International Journal of Business and Economic Sciences Applied Research
IJBESAR
ijbesar.ihu.gr

Banking Sector Race to Efficiency during the COVID-19 Pandemic Crisis in Croatia: Does the Size Matter?

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ARTICLE INFO

Article History

Received 31 August 2022;
Accepted 15 December 2022

JEL Classifications
D24, G21

Keywords:
Croatian banking sector, total factor productivity, size, COVID-19 pandemic crisis, Malmquist DEA index

ABSTRACT

Purpose:
The consolidation of the banking market in Croatia is characterized by a decreasing number of banks, especially small banks. The inability to remain in the market is often the result of the inability to maintain sustainable efficiency over time. Therefore, the main aim of the study was to determine whether small banks can successfully participate in the efficiency race with large banks. Furthermore, it was essential to clarify whether the efficiency gap arises from technical or scale efficiency. Finally, we also analyse how the COVID-19 pandemic crisis has affected efficiency and the difference between large, medium, and small banks.

Design/methodology/approach:
The efficiency development of the Croatian banking sector over eight years is examined using the Malmquist - DEA performance measure under the assumption of variable returns to scale (BCC model) and using the input-oriented DEA model. We use the intermediary approach for defining input and output variables, and the study covers the period from 2013 to 2020. Data are taken from ORBIS database.

Findings:
Banks in Croatia increased their total factor productivity by 2.2% on average, mainly due to an increase in technological change (1.93%), implying innovation and new banking services. Moreover, the COVID-19 pandemic crisis has further accelerated the race for efficiency. Indeed, the results show that the improvement in efficiency was more remarkable than the average of the period studied, especially in terms of technical efficiency (1% in 2020 compared to the mean of the period of 0.28%), but also due to technological efficiency (2.02% in 2020 compared to the mean of the period of 1.93%). Finally, the COVID-19 pandemic crisis affected efficiency in different ways with respect to the size of banks. Large banks improved their total factor productivity by 7.19%, small banks by 2.64%, and medium-sized banks reduced it by 1.38%. In addition, large banks achieved efficiency improvements due to technological change, while small banks focused on both technical (1.70%) and technological (0.98%) efficiency improvements.

Research limitations/implications:
One of the limitations of the paper was that during period some takeovers were conducted in Croatian banking sector and therefore some banks were omitted from sample. Additionally, ORBIS database does not cover some data that could be better as indicators of outputs. Therefore, future research on this topic could include other input-output variables such as assets/labor and revenue (income). Our results suggest that innovation in the delivery of banking services is critical to maintaining the race for efficiency. Therefore, our results may lead managers to focus on technological change in the long run, but especially in times of crisis. Managers of small banks should focus on both managerial and technological improvements.

Originality/value:
This study primarily makes an empirical contribution to the topic of efficiency in the banking sector. We have analysed the impact of the COVID -19 pandemic crisis on banking

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The present study has been presented at the 14th International Conference "Economies of the Balkan and Eastern European Countries", EBEEC 2022, Florence, Italy (ebeec.ihu.gr)
DOI: 10.25103/ijbesar.152.02

efficiency, with particular attention to the size effect, which, to our knowledge, has not yet been thoroughly studied. Future research could build on this study by taking into accountother input-output variables and sample of CEE countries.

1. Introduction

Over the last 20 years, many transition countries have undergone privatization and restructuring of the banking sector. The privatization process has been characterized primarily by the acquisition of domestic banks by foreign banks, resulting in a more competitive market, technological advances, better risk management, and generally higher efficiency. New standards for market-oriented banking practices were introduced. A similar process took place in Croatia. However, many banks also failed during this period. In general, after peaking at 61 in 1997, the number of banks has steadily declined to 23 in 2021, with a sharp decrease in the number of small banks after the financial crisis and pandemics (16 in 2008 and 12 in 2021). Thus, most of the failed banks were small banks that could not cope with the higher standards of the central bank and the financial crises, resulting in lower profitability. On the other hand, the market leaders, i.e., the big banks, dominated the market throughout the period, with a market share of more than 40% (44% in 2021) for the two biggest banks and 80% (80.1% in 2021) for the five biggest banks. Thus, the market has become increasingly concentrated, virtually neglecting the importance of small banks.

