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MEASURING BANK EFFICIENCY: CROATIAN BANKING SECTOR RESEARCH

ABSTRACT

Interest on measuring the efficiency of banking industry has increased substantially in recent years, both for the industry holders and service users and especially for researchers and regulators. Persisting fragmentation of banking sectors in European Union is still high, despite the Banking union progress. The aim of this paper is to contribute to development of methodology for measuring the efficiency of banking sector of Republic of Croatia. Main characteristics of Croatian financial sector is that it is bank-centric system and highly concentrated, with the five biggest banking institutions holding over 80% of total banking assets. More than 90% of banking sector assets are in foreign ownership, like in many other transition countries. Data for all 20 commercial banks operating in Republic of Croatia are included in this research. Non-parametric Data Envelopment Analysis (DEA) under Variable Returns on Scale (VRS) model was used to compare the efficiency results of individual banks by using different pairs of inputs and outputs in the input-oriented models. Fifteen different DEA models were developed, using different variables selected in regression analyses. Kolmogorov-Smirnov test was applied to define the selection of variables for future models. The research represents a contribution to existing researches of banking profitability in Croatia and in general. Findings of the research contribute to appropriate selection of data for the future measurement of bank efficiency in Croatia, but also in other comparable transition countries. It also provides background for future researches of banking efficiency in extended time period, using different models with other pairs of variables or in separate groups of banks according to ownership or size.

Keywords*: Bank efficiency, DEA model, Croatian banks.*

1. Introduction

Stable financial system is crucial precondition for economic growth, performs an essential function in channeling surplus funds from savers to borrowers and contributes to the increase of welfare in economy. In bank-based economies, with banks playing the most important role in financial system, and a small influence of other financial intermediators, as in the Republic

of Croatia, this role is even more important. Their responsibility arises from fact that they collect funds from borrowed deposits and transfers them in different types of loans supporting the economy and business cycle, but simultaneously taking a certain level of risk in collection of these loans. The diversification of their portfolios affects their returns and the level of risk they take, which affects national economy. Ribić and Vakanjac (2017) mention significant changes that have taken place in the Croatian banking sector over the last decade, which affect the profitability of banks - on one hand the legislation is becoming stricter, and on the other hand banking users are increasingly more educated with easier access to information. Also, according to Arčabić (2015), in the financial sector there is more uncertainty and less control over the changes taking place in the environment. All of the above greatly affects the financial results of banks - it is the obligation of banks to regularly publish business reports, and this, combined with available computer tools for statistical data processing, provides a completely new insight regarding banks' profitability.

The most common method for measuring bank profitability is the use of traditional profitability ratios such as return on assets (ROA) and return on equity (ROE). Many authors in their studies use these ratios to compare profitability of national or regional banking sectors (Kohlscheen, Murcia, Koncreras, 2018; Trujilo-Ponce 2013), or combined them with other ratios such as in study of Golubeva, Duljić and Keminem (2019) in which they measure the impact of liquidity risk on profitability of European banks combining ROA and ROE with new liquidity ratios introduced in Basel III regulations. Adjusted traditional ratios can also be used for measuring the impact of income diversification on risk-adjusted performance of banks. Volatility of profitability ratios for each bank as standard deviations of ROA and ROE over some period is used as risk performance measures (Sanya, Wolfe, 2011).

Despite widespread use of this ratios, there are some limitations in usage of this ratios to compare a whole group of individual entities in some industries such as involvement in different operations of individual firms, seasonal factors or different operating and accounting practices (Lesakova, L. 2009), or, in case of banking, limitation due to variables included in the calculations (Tuškan, Stojanović 2016).

This paper investigates the possible models for measuring efficiency of Croatian banks using the mathematical programing approach Data Envelopment Analyses (DEA) for measurement of relative efficiency between different business units, in our cases individual banks. Different DEA models were developed supported by correlation analysis, linear regression models and descriptive statistics performed to support selection of chosen variables. Based on feed-back of regression analyses, combination of different items collected from financial reports of Croatian banks were used as input and output for DEA models.

The need to explore appropriate combination of input and output variables for DEA model and for measurement of bank profitability of Croatian banking sector is obvious due to very small number of literature and studies on this topic.
Data sample consists of all 20 banks operating in Croatian banking sector in 2020. The most significant financial items were extracted from financial reports of individual banks for 2019 year.

On the base of structure of banks financial reports in this study we set the following hypotheses:

H1: Largest banks show better efficiency scores than the small ones

H2: Deposits and loans should be used as the key variables in DEA model to measure an efficiency of Croatian banks

To confirm stated hypotheses, 7 input and 5 output variables were selected from financial reports and combined in 15 different DEA models using different combination of variables, as a result of regression analyses.

