national savings for investments. The financial system provides the possibility of achieving a compromise between reward and risk in terms of capital allocation from a macroeconomic point of view, as well as the use of diversification possibilities. The banking system in Poland was adapted to the conditions of a market economy with the introduction of the Act of February 26, 1982, the Banking Law. Another transformation of the banking system in Poland is the result of the amendment carried out in 1989. According to the amended act, a model of a universal bank emerged, i.e., an institution that is completely free in terms of the services offered and operation on financial markets. This model has been in force in Poland up to now (Banking Law of Polish, 1997).

In Poland, the structure of the banking system is two-tier. It is shaped by the central bank, which is the National Bank of Poland, as well as commercial banks. In addition to the above-mentioned components of the banking system in Poland, we include the Polish Financial Supervision Authority, and the Bank Guarantee Fund. In Poland, banks are managed by the Polish Financial Supervision Authority. She took over this function in 2008 from the Banking Supervision Commission. In turn, the work of the Polish Financial Supervision Authority is supervised by the Prime Minister. In addition, each bank has its own president who manages the institution from the inside. The two-tier banking system in force in Poland consists of three groups of institutions, namely: stabilizing, market-creating, and auxiliary institutions. Stabilizing institutions – these are institutions that are responsible for supervising the proper functioning of the entire system. These include the National Bank of Poland, the Polish Financial Supervision Authority, and the Bank Guarantee Fund. The National Bank of Poland is responsible for regulating the liquidity of banks and supporting financial stability (including the banking sector). The Polish Financial Supervision Authority ensures control over the conduct of banking activities and takes measures to ensure the proper functioning of the financial market.

The Bank Guarantee Fund is an institution that guarantees bank deposits in Poland. It also provides assistance to banks that are at risk of bankruptcy. Market-creating institutions (in other words, the banking sector) are the banks that operate within a given banking system. In Poland, these are

commercial banks, cooperative banks, and branches of credit institutions. Auxiliary institutions these include institutions that do not conduct deposit and lending activities. The following entities should be mentioned here: non-bank issuers of payment cards, insurance institutions, the National Depository for Securities, the National Clearing House, the Credit Information Bureau, and institutions associating banks (e.g., the Polish Bank Association).

The banking system in Poland performs the following functions (System Bankowy, 2001):

• issue: only the National Bank of Poland (NBP) has the right to issue banknotes and coins. In addition, the coins introduced into circulation: "grosz" and "zloty," have the statutory power to release from all liabilities, and no person can refuse to accept them as a form of payment;

• regulatory: this function is based on controlling the supply of money, taking into account the demand for it, due to the fact that the central bank cannot create "empty" money, devoid of cover in goods and services;

• deposit and credit; this is related to the system of converting deposits into credits and loans.

• settlement: money is transferred by the bank from debtors to creditors;

• allocative, because this allows the flow of financial resources from less efficient branches of the economy and business entities to be feasible;

• financial and advisory: this function is based on the protection of clients' interests through the assistance of appropriate advisory staff;

• stimulating: it has an impact on the development of local entrepreneurship due to the fact that the bank transfers capital.

Since 1996, Poland has been a member of the OECD (Organization for Economic Cooperation and Development). From then on, the Polish banking system could no longer introduce new restrictions on capital turnover and was obliged to gradually eliminate the existing restrictions and the uniform treatment of entities from all countries. Poland also committed that, starting in 1999, it would not restrict banks from OECD countries from opening their branches on the territory of the Republic of Poland (Solarz, 1996).

According to the Banking Law of 27, August 1997, which is in force today (Ustawa Prawo bankowe, 1997). In light of previous regulations, foreign entities can be present in Poland in the form of joint-stock companies established by them, the purchase of shares in an existing bank or branch, or the representative office of a foreign bank. Since Poland's accession to the European Union, i.e. since May 1, 2004, the principle of a uniform banking license has been in force, according to which each credit institution authorized to conduct banking activity in one of the Member States has the right to conduct such activity in other EU countries. This activity concerns the opening of branches in other countries and the provision of services within the EU on a cross-border basis (Pawłowska, 2019).

As a result of the literature review in the study, after the investigation the efficiency analysis section about the banking sector, in the second sector, information about the theoretical background of the methods used in the study was presented. In the third sector, banks and input - output variables that are within the scope of the study are introduced. In the fourth sector, the analysis findings are presented and interpreted. In the last section, discussion and a conclusion are given.

2. Literature Review

There are many efficiency analyses in the literature to examine the banking sector. Most of these studies were examined for the selection of the model and variables to be applied in the research.

In the study conducted by Drake, Hall, and Simper in 2009, the efficiency of the Japanese banking system was investigated with data envelopment analysis by using total deposits, total operating expenses, total provisions, total non-interest expenses,total other operating expenses as inputs and total loans, total other earning assets, net commission, fee, and trading income, other operating income, net interest income as outputs.

In a study conducted by Küçükkaksoy and Selcan in 2013, with the balance sheet and income statement data of the years 2004 and 2011 of 10 private capital deposit banks and 5 foreign capital deposit banks operating in the Turkish banking sector between 2004 -2011, the efficiency of banks by using data envelopment analysis model and 3 input (total deposit, interest expenses and personnel expenses) and 2 output (total loan and interest income) variables were used. As a result of the study, it was determined that 7 banks in 2004, 2005, 2008, 2010 and 2011, 6 banks in 2006,

8 banks in 2007 and 5 banks in 2009 were technically efficient under the assumption of variable returns by scale.