The questions that arise from this are- Why small banks couldn't keep their place in the market and was the pandemic a major factor? Can small banks maintain their efficiency at the level of large banks? Are large banks more efficient than small banks?

The theory generally explains the higher efficiency levels of large banks in terms of economies of scale and scope. Economies of scale imply that the firm's resources are used more efficiently to produce multiple units of the same service package. Economies of scope indicate that some resources are used more efficiently to deliver numerous services rather than just one. In particular, large banks are generally more efficient than small banks because of the growth in scale that leads to cost savings. Namely, fixed costs are spread across a larger number of services (Rose and Hudgins, 2010). Studies such as Hughes et al., 2001, Jemrić and Vujčić (2002), Drake and Hall (2003), Hasan and Marton (2003) confirm the theory that large banks are more efficient.

However, some studies suggest that the average cost curve in the banking sector is roughly U-shaped. Costs decrease with size up to a certain value of total assets, and unit costs increase beyond that value. These results suggest that medium-sized banks have higher scale efficiency than large and small banks (Berger et al., 1987; Stimpertand Laux, 2011). In addition, Tariq and Arfeen (2012) find that banks benefit from economies of scale as their size increases. Still, larger banks begin to experience scale disadvantages, and then very large banks start to share economies of scale again.

Moreover, Rose and Hudgings (2010) conclude that there is evidence of at least moderate economies of scale in banking and that most studies find weak or no evidence of economies of scope. Even more recent studies such as Benito (2008), Almumani (2013), Karray and Chichti (2013), Řepková (2014) do not confirm the thesis that larger banks are more efficient than small banks. Finally, Andries andUrsu (2016) show that large banks were more sensitive to cost efficiency than small banks during the financial crisis. On the other hand, large banks were less affected by the crisis regarding profit efficiency.

Regarding the COVID-19 crisis, Carletti et al. (2020) point to mid-sized banks and emphasize that they will suffer because they will not manage the cost efficiencies and IT investments that are critical in the new environment. In addition, digitalization will receive a substantial boost, and new entrants will challenge banks. This means that banks will have to increase their efficiency. Similarly, Marcu (2021) also states that banking innovations and digital strategies are essential factors. More specifically, the banking system has continuously adapted to customer expectations and the need to reduce costs while the pandemic accelerated digitalization in the banking sector. In this sense, digitalization can be considered as an important driver of cost-efficiency. The question is whether small and medium-sized banks can follow the investment volume of IT. In terms of bank size, Korzeband Niedziółka (2020) use a sample of 13 Polish banks to show that the largest banks are the most resilient to the impact of the pandemic. Likewise, Bernardelli et al. (2021) show that large retail banks were less affected than medium-sized banks with relatively rich corporate portfolios. Moreover, Demirgüç-Kunt, A. et al. (2021) found that larger banks experienced larger declines in their stock returns, reflecting their larger expected role in coping with the crisis. This implies that large banks were forced to be more efficient to maintain profitability stability for their stakeholders. Finally, concerning the COVID-19 crisis, Dissanayake and Wu (2021) found that countries with efficient banking institutions could lend significantly more to businesses and households during the crisis. Moreover, these countries are associated with better output growth after the pandemic. Crucial efficiency aspects are generally lower bank overhead costs and net interest margins.Finally, the banking sector is an important channel for financing investment, especially in bank-oriented financial systems. Increasing the efficiency of the banking sector thus contributes to economic growth and prosperity (Hashem, 2016), which seems particularly important in times of crisis and post-crisis.

Therefore, there is no consensus on the relationship between bank size and efficiency. Moreover, the literature on pandemics and their impact on the banking system is still developing, so this paper attempts to contribute by

DOI: 10.25103/ijbesar.152.02

analyzing the effect of COVID-19 pandemic on the banking sector efficiency in Croatia. Also, the results regarding the size importance vary depending on the countries in the sample, the period studied, the measurement of efficiency, and the methodology used. Empirical studies for Central and Eastern European countries (CEE) are rare. Therefore, there is a need to investigate this issue further. Thus, this paper examines bank size as an explanatory variable for efficiency with a special aspect of the COVID-19 effects.