DEA analyses is performed by using DEA Frontier software, and the regression analyses is performed using IBM SPSS software.

This paper is divided into the following parts - introduction, in which the reader is briefly introduced to the topic of the paper, literature review, elaboration of the topic describing the situation in the Croatian banking sector during 2018/2019, model and research results as the backbone, and finally, conclusion as a summary of all the information presented in this paper.

2. Literature review

The application of the DEA model for the purpose of measuring profitability is gaining on importance. Specifically, Tuškan and Stojanović (2016) deal with the application of the DEA model for the purpose of measuring the profitability in the European banking sector. Their research covered 28 European banking systems in the period from 2008 to 2012. For the purpose of data analysis, Tuškan and Stojanović use ROA, ROE and CIR (Cost to Income Ratio) indicators. The authors concluded that the application of the DEA model is an important tool for detecting inadequate business strategies that might result in a decline of business activity. Maradin, Olgić - Draženović and Benković (2019) focus on the Croatian banking sector, citing variables that can be used in the DEA model as indicators of business success (asset value, number of employees, interest and non-interest income, deposits and loans).
Goyal et. al. (2019) analyzed the efficiency of the Indian banking sector on the example of 66 banks for the period from 2015 to 2016. Their analysis discovered that the efficiency of the Indian banking sector is only 73.44%. The application of the DEA model has identified weak consolidation of industry as a key problem of the Indian banking sector. In her paper, Repkova (2015) applied the DEA model on the example of Czech commercial banks in a nine-year period (2003-2012). The DEA model was applied under two assumptions - VRS (Variable Return to Scale) and CRS (Constant Return to Scale) - the average efficiency under the VRS assumption was 84-89%, while the latter was 70-78%. The author found that the group of larger banks is less efficient than other banks in the group due to excess deposits and the size of operations. Kočišova (2016) analyse efficiency over the banking systems of European Union countries for the period 2008 – 2014 using DEA method. This study uses total deposits, number of employees and fixed assets as inputs and total loans and other earning assets as outputs. The results indicated that the average cost efficiency moved from 20.90% in case of Poland to 100% in case of United Kingdom, Netherlands, Sweden, Malta, and Luxembourg, but also that the large banking systems show better efficiency than the small ones.
Many studies use regression analyses to support the choice of input and output variables for DEA model. Ouenniche, J., Carrales, S. (2018) analysed the efficiency profile of UK commercial banks using DEA analysis with regression-based feedback using regression for providing DEA with relevance information of the inputs and the outputs chosen by the analyst. Chortareas, Girardone, and Ventouri, (2013) used DEA for estimating bank-efficiency scores for a sample of commercial banks of European Union member states, and then used regression to measure dynamics between financial freedom index and bank efficiency levels.

Titko, Stankevičiene and Lace (2014) analyze the Latvian banking sector, also using the DEA model under the VRS (Variable-Return-Scale) assumption - the authors identified the most successful Latvian banks. They used linear regression analyses to substantiate the variables selection for DEA. Our research followed their methodology for Latvian banking sector, and their study was a base for developing different DEA models for Croatian banking sector presented in this research.

2.1. Data Envelopment Analyses DEA

DEA is widespread accepted method for measuring efficiency of individual decision-making units (DMU) as, for example, financial institutions. It was first defined by Charnes, Cooper and Rhodes (1978) as a non-parametric mathematical programming model applied to selected data that provide the estimation of relations in production function or efficient production. This model is known as CCR DEA model upon its founders. According to Alber et al. (2019), each DMU spent a certain amount of programming *i* inputs and produces *r* of different outputs. If it is supposed that these inputs and outputs are non-negative, and each DMU has at least one positive input and output value, then the productivity of DMU can be expressed in formula:

$$h_j = \frac{\sum_r^s=1 \; u_r y_{rj}}{\sum_i^m=1 \; v_i x_{ij}} \qquad (1)$$

where *u* and *v* are the weights assigned to each input and output. The preconditions for optimal functioning of DEA approach are that the weights for each DMU are deployed subject to the constraint that no other DMU has an efficiency greater than 1 if it uses the same weights, implying that efficient DMUs will have a ratio value of max. 1.
The result of efficiency of particular DMU is the ratio of the total weighted output divided by the total weighted input, expressed in values up to 1, as in formula:

$$h_j = \frac{\sum_r^s=1 \; u_r y_{rj}}{\sum_i^m=1 \; v_i x_{ij}} \leq 1 \text{ for } j = 1 \,..\, n \qquad (2)$$