Dutta, Jain, and Gupta (2020) analyzed the performance of non-banking financial companies (NBFCs) in the Indian context by using data envelopment analysis. In the first stage, panel data for the years 2014-2018 were taken to calculate super efficiencies, and in the second stage, in order to find exogenous factors significantly affecting the model, Tobit regression analysis was used. As a result of the study, where total assets and employee cost are considered as input, interest income, non-interest income, and operating profit as output, according to traditional models, the total number of efficient decision-making units is 8 out of 43 and considering the super efficiency algorithm, 15 units were found. Malmquist Indices, productivity indices of NBFCs in 5 years, have been found to have a maximum productivity increase of 8.53%.

Hammami et al. (2020) , in their study, by ranking of the Euclidean common weight set (ECSW) with DEA It has been applied to the banking sector in the euro zone. In the Euro Area in 2014-2018, of 59 of 67 banks traded in 17 countries that a data set has been obtained. In the study, deposits, number of employees and operating costs are used as input variables, and operating income and total assets are used as output variables. As a result of the ECSW approach, it has been observed to perform better from other common weight approaches in terms of ranking consistent with banks' credit ratings in and both numerical and real life examples.

Tsionas (2020) measured the efficiency of 285 banks in the USA by using the DEA method. In the study, consumer loans, real estate loans, commercial and industrial loans, and securities as input variables; the number of employees, physical capital, purchased funds, interest-bearing transaction accounts, and non-transaction accounts were considered as output variables.

In the study, Balcı and Ayvaz (2020) measured the efficiency of 15 deposit banks operating in the Turkish banking sector between 2014-2018 with the data envelopment analysis that of 3 public, 6 private and 6 foreign deposit banks and the Malmquist index. As input, personnel expenses / total assets (%), total loans / total assets (%), equity / total assets (%), total deposits / total assets (%),and as output, earning power of assets (net profit / total assets), earning power of equity (net profit / equity) (%) were used to analysis efficiency of banks. As a result of the study, with the assumption

of constant return to scale 4 banks, 8 banks were found efficient under the variable return to scale assumption between 2014-2018.idze

In their study, Yagubov and Yagubov (2020) investigated the efficiency of ten commercial banks with the highest total number of assets in Azerbaijan in 2016, by using the DEA method in the period 2011-2016. Three inputs (total assets, total equity, and interest expenses) and two output variables (interest income and net profit) are used in the study by using the CCR (Charnes, Cooper, Rhodes) model. As a result of the study, it was determined that only Turan Bank was efficient in the period before the devaluation that took place in 2015, while the banks in the post-devaluation period were generally efficient, and Pasha Bank achieved the highest efficiency.

The efficiency measurement of all 25 banks operating in Azerbaijan during 2015-2019 was investigated by Salamzade Fuad and Bagirov Alig using constant return to scale, variable return to scale, and Super efficiency models of an input-oriented Data envelop analysis. In the research, interest expenditures, personnel expenditures, general and retained expenditures and deposits have been used as input and loans, interest income and non-interest income as output. As a result, it has been determined that the efficiency of the banks included in the analysis increased from 2015 to 2019 and that the banks worked and developed more efficiently.

In the study conducted by Czerwonka (2019), the efficiency of Poland's 12 largest commercial banks between 2013 and 2018 was measured. The aim of the research was to examine whether the largest commercial banks are more efficient than the others and to determine the main reasons for the inefficiency of commercial banks. Data Envelopment Analysis (DEA) was used as the research method. The obtained results indicate that the average efficiency is 0.903. It turns out that the largest banks are, on average, quite efficient and do not have much room for improvement. In the case of large banks, the average technical efficiency PE is 0.96, while in the case of pure technical efficiency PTE, it is as high as 0.99.

3. RESEARCH METHODOLOGY

In this study, 2 models of Data Envelopment Analysis (DEA) - CCR Model and BBC Model were used to measure the efficiency of banks.

3.1. Input Oriented CCR Model

In this study, a constant scale of returns to CCR model with input - oriented DEA was used. The constant scale of returns CCR model using the analysis by (Charnes, Cooper, & Rhodes 1978) was the first tool that provided the basis for the development of DEA approach (Baghirov 2017). Variable weight method is used in DEA. The weights are created linearly from data obtained as a result of multiple assumptions and constant weight selected calculations are omitted (Kutlar & Salamov 2018).The following are the three factors to be kept constant in determining these weights through linear programming; All data and weights must be positive; the ratio of weighted outputs to weighted inputs must assume a value between 0 and 1, and weights must be used for all DMUs included in the model (Charnes A. , Cooper , Lewin, & Seiford 1997).

In the literature, these weight values are called "virtual input-output" or "virtual weights," and the weights are tested for determination in order to maximize the efficiency rate through linear programming (Kutlar & Salamov 2018).The mathematical representation of the model is as shown below (Cooper, Seiford, & Zhu 2011).

$$\frac{\text{virtual output}}{\text{virtual input}} = \frac{u_1 y_{1o} + u_2 y_{2o} + \ldots + u_s y_{so}}{v_1 x_{1o} + v_2 x_{2o} + \ldots + v_m x_{mo}}$$

In this analysis,an input oriented CCR model will be discussed. Input oriented model CCR, a solution model that aims to minimize the input level by determining the most appropriate set of inputs to optimize the most efficient rate for a given set of output has been implemented. The purpose of the CCR model is to maximize the ratio of virtual output and input, and the ratio of virtual output to virtual input for DMU, provides efficiency measurement, which is a function of multipliers. If j is the efficiency of the decision unit h_j, the goal is to maximize this value . In this case, the input-oriented function can be expressed in the following formula (Charnes, Cooper, & Rhodes 1981).

$$Max h_j = \frac{\sum_{s=1}^{n} u_s y_s}{\sum_{i=1}^{m} v_i x_i}$$

The first restriction has been imposed so that the efficiency rate of DMU does not exceed 1. If it exceeds 1, it means the efficiency rate is over 100%. Restrictions can be shown as in the formula below (Charnes, Cooper, & Rhodes 1978).