Hence, the objective of this paper is to analyze the total factor productivity change of Croatian banks for the period 2013-2020. Namely, in order to estimate different kinds of efficiencies, i.e. technological changes and technical efficiency changes, the Malmquist – DEA index, based on an input oriented BCC model, was chosen for this analysis. Additionally, the goal is to determine the existence of a size effect in the Croatian banking sector and whether it is due to technical or scale efficiency. The final aim is to capture the time dimension of efficiency development in small, medium, and large banks, with a special focus on total factor productivity changes in the time of pandemic COVID-19.

Malmquist DEA index is applied in the analysis of the Croatian banking sector in order to investigate total factor productivity changes. Jemrić and Vujčić (2002) used the panel data in measuring the efficiency of Croatian banks, but they applied just a number of individual cross-section analyses. DEA analysis has a stationary character and delivers a snapshot of providers and their efficiency, while Malmquist DEA index provides more reliable evidence of their performance by tracking the performance of each provider through sequence periods. Therefore, calculating the Malmquist DEA index on panel data resolves the major weakness of DEA (Sun, 2011).

The rest of the paper is organized as follows. The next section presents conceptual comparative framework of banking efficiency and literature review of empirical results on size effects on bank efficiency. The third section explains the methodology and the data sample, while the fourth section discloses and discusses the empirical results and provides an economic interpretation of the results. The last section is the conclusion, which summarizes the study results and provides suggestions for future research.

2. Review of Literature

2.1 Conceptual comparative framework of banking efficiency

Banks are a very important factor for the whole economy, especially in bank-oriented financial systems. Indeed, the banking sector transfers funds and finances investments, thereby increasing the efficiency of the whole economy and contributing to economic growth. In this sense, the efficiency of the banking sector is very important (Alber et al., 2019).

According to Mokhtar et al. (2016), the concept of efficiency measurement was first discussed by Farrell (1957), who divided it into technical efficiency (TE) and allocative efficiency (AE), with further subdivision into cost and profit efficiency. A market participant is said to be technically efficient if it is able to produce the maximum amount of output with a given set of inputs or use fewer inputs to achieve a given level of output. An efficient bank can achieve a maximum value of one compared to an inefficient bank. In addition, a producer is said to be allocative efficient if it can use inputs at an optimal ratio given input prices and production technologies. A participant is cost efficient if he is able to produce a given output without wasting resources, i.e., at minimum cost. Similarly, it is considered profit efficient if it is able to maximise the profit from the allocated inputs and outputs (Mokhtar et al., 2016).

There are two general methods for measuring efficiency - the parametric and nonparametric approaches. The parametric approach allows for noise in the measurement of inefficiency, but requires the specification of the production functional form. The nonparametric approach, on the other hand, is simple, easy to calculate, and does not require specification of functional form. However, it has the disadvantage that all deviations from the best-practise frontier are attributed to inefficiency. Common parametric methods are the Stochastic Frontier Approach (SFA), Thick Frontier Approach (TFA), and Distribution Free Approach (DFA), while nonparametric techniques are Free Disposal Hull Analysis (FDH) and Data Envelopment Analysis (DEA) (Mokhtar et al., 2016). Most studies use either nonparametric or parametric techniques in their respective studies on banking efficiency.

With respect to the banking sector efficiency, there are two main approaches used in the banking theory literature: the intermediation approach and the production approach. The production approach assumes that financial institutions act as producers of services, i.e., banks use physical inputs such as labour and capital to provide deposits and loans. The intermediation approach views banks as intermediaries between savers and borrowers. More specifically, banks are viewed as financial intermediaries that use labour and deposits and convert them into loans and other profitable assets. The intermediation approach is suitable for banks where most activities consist of converting large deposits and other funds into loans and investments and is more appropriate for evaluating financial institutions as a whole, while the production approach is more appropriate for evaluating the efficiency of bank branches (Mokhtar et al., 2016; Alber et al., 2019).