This CCR DEA model assumes constant returns to scale (CRS) which, in production function, means that any increase in inputs results in equivalent increase in outputs. As it isn't always the case, some researches implemented variable return to scale in DEA model (VRS) (Banker, Charnes, Cooper, 1984). This model is known as BCC model. The main difference between CCR and BCC models is the fact that CCR model does not consider the fact that different business units operate in different scales, and the VRS model ensures that the individual DMU benchmark corresponds to a similar one. In our study VRS model is applied in computing DEA efficiency of Croatian banking sector.
DEA model also differ in selection of input or output-oriented models. In input-oriented DEA, a DMU expresses the potential savings of inputs in the case of operating efficiently. In contrast, with output-oriented DEA, a DMU measures its potential output increase given its inputs do not vary (Taboada et al., 2020).
The selection of input and output variables significantly affects the efficiency results. The available literature on this topic in financial services measurement is unadjusted. Ahn and Lei

(2014) in their study on the specification of the input-output set for DEA-based bank efficiency measurement examine whether the choice of variables is in connection with the criteria upon which bank makes decisions. They found out that there is no consensus between researches on choice of input and output variables, and, because the results of efficiency measurement are sensitive to the choice of variables, the efficiency results are incomparable and inconsistent. The most commonly described approaches or models based on banks behaviour are intermediation approach, production approach and profitability approach. Alder et al. (2019) define that the production approach assumes that financial institutions serve as producers of services for depositors and perform transactions resulting in loans. The intermediation approach is comparable to production approach. It relies on the opinion that banks act as financial intermediaries whose primary role is to obtain funds from savers and transform them into the money they lend to borrowers. This model measures the efficiency of bank in these operations. Profitability approach is based on profit-oriented outputs such as interest income, commission income and other non-interest income. This approach examines how well the bank uses its inputs to produce outputs (Tuškan, Stojanović, 2016).

3. Banking sector in Croatia

According to Croatian National Bank (2019), there are currently 24 active credit institutions in Croatia, 20 of which are banks (Addiko Bank, Agram banka, Banka Kovanica, Croatia banka, Erste & Steiermarkische Bank, Hrvatska poštanska banka, Imex banka, Istarska kreditna banka Umag, J&T banka, Karlovačka banka, KentBank, OTP banka Hrvatska, Partner banka, Podravska banka, Privredna banka Zagreb, Raiffeisenbank Austria, Samoborska banka, Sberbank, Slatinska banka, Zagrebačka banka) and four residential savings banks: HPB, PBZ, Raiffeisen and Wustenrot residential savings bank.

Croatian banking system is still dominated by foreign-owned banks, whose share in total bank assets is 90.2%, of which 48.9% are Italian-owned assets and 29.9% are in Austrian ownership (Croatian National Bank, Banks Bulletin, 2019).

In the structure of financial sector, the most represented are banks (68.2%), followed by mandatory pension funds (15.6%), insurance companies (6.9%), investment funds (3.5%), and leasing companies (3.1%), residential savings banks (1.3%) and voluntary pension funds and factoring (less than 1%) (Croatian Banking Association, 2018). According to Eurostat (2020), the share of the financial sector in the total gross value in 2019 was 6.1% (an increase compared to 2017). The ratio of assets and total assets of five largest banks in Croatia in 2017 was 72.79% and the concentration of the top five banks on the market is relatively high (Croatian Banking Association, 2018).

Struggling to survive, some banks mergers and acquisitions took place in Croatian banking sector in last two years which resulted in an increase of the concentration indicator: in 2018 Veneto merged with Privredna banka Zagreb, Splitska banka merged with OTP, and in 2019 Jadranska banka merged with Hrvatska poštanska banka. Such developments increased the share of assets of the first five banks by approx. 75% to 81.4%, while the Herfindahl-Hirschman asset index in 2019 rose to 1634. The Herfindahl - Hirschman concentration index is most often used as an indicator of industrial concentration and plays a very important role in the decision - making process on mergers or acquisitions. Each bank in some market participates in the value of this index, and the greater share the bank holds, the more relevant is its contribution to the index (Boda, 2014). A higher-than-prescribed HHI index value also increases the likelihood that these banks will hold higher price levels than competitors over a period of time.