$$\frac{\sum\limits_{s=1}^{n} u_s y_s}{\sum\limits_{i=1}^{m} v_i x_i} \leq 1$$

The following restriction has been introduced so that the weights of the inputs and outputs to be used are not negative.

$$u_r \geq 0; \ v_i \geq 0;$$

j: DMUs, j = 1,2…..,s; s : number of ouput , s = 1,2…..n; i : number of input,i = 1,2…...m

In the formula; y_s :j`th, the value of the s'th output produced by the DMU,  $x_r$ : j'ththe value of the r`th input produced by the DMU, u_r : weight given to r`th output, v_i : weight given to the i'th input. If the efficiency scores are 1, the DMU included in the analysis is efficient, if it is less than 1, it indicates that it is not efficient (Kutlar & Salamov 2018).

3.2. Input Oriented BCC Model

A study conducted by (Banker, Charnes, & Cooper 1984) on the assumption of scale of return it was named BCC formulation. This model was developed on the basis of the CCR model based on the assumption of constant scale of return and a model based on the assumption of variable return to scale was created (Baghirov 2017). BCC method measures efficiency by considering only technical efficiency. The BCC model's efficiency score limits will always be less than or equal to the CCR efficiency score limits. As in the CCR model, the BCC model also uses two methods, input-oriented and output-oriented (Banker, Charnes, & Cooper 1984). In this study, an input-oriented BCC model will be used. The Input Oriented BCC Model has been created in order to provide the intended output to determine the best amount of input. The function of the input-oriented BCC model is as follows (Kutlar & Salamov 2018):

$$MaxZ = \sum_{r=1}^{s} u_r y_{r0} - \mu_0$$

According to the following conditions:

$$\sum_{i=1}^{m} v_i x_{i0} = 1; \quad j = 1, \dots , \text{n:}$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} - \mu_0 \leq 0; \quad r = 1, \dots , p; i = 1, \dots, m;$$

The following restriction has been introduced so that the weights of the inputs and outputs to be used are not negative.

$$u_r \geq \varepsilon \;;\; v_i \geq \varepsilon \,, \quad \mu_0 : \text{unrestricted}$$

Here; u_r: The weight given to the r`th output by DMU, $v_i$: The weight given to the i`th input by DMU, y_{r0}: i'th input used by DMU, y_{rj}: r`th output produced by the j`th DMU, x_{ij}: i'th input used by the j`th DMU, ε: a small enough positive number, μ_0: the scale of return is defined as variable. The efficiency value of the effective DMUs in the Input Oriented BCC model is equal to one (Selamzade 2019). In the case of efficiency, it is impossible to make any changes to the input and output vectors. The efficiency value of ineffective DMUs is less than one (Yalçın 2012).

3.3. Determination of Decision Units and Variables

In order to meet the minimum conditions of the analysis and come to a clear result, the number of banks we take part in determining the Determination of Decision Units and Variables. All domestic and foreign banks operating in the Poland Republic are included in the analysis, and which has been accepted as the Decision Making Unit (DMU). The input and output data used in this study were collected on the basis of the banks' year-end independent audit reports. In the analysis, efficiency scores of DMUs were calculated without making any distinction between domestic and foreign banks. In the study, input-oriented Data Envelopment Analysis (DEA) was conducted for 19 banks in Poland with the data of 2016-2022. Of the 19 Polish banks included in the analysis, 9 are domestic banks and 10 are foreign (BNP Paribas Bank Polska and Crédit Agricole Bank Polska, mBank and Deutsche Bank Polska from Germany, ING Bank Śląskione from Niderlanin, DNB Bank Polska from Norway, Nest Bank from the United Kingdom, Bank Handlowy w Warszawie USA, Bank Millennium from Portugal and Santander Bank Polska from Spain). The input-oriented analysis method is to calculate how much the inputs are minimized to produce the current outputs of DMUs. Fixed-return-to-scale Charnes, Cooper Rhodes (CCR) and variable-return-to-scale Banker, Charnes, Cooper (BCC) models were used in the analysis. The names of the banks of Poland included in the study are shown in the table below.

Table 1: Names of banks of Poland included in the analysis

N	Name of Polish Domestic Banks	N	Name of Polish Foreign Banks
1	Bank Polska Kasa Opieki	1	Bank Millennium
2	SGB-Bank	2	DNB Bank Polska
3	PKO Bank Polski	3	mBank
4	Bank Pocztowy	4	Nest Bank
5	Bank Polskiej Spółdzielczości	5	Bank Handlowy w Warszawie
6	Plus Bank	6	ING Bank Śląski
7	Getin Noble Bank	7	Crédit Agricole Bank Polska
8	Alior Bank	8	Santander Bank Polska
9	Bank Ochrony Środowiska	9	Deutsche Bank Polska
		10	BNP Paribas Bank Polska

The input and output variables shown in Table 2 were used to analyze the efficiency of banks operating in the Polish banking sector. In the study, 3 inputs (interest and non-interest expenses and deposits) and 3 outputs (loans, interest and non-interest income) were used for efficiency analysis. Non-interest income includes dividend income, commission and fee income and other operating income and Non-interest expenditures, commission and fee expenses, other operating expenses, general and administrative expenses.

Table 2: Input and Output Variables

Input			Output		
Interest Expenditures	Non-Interest Expenditures	Deposits	Loans	Interest Income	Non-Interest Income

The data taken from the annual accounts of banks were zlotys for Poland. The Polish zloty was included in the analysis by converting it to the average exchange rate of the US dollar in all years. All the data included in the analysis are given on the basis of US dollar and analyzed with the DEA-Solver program.