2.2 Previous studies

The relationship between the size of a bank and its efficiency is relatively well represented in the economics literature, with Rose and Hudgings (2010) providing detailed explanations. They point to the greater efficiency of large banks resulting from economies of scale and scope. However, previous and recent empirical studies disagree on the relationship between bank size and efficiency. On the one hand, many studies confirm that larger banks are generally more efficient than small banks due to economies of scale and scope (Hughes et al., 2001). Moreover, there seems to be

DOI: 10.25103/ijbesar.152.02

a strong relationship between bank size and technical and scale efficiency, as evidenced by the study of Drake and Hall (2003) for the banking sector in Japan. On the other hand, some recent studies have confirmed the opinion of a U-shaped average cost function (Stimpertand Laux, 2011; KarrayandChichti, 2013; Řepková, 2014).

The empirical literature confirming the importance of banks' size for their efficiency mainly relies on economies of scale and scope in its explanations (Hughes et al., 2001, Drake and Hall, 2003). Hasan andMarton (2003), who examined the performance and efficiency of the banking sector in Hungary for the period 1993-1998 found, among other things, that there was an inverse relationship between size and inefficiency, i.e., that larger institutions were relatively more efficient. Drake et al. (2006), who studied the impact of macroeconomic and regulatory factors on bank efficiency in Hong Kong, found a very strong relationship between size and efficiency in terms of pure technical efficiency. Namely, the largest banks performed better than smaller banks. They also confirmed the importance of environmental factors in significantly altering the relationship between size and technical efficiency.

Andrieş and Cocriş (2010) used both the DEA and the SFA method and analyzed the efficiency of the main banks in Romania, the Czech Republic, and Hungary for period 2000-2006. Their results showed that bank size, annual inflation rate, degree of banking reform and interest rate liberalization, and ownership form are the most important determinants of efficiency. Kristo (2013) used cost efficiency indicators based on the SFA methodology to understand the efficiency of the Albanian banking system. The author concluded that the largest banks seem to be more efficient than the smaller banks. However, some papers find no differences between efficiency when bank size is considered. For example, Fernando and Nimal (2014), analyzing the technical efficiency of the banking sector in Sri Lanka for the period 2007-2011, concluded that there were no significant differences in efficiency between small and larger banks. They also concluded that although most large banks operate with increasing returns to scale, and small banks operate with decreasing returns to scale, this difference does not exist.

Recent studies do not support the existence of the size effect over time. Moreover, some studies suggest that efficiency depends on a particular environment and that small banks seem to be more efficient under certain circumstances. First, using the sample of Spanish commercial, savings, and cooperative banks for the period 1970-2006, Benito (2008) finds that the relationship between size and growth is not stable over time but changes depending on the competitive environment of banks. However, he concludes that larger banks have grown at the same rate or faster than smaller banks and that the size distribution of Spanish banks will become more skewed, and concentration will tend to increase in the coming years. Second, Kwan (2006) examined the cost efficiency of commercial banks in Hong Kong using the SFA method. The results showed that the average large bank was less efficient than the average small bank, i.e., there is a positive correlation between bank size and inefficiency. It is assumed that the size effect is related to the difference in portfolio composition.

In addition, Staub et al. (2010) studied cost, technical, and allocative efficiency for Brazilian banks using cost data from 2000 to 2007 and DEA methodology. Their results showed that size is not critical for economic efficiency. However, the results also showed that micro banks are the most efficient in terms of allocative efficiency, confirming the niche market hypothesis, which states that small banks have cost advantages to operate in niche markets. The statistical results were not significant. Also, size was not a significant determinant of technical efficiency.

Moreover, Almumani (2013) measured the relative efficiency of banks in Saudi Arabia for the period 2007-2011 using a basic DEA methodology. Interestingly, the results showed that the relative efficiency of smaller banks is significantly better than that of medium and larger banks. Besides that, banks with higher capital adequacy ratios were less efficient. Banks with higher capital ratios are less risky and manage safer and lower-yielding portfolios, which may explain the results.

Also, using a panel of 402 commercial banks from 15 developing countries over the period 2000-2003, Karrayand Chichti (2013) have shown that inefficiency in all banks is mainly due to pure technical inefficiency, while high levels of scale inefficiency also characterize the largest banks. Their results are contrary to the basic theoretical assumptions. The explanation is that small banks are more focused on non-interest activities, which can be explained by better specialization and/or by offering differentiated services to their customers.