In addition, there was an increase in the assets of other largest and systemically important banks in Croatia (Zagrebačka, Erste & Steiermarkische, Privredna banka Zagreb, Raiffeisenbank Austria, OTP, Addiko Bank, Hrvatska poštanska banka) (Croatian National Bank Bulletin, 2019).
In 2018, banks' profits amounted to 5.6 billion HRK. During 2018, there was a decline in interest income, a decline in net income from fees and commissions, net other non-interest income and a decline in other gains (losses). At the same time, positive effects of interest, general and impairment losses and provisions were recorded – due to increased sale of receivables. 2015 was the most unfavorable year in terms of bank profitability, when ROAE decreased by 8.8% and ROAA (Return on Average Assets) decreased by 1.3%. In terms of indicators for 2018, high levels of total profitability are largely the result of above-average high ROAA and ROAE recorded at leading banks, while the remaining banks in the sector recorded significantly lower values of these indicators (Croatian National Bank, 2019).
Only a few studies are available on topics of profitability of Croatian banking sector over the last period. As it was possible to find, only a few authors have attempted to determine the efficiency of Croatian banking sector using different DEA approaches.

Papers published on this topic are presented in Table 1.

Table 1: Studies on bank efficiency of Croatian banking sector

Authors	Research period	DEA model	Input/output variables
Jemric, Vujčić	1995 - 2000	operating approach, intermediation approach	*For operating approach:* Input: interest and related costs, commissions, labour costs, capital related administrative costs Output: Interest and related revenues, non-interest revenues *For intermediation approach:* Input: Fixed assets and software, number of employees, total deposits Outputs: Total loans extended, short-time securities issued by official sectors
Jurčević, Žaja	2005 - 2009	profitability approach	Input: Interest expenses, non-interest expenses, other expenses (labour and capital related) Output: Interest income, non-interest income, other income from business activity
Davidovic, Uzelac, Zelenovic	2006 - 2015	intermediation approach	Input: interest and non-interest expenses Output: interest and non-interest revenues

Source: Author's own representation (2021)

As seen from the Table 1, only the authors in the first study used deposits and loans for variables in the applied DEA methodology, although they are common variables in other bank efficiency DEA related studies (Ouenniche, Carrales, 2018, p.561, Balcerzak et all, 2017, p.59).

4. Research model

The study evaluates data for twenty banks operating in Croatia in 2019 year: Addiko Bank, Agram banka, Banka Kovanica, Croatia banka, Erste & Steiermarkische Bank, Hrvatska poštanska banka, Imex banka, Istarska kreditna banka Umag, J&T banka, Karlovačka banka,

KentBank, OTP banka Hrvatska, Partner banka, Podravska banka, Privredna banka Zagreb, Raiffeisenbank Austria, Samoborska banka, Sberbank, Slatinska banka and Zagrebačka banka. The research was conducted based on data from the banks' financial reports from June 2019, published on the database of Croatian National Bank. The amounts in financial reports are expressed in thousands of HRK.

In the initial phase of the research, the input and output variables were defined. During the analysis of the financial reports, seven input variables were selected: customer deposits, profit /loss due to owners, equity, interest expense, commission expense, staff expense and other administrative expenses; and five output variables: loans, securities, interest income, commission income and net profit/loss. We considered the selection of the variables based on their significance in reports.

Some selected input variables represent liabilities in banks' balance sheets such as deposits from customers. It generates costs referred to other selected variables expressed as expense in banks' profit and loss account, such as interest expenses and commission expenses. Also, selected output variables represent assets in banks' balance sheet such as loans and securities and related income such as interest income and commission income expressed in profit and loss account.

Table 2: Selection of potential variables

	Input		**Output**
Input 1	Deposits from customers	Output 1	Loans
Input 2	Profit (loss) due to owners	Output 2	Securities
Input 3	Equity	Output 3	Interest income
Input 4	Interest expenses	Output 4	Commission income
Input 5	Commission expenses	Output 5	Net operating profit (loss)
Input 6	Staff expenses		
Input 7	Other administrative expenses		

Source: Processed by the author's (2021)

Correlation analysis of selected variables was performed using IBM's SPSS program. The correlation results for inputs and outputs are shown in figures below.

Table 3: Correlation of input variables in SPSS software

Item		**Deposits from customers**	**Profit (loss) due to owners**	**Equity**	**Interest expense**	**Commission expense**	**Staff expense**	**Other adm. expenses**
Deposits from customers	Pearson correlation	1	0,975**	0,834**	0,966**	0,685	0,982**	0,948**
	N	20	20	20	20	20	20	20
Profit (loss) due to owners	Pearson correlation	0,975**	1	0,854	0,923**	0,613	0,955**	0,883**
	N	20	20	20	20	20	20	20
Equity	Pearson correlation	0,834**	0,853**	1	0,923**	0,597	0,818**	0,884**
	N	20	20	20	20	20	20	20
Interest expense	Pearson correlation	0,966**	0,923**	0,923**	1	0,596	0,915**	0,920**
	N	20	20	20	20	20	20	20