4. RESEARCH FINDINGS

4.1. BCC Model

The results of 19 banks' scores by years and 7-year average scores of the fixed return to scale BCC model of input-oriented DEA for the period 2016-2022 are shown in Table 3. The ranking is made according to the annual average performance of the banks.

Table 3: BCC Efficiency Scores between 2016-2022

Calculated by the co-authors according to the analysis results.

C-Constant, I-Increasing and D-Decreasing, RTS-returns to scale

N	Name of Banks	2016		2017		2018		2019		2020		2021		2022		AS of Banks
		Scores	RTS	Scores	RTS	Scores	RTS	Scores	RTS	Scores	RTS	Scores	RTS	Scores	RTS	
1	Bank Polska Kasa Opieki	1,00	C	1,00	C	1,00	C	1,00	C	1,00	D	1,00	C	1,00	I	1,00
2	SGB-Bank	1,00	C	1,00	C	1,00	C	1,00	C	1,00	C	1,00	C	1,00	D	1,00
3	Bank Millennium	1,00	C	1,00	C	1,00	C	1,00	C	1,00	C	1,00	C	1,00	C	1,00
4	DNB Bank Polska	1,00	C	1,00	C	1,00	C	1,00	C	1,00	I	1,00	C	1,00	C	1,00
5	mBank	1,00	C	1,00	C	1,00	C	1,00	C	1,00	C	1,00	D	1,00	C	1,00
6	Nest Bank	1,00	C	1,00	C	1,00	C	1,00	C	1,00	D	1,00	D	1,00	C	1,00
7	PKO Bank Polski	1,00	D	1,00	D	1,00	D	1,00	C	1,00	D	1,00	C	1,00	D	1,00
8	Bank Pocztowy	1,00	I	1,00	I	1,00	I	1,00	I	1,00	I	1,00	I	0,89	D	0,98
9	Bank Handlowy w Warszawie	1,00	I	0,88	I	1,00	C	1,00	I	1,00	C	1,00	C	1,00	C	0,98
10	ING Bank Śląski	1,00	D	1,00	C	1,00	C	1,00	C	0,91	D	1,00	C	0,86	D	0,97
11	Crédit Agricole Bank Polska	1,00	C	1,00	C	1,00	C	1,00	C	1,00	D	1,00	C	0,76	C	0,97
12	Santander Bank Polska	1,00	C	0,88	C	1,00	C	0,99	D	0,86	D	0,94	D	1,00	C	0,95
13	Bank Polskiej Spółdzielczości	1,00	C	1,00	C	1,00	C	1,00	C	1,00	I	1,00	C	0,66	C	0,95
14	Deutsche Bank Polska	1,00	D	0,91	D	0,89	D	1,00	D	1,00	D	0,85	D	1,00	C	0,95
15	Plus Bank	1,00	D	0,78	C	0,84	C	0,97	D	0,94	D	1,00	C	1,00	C	0,93
16	BNP Paribas Bank Polska	1,00	D	0,95	D	0,88	D	0,88	D	0,45	I	0,96	D	1,00	I	0,87
17	Getin Noble Bank	1,00	D	0,99	D	1,00	D	0,78	D	0,37	I	0,72	D	1,00	C	0,84
18	Alior Bank	0,90	D	0,91	D	0,89	D	0,96	I	0,44	I	0,89	D	0,79	D	0,83
19	Bank Ochrony Środowiska	0,77	D	0,75	D	0,77	C	0,83	D	0,57	I	1,00	C	1,00	C	0,81

According to the BCC model analysis result shown in Table 3, 7 banks were full efficient with a score of 100% between the years 2016-2022. Of the 7 full efficient banks, 3 were domestic (Bank Polska Kasa Opieki, SGB-Bank and PKO Bank Polski), and 4 were foreign banks (Bank

Millennium, DNB Bank Polska, mBank and Nest Bank). Between these years, the number of banks with an average efficient score close to full efficiency and between 0.90-1.00 is 8. Of these 8 banks, 5 were foreign banks and 3 were domestic banks. The average efficiency score of other 4 banks was 0.81-0.90. Efficiency scores of banks according to years and banks in the analysis made with the BCC method

- In 2016, 17 out of the 19 banks included in the analysis have performed fully effectively and productively. While each of the foreign banks was fully efficient, 2 domestic banks (Alior Bank and Bank Ochrony Środowiska) were inefficient banks. In 2016, the average efficiency score was higher than the average efficiency score of domestic banks.

- In 2017, 12 out of the 19 banks included in the analysis have performed fully effectively. While 7 the foreign banks and 5 domestic banks have been fully efficient. The two banks with the lowest scores have been domestic banks Plus Bank (0.78) and Bank Ochrony Środowiska (0.75).

- In 2018, full efficiency was observed in 14 banks, 6 of which were domestic and 8 foreign banks, while the effect was not observed in 5 banks. 5 banks were inefficient. Three of these were domestic banks and two were foreign banks. The number of foreign fully effective banks was more than that of domestic banks.

- In 2019, full efficiency was observed in 13 banks, including 5 domestic and 8 foreign banks. 6 banks were inefficient. Of the 6 ineffective banks, two are foreign and four are domestic banks.

- In 2020, 12 out of the 19 banks included in the analysis have performed fully effectively and productively. Of the 7 banks that were ineffective, three were foreign and four were domestic banks. The efficiency scores of Bank Ochrony Środowiska (0,57), BNP Paribas Bank Polska (0,45), Alior Bank (0,44) and Getin Noble Bank (0,37) were below 0.60 and showed ineffective operation.

- In 2021, 14 out of the 19 banks included in the analysis have performed fully effectively and productively. Of the 5 banks that were ineffective, three were foreign and two were domestic banks.