Řepková (2014) analyzed the efficiency of the Czech banking sector using panel data from 2003 to 2012. Using DEA window analysis based on an input-oriented model, the author's results interestingly showed that large banks were less efficient than other banks. The explanation was that large banks have excess deposits on their balance sheets and inadequate operating size.

Finally, some work points to the importance of distinguishing between cost and profit efficiency. Andries and Ursu (2016) studied the impact of the financial crisis on efficiency, taking into account, among other factors, bank size. Their study based on 783 commercial banks from the EU during 2004-2010 showed that the impact of the crisis on cost inefficiency was higher for large banks, which were more affected by the global financial crisis. On the other hand, large banks were less affected by the crisis regarding profit efficiency.

It is impossible to draw a definite conclusion about the analyzed relationship from the present literature review, especially for transition countries. Although some researchers address this issue, most neglect the detailed technical and scale efficiency analysis. For example, Drake et al. (2006) do not analyze the relationship between size and scale efficiency. Moreover, the previous studies do not recommend which business segment and what should be improved in less efficient banks in terms of their size. Furthermore, this research also considers additional factors regarding the

DOI: 10.25103/ijbesar.152.02

effects of pandemic COVID-19. We also examine the importance of the size effect over a longer time horizon, covering the period before and during the COVID-19 crisis.

3. Data and Methodology

Efficiency is defined as the ratio used for production factors, i.e. inputs and outputs, where the provider is efficient if it produces, for a given level of input variables, a greater amount of output variables or if it uses, for a certain amount of output, fewer input variables (Ozcan, 2008). In order to investigate total factor productivity changes of Croatian banks, due to data availability, the intermediary approach for defining input and output variables was selected. In addition, Mokhtar et al. (2006) found that the intermediation approach is the most commonly used approach to determine the appropriate input and output variables. Therefore, values for all selected variables were taken for 17 banks from the Orbis database, for the period 2013-2020. More precisely, as in paper of Jemrić and Vujčić (2002),fixed assets, total customer deposit, and the number of employees present input variables, while loans and other securities present output variables. Descriptive statistics for the data set are presented in Table 1.

Table 1: Descriptive statistics of the selected input and output variables, 2013-2020

Variables		Minimum	Maximum	Average
Inputs	Fixed Assets	762,228.3782	345,632,994.4	53,065,290.51
	Total customer deposits	95,350,799.97	15,615,121,458	2,303,141,251
	Number of employees	67	6,274	1,161.617647
Outputs	Loans, EUR	51,281,380,49	11,161,355,023	1,975,338,434
	Other securities	5,800,549.165	1,878,988,504	410,955,659.9

Source: Orbis database, 2022

With the aim of setting the efficiency frontier using the aforementioned presented variables, different statistical and mathematical approaches can be applied stressing the different ways of defining the frontier and interpreting results. While the statistical approach is based on econometric models and has the characteristics of stochasticity (randomness), the mathematical approach is based on the models known as linear programming and is deterministic by nature (Worthington, 2004).In order to evaluate relative efficiency, data envelopment analysis (DEA) is the most commonly used tool of mathematical linear programming. Its advantage in regards to DFA or SFA (which present statistical tools), is the fact that it doesn't require specific functions of providing services, where the non-parametric bases of multiple input and output variables present the base for the formulation of production (Gardijan and Koić, 2012). Furthermore, the DEA approach is confirmed by Trivedi et al. (2016), who replicate the DEA approach of efficiency measurement for financial institutions. Finally, in order to implement the selected DEA approach, it is necessary to choose the appropriate DEA model. Namely, DEA models differ according to scale and orientation. As managers have higher control over the input than over output variables, input oriented DEA model was chosen. Furthermore, according to the literature review, discussing the existence of economies of scale and scope, the BBC model was chosen, assuming variable returns to scale.