Item		Deposits from customers	Profit (loss) due to owners	Equity	Interest expense	Commission expense	Staff expense	Other adm. expenses
Commission expense	Pearson correlation	0,685	0,613	0,597	0,596	1	0,733	0,739
	N	20	20	20	20	20	20	20
Staff expense	Pearson correlation	0,982**	0,955**	0,818**	0,915**	0,733	1	0,945**
	N	20	20	20	20	20	20	20
Other administrative expenses	Pearson correlation	0,948**	0,883**	0,884**	0,920**	0,739	0,945**	1
	N	20	20	20	20	20	20	20

Source: Processed by the author's (2021)

The results of correlation of input variables reveals that the variables are mostly in strong correlation. Deposits from customers were selected, in combination with two other mutually least correlated variables – commission expense, interest expense and profit/loss due to owners. Correlation of output variables presented in Table 4 reveals a strong relationship between almost all variables, so each of them can be used separately as a singular output for regression model with selected input variables.

For regression analysis, with the aim of determining the appropriate variables for the DEA model, all of the output variables were selected except net operating profit/loss since it shows the strongest correlation with all other variables.

Individually, as presented in Table 5, selected variables are loans, securities, interest income and commission income as dependent variable and deposits from customers, commission expense, interest expense and profit / loss due to owners as predictors.

Table 4: Correlation of output variables in SPSS software

Item		Loans	Securities	Interest income	Commission income	Net operating profit/loss
Loans	Pearson Correlation	1	0,826**	0,817**	0,965**	0,971**
	N	20	20	20	20	20
Securities	Pearson Correlation	0,826**	1	0,623	0,913**	0,892**
	N	20	20	20	20	20
Interest income	Pearson Correlation	0,817**	0,623	1	0,778	0,788
	N	20	20	20	20	20
Commission income	Pearson Correlation	0,965**	0,913**	0,778	1	0,950**
	N	20	20	20	20	20
Net operating profit/loss	Pearson Correlation	0,971**	0,892**	0,788	0,950**	1
	N	20	20	20	20	20

Source: Processed by the author's (2021)

Regression analysis determined that most of the independent variables were statistically significant (p-value less than 0.05), so it is possible to combine them as explanatory variables for outputs to create models for testing bank profitability by the DEA method. Inputs with statistically significant coefficient will be used with the output variable in one model. Those variables whose significance exceeds 0.05 (customer deposits, profit / loss due to owners, commission expense and interest expense in combination with interest income) were combined with other statistically significant variables.

Table 5: Regression analysis of selected variables

Dependant variable	R Square Adjusted	Sig.	Predictors	Sig.
Loans	0,999	0,000	Deposits from customers	0,000
			Commission expense	0,000
			Interest expense	0,000
			Profit/loss due to owners	0,000
Securities	0,984	0,000	Deposits from customers	0,000
			Commission expense	0,000
			Interest expense	0,003
			Profit/loss due to owners	0,000
Interest income	0,796	0,000	Deposits from customers	0,921
			Commission expense	0,548
			Interest expense	0,027
			Profit/loss due to owners	0,992
Commission income	0,997	0,000	Deposits from customers	0,000
			Commission expense	0,000
			Interest expense	0,383
			Profit/loss due to owners	0,000

Source: Processed by the author's (2021)

By results of regression analysis, 15 models for DEA analysis were defined. Models include different combinations of input and output variables - six models with two variables, five models with three variables, three models with four variables, and one model with six variables. Efficiency of each model is performed in DEA Frontier software, using input-oriented model which examines whether individual unit uses to much input to produce current level of outputs.

Table 6: 15 developed DEA models

MODELS	Inputs	Outputs
MODEL 1 (M1)	Deposits from customers	Loans
MODEL 2 (M2)	Commission expense	Loans
MODEL 3 (M3)	Profit/loss due to owners	Securities
MODEL 4 (M4)	Interest expense	Securities
MODEL 5 (M5)	Interest expense	Interest income
MODEL 6 (M6)	Deposits from customers/Profit/loss due to owners	Commission income
MODEL 7 (M7)	Commission expense/Interest expense	Commission income
MODEL 8 (M8)	Deposits from customers/Commission expense	Loans/Interest income/Securities
MODEL 9 (M9)	Profit/loss due to owners/ Interest expense	Securities/Commission income
MODEL 10 (M10)	Interest expense/Profit/loss due to owners	Interest income