- In 2022, 14 out of the 19 banks included in the analysis have performed fully effectively and productively. Of the 5 banks that were ineffective, two were foreign and three were domestic banks.

According to the frequency of reference to other banks mBank, SGB-Bank and Credit Agricole Bank Polska were recommended to other banks 20, 19 and 17 times, respectively, in 2016.

According to the results of the analysis, it is seen that the number of recommendations of foreign banks to other banks is relatively higher than that of domestic banks. This means that foreign banks are predicted to operate more efficiently. In order to make it efficient, the banks should reduce the capacity and use efficient resources, in other words, it can be said that the banks could be efficient when they produce available outputs with lesser inputs. Between 2016 and 2022, the returns to scale of fully effective banks remained stable, except for PKO Bank Polski. Decreasing returns to scale were observed in the majority of ineffective banks. The Increasing returns to scale was observed in 2020. The lowest effectiveness score was not found in 2020. In fact, the efficiency threshold of three banks was below 0.50.

The evaluation in terms of average score of foreign and domestic bank for Poland and average score for overall of 19 banks included in BCC Model analysis between 2016-2022 years is shown in the figure 1 below.

Figure 1: Average Efficiency ofryq the BCC Model of Banks by Years (%)
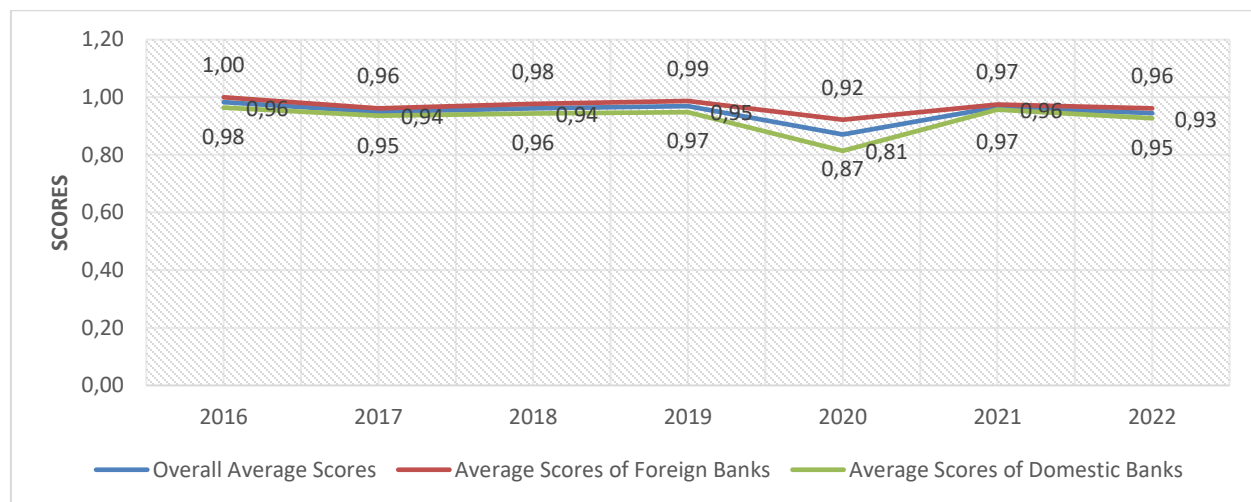
When the efficiency scores of foreign and domestic banks of Poland between 2016-2022 were compared on the basis of average scores, it is estimated that foreign banks operate more effectively than domestic banks. When the efficiency scores of foreign and domestic banks are compared on the basis of average scores, it is also observed that foreign banks operate more effectively than domestic banks. In terms of overall average scores, when the efficiency scores of the polish banks

included in the analysis are investigated, it is seen that the efficiency of the banks' performed varies between 0.87 score and 0.98 score between 2016 and 2022. The lowest average efficiency was in 2020 with 0.87 scores. The lowest average score in 2020 appears to be due to the 2019 COVID pandemic.

In terms of the average scores of foreign banks, when the efficient scores of the Polish banks included in the analysis are investigated, it is seen that the efficiency of the banks between the years 2016-2022 has changed between 0.81 scores and 0.96 scores. The lowest average efficient of foreign banks was realized in 2020 with 0.81 scores. The lowest average score for foreign banks in 2020 appears to be due to the 2019 COVID pandemic.

In terms of the average scores of domestic banks, when the efficient scores of the Polish banks included in the analysis are investigated, it is seen that the efficiency of the banks between the years 2016-2022 has changed between 0.92 scores and 1.00 scores. The lowest average efficient of foreign banks was realized in 2020 with 0.92 scores. The lowest average score for domestic banks in 2020 appears to be due to the 2019 COVID pandemic, as well as for foreign banks.

It is estimated that the reason for the decrease in the average efficiency scores of banks in 2019 and 2020 is the COVID 19 pandemic that started in 2019. While it had the lowest efficiency scores with 0.81 scores in 2020 for domestic banks and with 0.87 scores in 2020 for foreign banks it was observed that efficient in the activities of banks increased as the severity of the COVID 19 pandemic decreased as of 2021. While the general average scores are evaluated in terms of the average scores of foreign and domestic banks, the effect of the 2019 COVID pandemic is seen. The COVID 19 pandemic has affected both domestic and foreign banks, and the efficiency of banks has decreased. When the efficient of domestic banks and foreign banks is compared, it is seen that the average efficient and scores of domestic banks is lower.

4.2. CCR Model

Efficiency scores and averages for 41 banks in 2016-2022 and 41 banks in other years with fixed return CCR model of input-oriented DEA to scale are shown in Table 3. The ranking is based on the annual performance average of the banks.