Furthermore, in order to avoid the stationary character of basic DEA models, i.e. to quantify the evolution of efficiency over a period of time, DEA window analysis and Malmquist DEA index can be used. While DEA window analysis evaluates the performance of decision-making units over time, treating them as s different entities in each analyzed period, the Malmquist DEA index provides an opportunity to compare the bank's performance from one period to another (Sanchez–Ortiz, 2021). Moreover, Malmquist DEA index can analyze different drivers of total factor productivity change. Namely, on the one side, it measures the changes in technical efficiency presenting how the decision-making units have managed to catch up to the relative frontier. On the other side, it measures the change in technology presenting changes in the position of the whole relative frontier (Prior, 2006). As the idea of the paper is to find out whether the identified changes from one period to another are due to pure efficiency improvement, technological changes in service delivery, or are the consequence of both these changes, the Malmquist DEA index is chosen in this study.

4. Empirical Results and Discussion

As we explained in the previous section, in order to evaluate change in relative technical efficiency over time, Table 2 presents total factor productivity change (TFPCH), i.e. the results of the Malmquist DEA index and its components. Namely, the mentioned measure is decomposed into technical efficiency changes (EFFCH) and technological changes (TECHCH).

DOI: 10.25103/ijbesar.152.02

Table 2: Total factor productivity change and its components for banks in the Croatian bank system, 2013-2020

Banks	EFFCH	TECHCH	TFPCH
ADDIKO BANK D.D. ZAGREB	1.0067	0.9654	0.9719
AGRAM BANKA D.D. ZAGREB	1.0000	1.0223	1.0223
BANKA KOVANICA D.D. VARAZDIN	1.0132	1.0286	1.0422
CROATIA BANKA D.D.	1.0018	1.0757	1.0780
ERSTE & STEIERMARKISCHE BANK D.D.	1.0000	1.0775	1.0775
HRVATSKA POSTANSKA BANK D.D.	1.0000	1.0779	1.0779
IMEX BANKA D.D.	0.9869	1.0176	1.0022
ISTARSKA KREDITNA BANK UMAG D.D.	1.0010	1.0191	1.0155
J&T BANKA D.D.	1.0146	1.0744	1.0905
KARLOVACKA BANKA D.D.	0.9998	1.0013	1.0022
KENTBANK D.D.	0.9800	0.9917	0.9713
PARTNER BANKA D.D.	0.9914	1.0129	1.0043
PODRAVSKA BANKA	1.0160	1.0151	1.0325
PRIVREDNA BANKA ZAGREB D.D	1.0237	0.9712	0.9929
RAIFFEISENBANK AUSTRIA D.D.	1.0128	1.0457	1.0606
SBERBANK D.D.	1.0000	0.9403	0.9403
ZAGREBACKA BANKA D.D.	1.0000	0.9921	0.9921
Mean	1.0028	1.0193	1.0220

Source: Orbis database, 2022

If the values of those components are greater than one, they indicate progress, while the value lower than one indicates regress (a value equal to one presents no change). The total factor productivity changes analysis was conducted using computer software Frontier Analyst Banxia.

Over the analyzed period, the total factor productivity change of Croatian banks is found to be at 1.0220, which presents an increase in productivity of 2.2%. The aforementioned change in productivity arises from both, an increase in technical efficiency (EFFCH=1.0028) and a slightly higher increase in technological change (TECHC=1.0193). During the analyzed period, the highest productivity increase, more specifically 9.05%, occurred in J&T Banka d.d (TFPCH=1.0905) which is associated with an increase in technical efficiency, representing a catch-up effect, but it is also associated with technological change in service delivery referring to innovation, according to which this bank shifted an efficient frontier to a higher level. Contrary, Sberbank d.d. experienced the most significant decline of 5.97% (FTPCH=0.9403), linked entirely to a decline in technological change.

With the aim to analyze aggregate total factor productivity change over time, Table 3 presents aggregate mean productivity change for each year.

Table 3: Total factor productivity change over the period 2013-2020, for Croatian banks

	EFFCH		**TECHCH**		**TFPCH**	
Year	Mean	% change	Mean	% change	Mean	% change
2014	1.0075	0.75%	0.9877	-1.23%	0.9977	-0.23%
2015	0.9914	-0.86%	1.0492	4.92%	1.0385	3.85%
2016	1.0144	1.44%	1.0963	9.63%	1.1109	11.09%
2017	0.9882	-1.18%	1.0253	2.53%	1.0133	1.33%
2018	1.0039	0.39%	1.0220	2.20%	1.0260	2.60%
2019	1.0042	0.42%	0.9346	-6.54%	0.9378	-6.22%
2020	1.0100	1.00%	1.0202	2.02%	1.0300	3.00%
Mean	1.0028	0.28%	1.0193	1.93%	1.0220	2.20%