MODELS	Inputs	Outputs
MODEL 11 (M11)	Interest expense/Commission expense	Interest income/Commission income
MODEL 12 (M12)	Deposits from customers	Interest income/Net operating profit (loss)
MODEL 13 (M13)	Profit/loss due to owners	Commission income
MODEL 14 (M14)	Interest expense/Deposits from customers	Commission income
MODEL 15 (M15)	Commission expense/Deposits from customers/Interest expense	Loans/Interest income/Commission income

Source: Author's developed (2021)

4.1. Results of the research

As already mentioned, 15 models have been created to analyze the profitability of the Croatian banking sector. Each combination was tested using the DEA method and results ranged from zero (not profitable at all) to one (maximally profitable). Also, the prerequisite for the analysis of data by using DEA method is positive values, therefore those variables whose numerical value was negative (profit / loss due to owners) in the case of Croatia bank and J&T Bank were replaced by zero (these two banks recorded operating loss as for 2019). DEA data analysis was processed under the VRS (Variable Return Scale) assumption. The results of the DEA analysis are shown in the summary table below.

Table 7: Results of DEA analyses for M1 – M8 models

Banks	M1	M2	M3	M4	M5	M6	M7	M8
Addiko	0,895	0,713	0,146	0,159	0,425	0,626	0,868	0,995
Agram	0,807	0,607	0,000	0,068	0,302	0,422	0,477	0,807
Kovanica	1	0,854	0,000	0,141	0,461	0,475	0,719	1
Croatia	0,765	0,736	0,000	0,141	0,336	1	0,575	0,825
Erste	1	0,664	0,033	0,027	0,542	0,831	0,606	1
HPB	0,802	0,106	1	1	0,584	1	1	1
IMEX	0,790	0,902	0,060	0,153	0,357	0,317	0,704	0,974
IKB	0,696	1	0,000	0,291	0,980	0,453	1	1
J&T	0,748	1	0,000	0,141	0,247	1	1	1
Karlovačka banka	0,730	0,387	0,000	0,227	0,614	0,531	0,592	0,730
KENT banka	0,885	0,842	0,000	0,119	0,429	0,404	0,594	0,937
OTP	1	0,809	0,073	0,180	1	0,578	1	1
Partner	0,241	0,453	0,000	0,108	0,293	0,287	0,691	0,947
Podravska	0,844	0,279	0,000	0,127	0,501	0,626	0,494	0,844
Privredna banka Zagreb	1	0,473	0,858	1	1	1	1	1
Raifeisenbank	0,793	0,139	1	1	0,599	1	0,986	1
Samoborska banka	1	0,360	0,000	1	1	1	1	1
Sberbank	1	0,776	0,402	0,232	0,332	0,417	0,537	1
Slatinska banka	0,863	0,411	0,000	0,208	0,551	0,593	0,584	0,863
Zagrebačka banka	1	1	1	1	1	1	1	1

Source: Author's developed with DEA software (2021)

Table 8: Results of DEA analyses for M9 – M15 models

Banks	M9	M10	M11	M12	M13	M14	M15
Addiko	0,343	0,738	0,868	1	0,337	0,626	1
Agram	0,284	0,694	0,611	0,684	0,232	0,422	0,807
Kovanica	0,168	0,838	1	1,000	0,000	0,475	1
Croatia	1	1	0,674	0,459	0,000	0,311	0,871
Erste	0,831	1	0,689	0,974	0,831	0,544	1
HPB	1	0,996	1	0,739	1	1	1
IMEX	0,248	0,863	0,876	0,610	0,000	0,317	0,981
IKB	0,768	1	1	0,515	0,303	0,768	1
J&T	0,995	0,995	1	0,728	0,000	0,467	1
Karlovačka banka	0,485	0,748	0,621	0,662	0,227	0,531	0,811
KENT banka	0,216	0,816	0,826	0,701	0,110	0,404	0,946
OTP	0,774	1	1	1	0,349	0,774	1
Partner	0,123	0,551	0,972	0,602	0,000	0,287	0,972
Podravska	0,570	0,934	0,502	0,614	0,495	0,626	0,918
Privredna banka Zagreb	1	1	1	1	1	1	1
Raifeisenbank	1	0,850	0,986	0,879	1	1	1
Samoborska banka	1	1	1	1	1	1	1
Sberbank	0,402	0,786	0,785	0,989	0,270	0,417	1
Slatinska banka	0,430	1	0,702	0,747	0,185	0,593	0,955
Zagrebačka banka	1	1	1	1	1	1	1

Source: Author's developed with DEA software (2021)

In terms of bank performance, the best results were obtained by Zagrebačka banka in all models. Other banks that show high efficiency results are Privredna banka Zagreb, Hrvatska poštanska banka, OTP banka, Raiffeisen Bank and Samoborska banka. These banks recorded a high or relatively high value of the minimum. All these banks except Samoborska banka are among the largest banks in Croatian banking market. From presented results it is obvious that the biggest banks in system show the best efficiency result so we can conclude that our first hypotheses that largest banks show better efficiency scores than the small ones are confirmed.