Table 4: CCR Efficiency Scores between 2016-2022

No	Bank Names	2016	2017	2018	2019	2020	2021	2022	Average
1	Bank Millennium	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
2	SGB-Bank	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
3	mBank	1,00	1,00	1,00	1,00	1,00	0,89	1,00	0,98
4	Bank Handlowy w Warszawie	0,95	0,85	1,00	1,00	1,00	1,00	1,00	0,97
5	Crédit Agricole Bank Polska	1,00	1,00	1,00	1,00	0,52	1,00	1,00	0,93
6	Bank Polska Kasa Opieki	1,00	1,00	1,00	1,00	0,68	1,00	0,81	0,93
7	ING Bank Śląski	0,93	1,00	1,00	1,00	0,55	1,00	1,00	0,93
8	DNB Bank Polska	1,00	1,00	1,00	1,00	0,56	1,00	0,86	0,92
9	Nest Bank	1,00	1,00	1,00	1,00	0,50	0,68	1,00	0,88
10	Santander Bank Polska	1,00	0,87	1,00	0,94	0,46	0,90	1,00	0,88
11	Plus Bank	0,80	0,93	0,98	1,00	0,56	1,00	0,73	0,86
12	Bank Polskiej Spółdzielczości	1,00	1,00	1,00	1,00	0,27	1,00	0,65	0,85
13	PKO Bank Polski	0,94	0,78	0,74	0,90	0,39	1,00	0,97	0,81
14	Alior Bank	0,83	0,88	0,88	0,96	0,43	0,86	0,78	0,80
15	Bank Pocztowy	0,92	0,85	0,85	0,88	0,38	0,69	1,00	0,80
16	Bank Ochrony Środowiska	0,76	0,74	0,77	0,83	0,35	1,00	1,00	0,78
17	BNP Paribas Bank Polska	0,79	0,80	0,80	0,87	0,45	0,91	0,66	0,75
18	Getin Noble Bank	0,91	0,83	0,87	0,64	0,31	0,69	0,71	0,71
19	Deutsche Bank Polska	0,62	0,54	0,64	0,65	0,23	0,69	0,64	0,57

In Table 4 According to the result of the analysis made with the variable returns to scale CCR model, 2 banks: Bank Millennium and SGB-Bank have been seen to be full efficient between 2016-2022. 5 banks: Bank Handlowy w Warszawie, Crédit Agricole Bank Polska, ING Bank Śląski, DNB Bank Polska and Bank Polska Kasa Opieki efficiency score have been between 90% and 99% has received efficiency score. The average score of the other 7 banks was 0.80-0.90, the score of 3 banks was 0.70-0.80. Deutsche Bank Polska had the lowest average score of 0.57. The average efficiency score of all banks included in the analysis has realized above 0.50. The banks with the full and lowest efficient scores in the analysis made by the CCR method have been

- In 2016, 9 fully efficient banks, including 3 domestic and 6 foreign banks and banks with the lowest efficient scores were BNP Paribas Bank Polska (0.79), Bank Ochrony Środowiska (0.76) and Deutsche Bank Polska (0.62). This means that 33% of domestic banks and 60% of foreign banks were operating at full efficiency.

- In 2017, 9 fully efficient banks, including 3 domestic and 6 foreign banks and banks with the lowest efficient scores were PKO Bank Polski (0.78), Bank Ochrony Środowiska (0.74) and Deutsche Bank Polska (0.54). This means that 33% of domestic banks and 60% of foreign banks were operating at full efficiency.

- In 2018, 11 fully efficient banks, including 3 domestic and 8 foreign banks and banks with the lowest efficient scores were PKO Bank Polski (0.77), Bank Ochrony Środowiska (0.74) and Deutsche Bank Polska (0.64). This means that 33% of domestic banks and 80% of foreign banks were operating at full efficiency.

- In 2019, 11 fully efficient banks, including 4 domestic and 7 foreign banks and banks with the lowest efficient scores were Bank Ochrony Środowiska (0.83) and Deutsche Bank Polska (0.64) and Getin Noble Bank (0.64). PKO Bank Polski, which was ineffective in 2016-2018, worked more efficiently and increased its efficient score by 0.90. This means that 44% of domestic banks and 70% of foreign banks were operating at full efficiency.

- In 2020, only 4 banks were able to operate fully efficiently. One of the four efficient banks was a domestic bank (SGB-Bank) and the other three were foreign banks (Bank Millennium, mBank and Bank Handlowy w Warszawie). Efficient banks constitute 21% of the total bank. The reduction in the number of active banks and inefficient activity has resulted from the onset of the 2019 COVID

pandemic. Due to the COVID 19 pandemic, the activity of 10 banks was extremely inefficient and below 0.50. The activity of the other 5 banks was close to inefficiency with a score of 0.50-0.70. The 3 most inefficient banks were Getin Noble Bank (0.31), Bank Polskiej Spółdzielczości (0.27) and Deutsche Bank Polska (0.23), respectively.

- In 2021, 11 banks were able to operate fully efficiently. One of the 11 efficient banks was a domestic bank and the other 5 were foreign banks. Efficient banks made up 58% of the total banks. This means that 67% of domestic banks and 50% of foreign banks were operating at full efficiency. The 3 banks with the lowest efficient scores were Getin Noble Bank (0.69), Deutsche Bank Polska (0.69) and Nest Bank (0.68). After the negative impact of the COVID 19 Pandemic, domestic banks are observed to be more efficient than foreign banks in 2021.

- In 2022, 10 banks were able to operate fully efficiently. 3 of the 10 efficient banks was a domestic bank and the other 7 were foreign banks. Efficient banks made up 53% of the total banks. This means that 33% of domestic banks and 70% of foreign banks were operating at full efficiency. The 3 banks with the lowest efficient scores were BNP Paribas Bank Polska (0.66), Bank Polskiej Spółdzielczości (0.65) and Deutsche Bank Polska (0.64). When foreign and domestic banks were compared in terms of 2021 and 2022, it was observed that foreign banks have increased their efficiency in 2022.