Source: Orbis database, 2022

According to the results presented in Table 3, total factor productivity on average increased by 2.20% over the analyzed period. This is mostly the result of an increase in technological change by 1.93%, while the technical efficiency increased by 0.28%. In other words, the presented increase was driven mostly due to innovation in the process of providing bank services to their clients who shift the relative efficiency frontier to a higher level. Although the most significant increase in total factor productivity occurred in 2016 (11.09%) it is important to stress an increase in total factor productivity in 2020 during the time of the pandemic. Namely, in 2020 total factor productivity increased by 3%, due to an increase in technical efficiency representing managerial efficiency (1%) but mostly due to

DOI: 10.25103/ijbesar.152.02

an increase in technological change (2.02%). With these results, an increase in total factor productivity change in 2020 is larger than the average increase of productivity in the whole analyzed period, especially in terms of technical efficiency (1% in 2020 compared to the mean of the period of 0.28%), but also due to technological efficiency (2.02% in 2020 compared to the mean of the period of 1.93%). It can be concluded, that the COVID-19 crisis has further accelerated the race for efficiency.

In order to analyze total factor productivity change in the time of pandemic COVID-19 according to bank size, all banks for the sample are grouped into three categories, small (10 banks), medium (3 banks), and large ones (4 banks), and their aggregate values of Malmquist DEA index and its components are presented in Table 4.

Table 4: Total factor productivity change in the pandemic (2019-2020), for Croatian banks grouped according to their size

	EFFCH		TECHCH		TFPCH	
Banks	Mean	% change	Mean	% change	Mean	% change
Large	1.0000	0.00%	1.0719	7.19%	1.0719	7.19%
Medium	1.0000	0.00%	0.9862	-1.38%	0.9862	-1.38%
Small	1.0170	1.70%	1.0098	0.98%	1.0264	2.64%

Source: Orbis Database, 2022

As can be observed from the table, large banks improved their total factor productivity by 7.19%, small banks by 2.64%, and medium-sized banks reduced it by 1.38%. Furthermore, large banks achieved efficiency improvements due to technological change which was probably mainly driven by the process of digitalization which large banks were able to conduct due to high investment in IT. On the other hand, the total factor productivity of medium banks decreased which confirms Carletti et al. (2020) who questioned IT investment possibilities of mid-size banks. Finally, small banks focused on both technical (1.70%) and technological (0.98%) efficiency improvements, which positively contributed to the productivity change. Results suggest that small banks can improve their efficiency, primarily through management improvements, but also through technological innovations. They adapted to customer expectations and the need to reduce costs by accelerating digitalization. Yet, their progress is significantly lower compared to large banks. As Hashem (2016) points out that profitable banks are, among others, those that have more efficient internal management, this implies that small banks need to further improve their technical efficiency.

Finally, in order to analyze more deeply the bank's size effect during a pandemic, Table 5 shows values of overall technical efficiency (OTE, calculated using the CCR input oriented model), pure technical efficiency (PTE, calculated using the BCC input oriented model) and scale efficiency (SE, calculated as a ratio of overall to pure technical efficiency).

Table 5: Overall, technical and scale efficiency of Croatian banks in 2020

Banks	OTE	PTE	SE
ADDIKO BANK D.D. ZAGREB	0.918	1	0.918
AGRAM BANKA D.D. ZAGREB	1	1	1
BANKA KOVANICA D.D. VARAZDIN	1	1	1
CROATIA BANKA D.D.	1	1	1
ERSTE & STEIERMARKISCHE BANK D.D.	1	1	1
HRVATSKA POSTANSKA BANK D.D.	1	1	1
IMEX BANKA D.D.	0.84	0.9	0.933
ISTARSKA KREDITNA BANK UMAG D.D.	0.827	0.848	0.975
J&T BANKA D.D.	1	1	1
KARLOVACKA BANKA D.D.	0.852	0.906	0.940
KENTBANK D.D.	0.865	0.866	0.999
PARTNER BANKA D.D.	0.88	0.939	0.937
PODRAVSKA BANKA	0.887	0.946	0.938
PRIVREDNA BANKA ZAGREB D.D	1	1	1
RAIFFEISENBANK AUSTRIA D.D.	0.917	1	0.917
SBERBANK D.D.	1	1	1
ZAGREBACKA BANKA D.D.	1	1	1
Mean	0.940	0.965	0.974
Large	0.979	1	0.979
Medium	0.973	1	0.973
Small	0.915	0.941	0.972