Table 9: DEA efficiency results of Croatian banks calculated in M1 – M15 models

Banks	Median	Min	Max	St.dev
Addiko	0,713	0,146	1,000	0,301
Agram	0,477	0,000	0,807	0,265
Kovanica	0,719	0,000	1,000	0,387
Croatia	0,674	0,000	1,000	0,354
Erste	0,831	0,027	1,000	0,321
HPB	1,000	0,106	1,000	0,249
IMEX	0,610	0,000	0,981	0,350
IKB	0,768	0,000	1,000	0,331
J&T	0,995	0,000	1,000	0,402
Karlovačka banka	0,592	0,000	0,811	0,228
KENT banka	0,594	0,000	0,946	0,330
OTP	1,000	0,073	1,000	0,324
Partner	0,293	0,000	0,972	0,341
Podravska	0,570	0,000	0,934	0,272
Privredna banka Zagreb	1,000	0,473	1,000	0,138
Raifeisenbank	1,000	0,139	1,000	0,235
Samoborska banka	1,000	0,000	1,000	0,373

Banks	Median	Min	Max	St.dev
Sberbank	0,537	0,232	1,000	0,291
Slatinska banka	0,593	0,000	1,000	0,293
Zagrebačka banka	1,000	1,000	1,000	0,000

Source: Author developed from DEA results (2021)

Looking at the medial values, the list of successful banks, in addition to those already mentioned, also includes Erste banka and J&T banka. In contrast, the least successful banks are, based on the results, Partner banka and Agram banka. It should be noted that in some models a few banks show 0 efficiency. The reason is that some banks record a loss for 2019, so under item profit/loss due to owners 0 is entered because DEA software couldn't operate with negative numbers. Also, 11 banks don't operate with securities, and it is obvious from efficiency results in models with this variable.
In order to identify the most successful models (i.e. the models that give the best results), descriptive statistics measures (median, maximum, minimum and standard deviation) were calculated for each of 15 models and for each bank according to the models.

Table 10: Descriptive statistics of DEA M1 – M15 models

Model	Median	Min	Max	S.Dev	Model	Median	Min	Max	S.Dev
M1	0,854	0,241	1,000	0,177	M9	0,669	0,123	1,000	0,336
M2	0,688	0,106	1,000	0,284	M10	0,965	0,551	1,000	0,134
M3	0,000	0,000	1,000	0,390	M11	0,924	0,502	1,000	0,167
M4	0,170	0,027	1,000	0,380	M12	0,743	0,459	1,000	0,188
M5	0,521	0,247	1,000	0,269	M13	0,251	0,000	1,000	0,384
M6	0,609	0,287	1,000	0,269	M14	0,568	0,287	1,000	0,257
M7	0,712	0,477	1,000	0,208	M15	1,000	0,807	1,000	0,063
M8	1,000	0,730	1,000	0,084					

Source: author's developed (2021)

Model 3, model 4, and model 13 were evaluated as the least efficient which is not a surprise because both model 3 and model 4 involves securities as a single output, and only 9 of 20 banks are involved in this kind of trading operations. The lowest medial values and the lowest minimum values were recorded in the mentioned models. Also, two banks reported a loss under item profit/loss due to owners, and also under net operating profit (loss), so these affect efficiencies for these models. Model 1, model 2, model 8, model and model 15 were rated as the most successful models. In these models, the minimum value is high and the highest median values were recorded. Also, the minimum standard deviation was determined for models 1, 10, 11 and 15. Common variables in the four most efficient models are deposits from customers, loans, interest income and interest expense. Common variables recorded in the three least efficient models are profit/loss due to owners and securities. The conclusion is that, in the future models and approaches in measuring Croatian bank's efficiency, securities and profit/loss due to owners should be avoided, as the sole variable, but they can be combined with other variables, such as loans or interest expense.

As shown in Table 10, both the lowest median value and the lowest difference between minimum and maximum is the largest for M3 and M4 model and amounts 1 and 0,97.
Kolmogorov-Smirnov (K-S) test was performed joining and comparing two models with securities with other models to test the null hypothesis that all samples are from same

distribution (Titko, J., Stankevičienė, J., Lāce, N. (2014). The test was also performed for all pairs of models. Results for pairs where significancy is at <.001 level and the null hypothesis is rejected are presented in Table 11 (significance at 0,05 level).