In accordance with the CCR model analysis result, in terms of recommendation weight to other banks, the top 3 most recommended banks between 2016-2022 were Bank Millennium, SGB-Bank and mBank. According to the results of the analysis, it is seen that the number of recommendations of foreign banks to other banks is relatively higher than domestic banks. Namely, foreign banks are predicted to operate more efficiently. When evaluated over the years, it has been determined that the COVID 19 pandemic has had a negative impact on Poland's domestic and foreign banks.

The evaluation in terms of average score of foreign and domestic banks and for overall of 19 banks included in CCR Model analysis between 2016-2022 years is shown in the figure 2 below.

Figure 2: Average Efficiency of the CCR Model of Banks by Years (%)
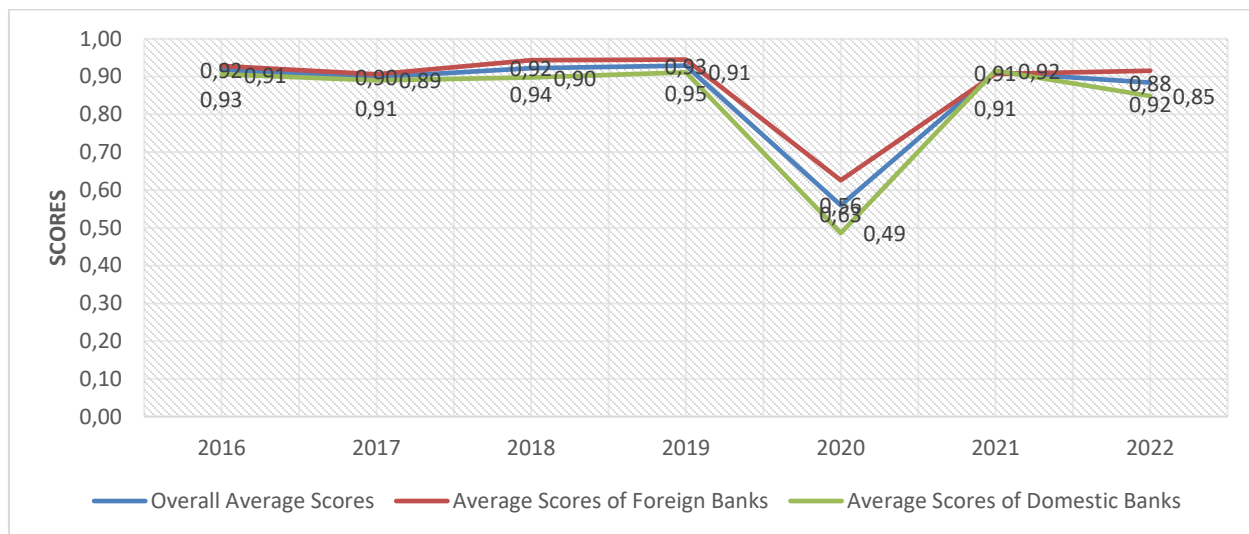
When the efficiency scores of the Polish banks included in the analysis are generally compared on the basis of foreign and domestic banks, foreign banks have operated more effectively and productively than domestic banks in the years 2016-2022. In terms of overall average scores, when the efficiency scores of the domestic banks included in the analysis are investigated, it is seen that the efficiency of the banks' performed varies between 0.56 score and 0.92 score between 2016 and 2022. The lowest average efficiency was in 2020 with 0.56 scores. The lowest average score in 2020 appears to be due to the 2019 COVID pandemic.

In terms of the average scores of foreign banks, when the efficient scores of the Polish banks included in the analysis are investigated, it is seen that the efficiency of the banks between the years 2016-2022 has changed between 0.63 scores and 0.95 scores. The lowest average efficient of foreign banks was realized in 2020 with 0.63 scores. The lowest average score for foreign banks in 2020 appears to be due to the 2019 COVID pandemic.

In terms of the average scores of domestic banks, when the efficient scores of the Polish banks included in the analysis are investigated, it is seen that the efficiency of the banks between the years 2016-2022 has changed between 0.49 scores and 0.91 scores. The lowest average efficient of foreign banks was realized in 2020 with 0.91 scores. The lowest average score for domestic banks in 2020 appears to be due to the 2019 COVID pandemic, as well as for foreign banks.

It is estimated that the reason for the decrease in the average efficiency scores of banks in 2019 and 2020 is the COVID 19 pandemic that started in 2019. While it had the lowest efficiency scores with 0.49 scores in 2020 for domestic banks and with 0.56 scores in 2020 for foreign banks it was observed that efficient in the activities of banks increased as the severity of the COVID 19 pandemic decreased as of 2021. While the general average scores are evaluated in terms of the average scores of foreign and domestic banks, the effect of the 2019 COVID pandemic is seen. The COVID 19 pandemic has affected both domestic and foreign banks, and the efficiency of banks has decreased. When the efficient of domestic banks and foreign banks is compared, it is seen that the average efficient and scores of domestic banks is lower.

5. CONCLUSION

The importance of the banking sector in a globalizing world is increasing day by day. In this study, the comparison of selected decision-making units has been examined with measurements of CCR and BCC models of input-oriented DEA for the period between 2016 and 2022. In the input-oriented DEA model, it is aimed at minimizing the level of inputs in order to produce existing outputs. Inputs and outputs providing the minimum conditions for analysis in the selection of decision-making units have been investigated, and all 19 banks operating in Poland were selected as decision-making units. In the study, three variables as input (interest expenses, general and administrative expenses, and deposits) and three variables as output (loans, interest income, and non-interest income) have been used as a thousand US dollars. In order to determine which year is more efficient, analyses made with CCR and BCC models have been made, and improvement suggestions have been developed for the inefficient years.