Source: Orbis database, 2022

DOI: 10.25103/ijbesar.152.02

According to results presented in Table 5, Croatian banks did not operate on the scale fit to their capacities, i.e. they were not successful in delivering their services at optimal scale. Namely, those having an efficiency score equal to 1 are relatively efficient ones and form the efficiency frontier, while those having an efficient score lower than 1 are relatively inefficient in relation to the banks on the frontier. While the large and medium banks are on average pure technical efficient, small banks are overall technically inefficient due to both – managerial inefficiency and scale inefficiency. Although according to Table 4 small banks on average increased their technical efficiency in 2020 (EFFCH=1.0170) they still didn't catch up relative efficiency frontier set up by large and medium banks.

In summary, both managerial and technological improvements are needed for small banks to maintain their efficiency, especially in the area of innovative banking services and in times of crisis. In addition, small banks should strive to channel deposits into profitable investments and benefit from economies of scale by increasing the size of the bank.

5. Conclusion and Recommendations

The aim of this paper was to analyse the total factor productivity change of Croatian banks for the period 2013-2020, using Malmquist – DEA index, based on an input oriented BCC model. Additionally, the goal was also to determine the influence of the COVID-19 pandemic crisis on bank efficiency, with special regards to size effect. Malmquist DEA index in comparison to DEA analysis, that has a stationary character and delivers a snapshot of providers and their efficiency, provides more reliable evidence by tracking the performance of each provider through sequence periods.

Our results revealed that total factor productivity change of Croatian banks has increased by 2.2%, both due to an increase in technical efficiency (EFFCH=1.0028) and a slightly higher increase in technological change (TECHC=1.0193). The presented increase was driven mostly due to innovation in the process of providing bank services. With regards to the effects of COVID-19 pandemic crisis in 2020, total factor productivity increased by 3%, due to an increase in technical efficiency representing managerial efficiency (1%) but mostly due to an increase in technological change (2.02%). With these results, an increase in total factor productivity change in 2020 is larger than the average increase of productivity in the whole analysed period, especially in terms of technical efficiency. It can be concluded, that the COVID-19 pandemic crisis has further accelerated the race for efficiency.

We also confirmed size effect. Namely, both large and small banks increased their efficiency. Still, progress of small banks is significantly lower compared to large banks. Large banks, due to greater capability of investment in IT, mainly regarding digitalization, achieved efficiency improvements due to technological change. Small banks improved their efficiency, primarily through management improvements, but also through technological innovations. Total factor productivity of medium banks decreased which confirms questionable IT investment possibilities of mid-size banks.

Finally, size effect was also confirmed during COVID-19 pandemic crisis. In comparison to large and medium banks, which are on average pure technical efficient, small banks are overall technically inefficient due to both – managerial inefficiency and scale inefficiency. Even though they have increased their technical efficiency in 2020, they still didn't catch up relative efficiency frontier set up by large and medium banks.

Our results indicate that small banks are still able to stay in the market and that they manage to maintain sustainable efficiency over time. Yet, in the context of competition, stakeholder expectations, and the recent crisis, the challenges to efficiency have never been greater. We conclude that small banks should focus on both managerial and technological improvements. More specifically, innovation in the delivery of banking services is critical to maintain the race for efficiency, especially in times of crisis. In addition, bank managers of small banks should seek to channel deposits into profitable investments and benefit from economies of scale through bank growth. Finally, it is important for policymakers to maintain a competitive banking sector, as competition promotes efficiency and productivity growth, while a concentrated industry leads to inefficiencies and neglects technological progress.

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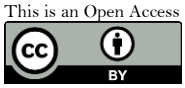

DOI: 10.25103/ijbesar.152.02