Table 11: Results of Kolmogorov-Smirnov two-sample test

Pair of models	Significance	Pair of models	Significance	Pair of models	Significance
M3M1	<.001	M3M10	<.001	M4M1	<.001
M1M3	<.001	M3M9	<.001	M4M2	<.001
M3M5	<.001	M3M12	<.001	M4M5	<.001
M3M2	<.001	M3M14	<.001	M4M6	<.001
M3M6	<.001	M3M15	<.001	M4M8	<.001

Source: Author's developed from SPSS program (2021)

To find appropriate variable to include in future models for evaluating the efficiency of Croatian banks, selection was performed with pairs of models where the null hypothesis (samples are drawn form same distribution) was confirmed. Appropriate models are presented in Table 12.

Table 12: Results of Kolmogorov-Smirnov two-sample test

Pair of models	Sig.	Common variable	Pair of models	Sig.	Common variable
M1M8	.082	Deposits from customers Loans	M3M13	.082	Profit/loss due to owners
M14M6	.978	Deposits from customers Commission income	M12M6	.082	Deposits from customers
M2M7	.082	Commission expense	M1M12	.082	Deposits from customers
M11M8	.329	Commission expense Interest income	M9M6	.560	Profit/loss due to owners Commission income
M14M2	.819	No common variable	M8M15	.978	Deposits from customers Commission expense Loans Interest income
M2M5	.329	No common variable	M6M5	.560	No common variable

Source: authors developed from SPSS program (2021)

Deposits from customers are a repeating variable in five models. The second most common variable is commission expense (three models) and interest income, loans and profit/loss due to owners in two models. It can be concluded that loans don't make significant difference. To test the possibility that deposit from customers make a significant difference, and should be included in future models, a regression analysis was performed. DEA efficiency results in models M1, M6, M8, M12 and M14 were used as a dependent variable, and inputs and outputs of each model as predictors. The test was performed with and without deposits from customers as one of the input variables. Results do not provide the evidence of significance of variable deposits from customers. Adjusted R square in models M6, M8 and M14 was higher without deposits from customers as one of the predictors than in cases when it was included in analysis. Therefore, the conclusion is that, although deposits and loans are the most significant items of bank's financial reports, we cannot confirm our second hypothesis that deposits and loans should be used as the key variables in DEA model to measure the efficiency of Croatian banks. Finally, the adjusted R^2 was compared in all models and the highest value was achieved in

model M3 where R^2 amounted .927, and in model M13 .872. High value was also reached in M4, M5 and M14 models. The results of our study are quite similar to the results presented in Titko (2014) for Latvian banking sector. Future researches on this topic should include different pairs of models, and possible selection of certain groups of banks according to ownership or size.

5. Conclusion

The aim of the paper was to perform measure of efficiency of overall Croatian banking sector, and to examine appropriate variables to be included in future models for evaluating bank efficiency. Two research hypotheses were tested in this research. The first hypotheses were that large banks show better efficiency scores than the small ones, and the second one that deposits and loans should be used as the key variables in DEA model to measure an efficiency of Croatian banks. The selection of variables was performed, and through regression analysis, suitable variables for the DEA models were selected. DEA analyses under VRS assumption has been applied over 15 models with different combinations of input and output variables. The best profitability indicators were achieved by Zagrebačka banka. This bank has achieved the best performance indicated by an efficiency score of 1 in all 15 models. Other banks that obtained high average efficiency scores are Privredna banka Zagreb, Hrvatska poštanska banka, OTP banka, Raiffeisen Banka and Samoborska banka. This result proves our hypotheses that largest banks show better efficiency than the small ones and is consistent with market position of these banks. DEA method has some limitations, such as selection of variables and impossibility of excluding undesirable inputs, but it is valuable tool for comparing values obtained by different units. Common variables in the four most efficient models are deposits from customers, loans, interest income and interest expense. Banks with lower level of efficiency should control these elements in order to improve efficiency performance. Kolmogorov-Smirnov test results showed that the second hypotheses that deposits and loans should be used as the key variables in DEA model to measure an efficiency of Croatian banks wasn't confirmed. Although the most significant in financial reports of all banks, omission of this items from models do not result in reduction of adjusted R^2 in these models. Models which include securities and/or profit/loss due to owners as a sole variable are not appropriate for Croatian banking sector, but could be combined with other variables. Future research is needed to identify other significant variables which can affect bank efficiency performance. It should include different pairs of variables in models, and could be applied to a certain group of banks according to their ownership or size.

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