According to the results of the BCC and CCR model analyses, the COVID-19 pandemic has affected the efficiency and productivity of both domestic and foreign banks in 2019–2020. During these years, the average productivity and efficiency scores for both domestic and foreign banks included in the analysis decreased both on a bank basis and on an average score basis.

According to the BCC model analysis result shown in Table 3, two banks were fully efficient with a score of 100% between the years 2016 and 2022. Of the two fully efficient banks, one was a foreign bank and one was a domestic bank. According to the result of the analysis made with the variable returns to scale CCR model, two banks, Bank Millennium and SGB-Bank, have been seen

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to be fully efficient between 2016 and 2022. According to the frequency of references to other banks, Poland's Crédit Agricole Bank Polska was recommended to other banks the most. As a result of the CCR and BCC models, it was determined that foreign banks are more efficient than domestic banks. It has been suggested for both countries to examine the functioning and working systems of domestic banks in line with the data of foreign banks and implement them in their own banks.

In addition, it was suggested that domestic banks should study foreign banks and activities and increase their efficiency by applying them to their own banks that are suitable for them. In line with the increase in bilateral economic relations and mutual cooperation between foreign and domestic banks, it is recommended that both banks increase their effectiveness by learning about each other's banking systems and activities and applying them together. The results of the article were shown in the literature study, and the results of the studies were appropriate. This article will provide a resource for future researchers working with the DEA.

References

Baghirov, A. (2017), 2008 Küresel Kriz Sonrası Azerbaycan Bankacılık Sisteminin Veri Zarflama Analizi İle İncelenmesi, *Uluslararası Ekonomik Araştırmalar Dergisi,* 3(1), 1-12

Balcı, E & Ayvaz, B. (2020). Efficiency and productivity analysis in Turkish banking sector with data envelopment analysis and Malmquist index. *Southeast Europe Journal of Soft Computing, 9*(1), 9-23.

Banker, R.D., Charnes, A. & Cooper, W.W.(1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management science*, 30(9), 1078-1092

Banking Law of Polish, (1997), The Bankıng Act of Poland Republic,

Charnes, A., Cooper, W.W., & Rhodes, E (1978). Measuring The Efficiency of Decision Making Units, *European Journal of Operation Research*, 2, 429-444.

Cooper, W.W, Lawrence, W., Seiford, M. & Zhu, J. (2011). *Handbook on Data Envelopment Analysis. Second Edition*. London: Springer New York Dordrecht Heidelberg.

Czerwonka, L., (2019), Efficiency in Polish listed commercial banks: a DEA approach *Research Papers Of Wrocław University of Economics,* 63(5), 7-18

Drake, L., Hall, M.J.B., & Simper, R. (2009). Bank Modelling Methodologies: A Comparative Non-parametric Analysis of Efficiency in the Japanese Banking Sector, *Int. Fin. Markets, Inst. and Money 19*, 1–15

Dutta, P., Jain, A. & Gupta, A. (2020), Performance analysis of non-banking finance companies using two-stage data envelopment analysis. *Ann Oper Res 295*, 91–116, Doi:10.1007/s10479-020-03705-6

Hammami, H., Ngo, T., Tripe, D. & Vo, D. T. (2020) Ranking with a Euclidean common set of weights in data envelopment analysis: with application to the Eurozone banking sector. Ann Oper Res, S.I. : MOPGP19. 1-20, Doi:10.1007/s10479-020-03759-6

Kutlar, A. and Salamov, F. (2018), Azerbaycan Devlet Hastanelerinin Stokastik Sınır Analizi Metodu ile Değerlendirilmesi, *Balkan and Near Eastern Journal of Social Sciences,* 04 (02), 55-64

Küçükkaksoy, I., & Selcan, O. (2013). Türk bankacılık sektöründe faaliyet gösteren bankaların etkinliklerinin veri zarflama analizi yöntemi ile ölçülmesi: 2004-2011 yılları uygulaması. *Ekonometri & İstatistik e-Publisher*, (18), 56-80

Prawo bankowe, Ustawa z dnia 29 sierpnia 1997 r. (Dz.U. 1997 Nr 140 poz. 939)

Pawłowska M. (2019), Konkurencja na rynku sprzedaży detalicznej w Polsce: badanie z wykorzystaniem indeksu Linda, Kwartalnik KES, 4/36, p. 20-40.

System bankowy w Polsce w latach dziewięćdziesiątych, National Bank of Poland, December 2001, p. 2.

Solarz, J. K., Wybra*ne aspekty dostosowania polskiego systemu bankowego do wymogów Wspólnot Europejskich i OECD*, ”Bank i Kredyt” 1996, No 5, p. 32–37.

Tsionas, M.G. (2020). A coherent approach to Bayesian data envelopment analysis, *European Journal of Operational Research, 281*(2), 439-448, Doi:10.1016/j.ejor.2019.08.039

Ustawa Prawo bankowe z dnia 29 sierpnia 1997 r. (Dz.U. 1997, nr 140, poz. 939).

Yagubov, S. & Yagubov, U. (2020). The efficiency of Azerbaijani banks: an empiric analysis, *55th International Scientific Conference on Economic and Social Development – Baku/Azerbaijan*, 581-587.

Yalçın H. (2012), Veri Zarflama Analizi ile Vergi Dairesi Başkanlıklarının Performansının Ölçülmesi, *Kadir Has Üniversitesi Sosyal Bilimler Enstitüsü Doktora Tezi*, İstanbul