



## ON THE DETERMINANTS OF THE BANK EFFICIENCY IN THE REPUBLIC OF SERBIA: TWO-STAGE DEA APPROACH

**Ivana Marjanović**

*University of Niš, Faculty of Economics, Republic of Serbia*

✉ [ivana.veselinovic@eknfak.ni.ac.rs](mailto:ivana.veselinovic@eknfak.ni.ac.rs)

**Jelena J. Stanković**

*University of Niš, Faculty of Economics, Republic of Serbia*

✉ [jelena.stankovic@eknfak.ni.ac.rs](mailto:jelena.stankovic@eknfak.ni.ac.rs)

**Georgios Tsaples**

*Department of Business Administration, University of Macedonia, Greece*

✉ [gtsaples@uom.edu.gr](mailto:gtsaples@uom.edu.gr)

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**Abstract:** The important role of the banking sector in the economic development of the country imposes the need for continuous measurement and monitoring of bank efficiency. Besides, identifying industry-specific and macroeconomic factors that affect the achieved efficiency is an important task in order to detect potential disruptions, as well as to provide adequate guidelines to improve the efficiency. Therefore, the main goal of this paper is to quantify the achieved efficiency and uncover its determinants. The study is conducted in two stages. In the first stage, using the DEA method, the efficiency of banks for the period from 2005 to 2022 will be assessed, while in the second stage, the factors of efficiency will be determined by applying Tobit regression. The results indicate that when it comes to industry-specific factors, greater market concentration unfavourably affects the efficiency of banks. Regarding the macroeconomic factors, the growth of gross domestic product, inflation rate and global financial crisis have a significant influence on the achieved level of bank efficiency in the Republic of Serbia. In addition to expanding the existing knowledge on quantification of efficiency and defining the determinants of efficiency on the example of banks in the Republic of Serbia, the results in this paper also hold relevance to policymakers and practitioners.

**Keywords:** Data Envelopment Analysis, intermediation approach, Tobit regression, industry-specific factors, macroeconomic factors.

**JEL classification:** C34, C44, G21

## **1. Introduction**

In the contemporary context, a comprehensive evaluation of a bank's operations becomes imperative, primarily due to the intensified competition resulting from globalization and liberalization trends. The pivotal role in the economic development of a country can be attributed to the banking sector making it crucial to assess its ongoing efficiency (Henriques et al., 2018). Banks serve as intermediaries, collecting funds and investing them in profitable projects to foster sustainable economic growth and development. Given their significant socioeconomic impact, studies have consistently indicated a correlation between the success of banks and the economic prosperity of a nation (Farahani & Dastan, 2013). Financial sector challenges can disrupt the economy, hindering companies in the real sector from accessing resources and limiting their ability to pursue the intended investments and expansion. Evidence suggests that bank insolvency can lead to systemic crises with adverse consequences for the overall economy (Fethi & Pasiouras, 2010).

The banking industry has undergone the substantial changes in recent years, attributed to globalization, advancements in information technologies, tightening of legislative rules, and shifts in consumer preferences (Titko et al., 2014). The global financial crisis triggered a significant transformation in the banking landscape, with international stock markets experiencing sudden collapses and numerous companies facing bankruptcy. As a result, financial institutions have encountered various challenges, leading to the primary objective of strengthening the competitive position of banks within the financial system (Wu, 2012). Given the interconnectedness between the performance of the banking sector and the overall national economy, the continuous assessment and monitoring of a bank's operations become pertinent for various stakeholders. The evaluation of a bank's performance yields valuable insights for stakeholders such as investors and creditors, offering critical information on the competitiveness of banks within the sector. It also highlights the areas of weakness and potential opportunities for the improvement. The evaluation of business performance at the level of banks holds significance for several reasons (Ferreira et al., 2011): firstly, studies conducted at the banking sector level often present only average business performance, lacking specific examples of exemplary practices or highlighting concerns regarding certain banking institutions; secondly, analysing the performance at the level of individual banking institutions allows for targeted and informed development strategies; thirdly, such analysis provides a wealth of information to guide recommendations and the implementation of practical solutions; and lastly, a thorough examination of business success at the level of banking institutions can shed light on specific aspects of their operations that require greater attention due to their sensitivity. Overall, the evaluation of business performance at the bank level enables a more nuanced understanding and facilitates focused efforts for the improvement. Moreover, comprehending the factors influencing bank efficiency is crucial, as it may determine the health of banks and the overall economy (Zheng et al., 2021). Hence, the objective of this paper is to

assess the efficiency of banks in the Republic of Serbia from 2005 to 2022 and to evaluate the determinants that contribute to the observed levels of efficiency.

The rest of the paper is structured as follows: section Theoretical Background provides a comprehensive review of the existing literature on efficiency assessment and the factors influencing bank efficiency. It also highlights previous research conducted in the context of the banking sector in the Republic of Serbia. Section Methodology, Data, and Model Development describes the methodologies employed and the data utilized to estimate the efficiency of Serbian banks and identify the determinants of efficiency. Section Results and Discussion presents the findings of the analysis and provides a detailed discussion of their implications while section Conclusion offers concluding remarks.

## **2. Theoretical Background**

The efficiency of banks serves as a significant indicator of the effectiveness of monetary and policy measures (Bătae et al., 2021). Nevertheless, researchers have not reached the consensus regarding the most suitable method for measuring the efficiency of banks. To overcome the limitation of solely relying on ratio analysis, efficiency measurement techniques that employ a frontier approach are utilized, as they consider multiple inputs and outputs in their analysis (Titko et al., 2014). Bank efficiency analysis can be categorized into two main approaches: the non-parametric approach and the parametric approach. The parametric approach, such as Stochastic Frontier Approach, necessitates the assumptions regarding the specific form of the cost or profit function being estimated and the distribution of efficiency (Kallel et al., 2019). On the other hand, the non-parametric approach, such as Data Envelopment Analysis (DEA), does not require such assumptions about the functional form. Regarding the scope of the study Berger and Humphrey (1997) highlighted that a majority of studies on bank efficiency (approximately 95%) have predominantly focused on developed countries, with the United States accounting for around 70% of these studies. However, numerous researchers argue that there is a need for more research that compares and measures the efficiency across and among different countries, aiming to enhance global financial stability (Eyceyurt Batir et al., 2017). Furthermore, exploring the determinants of banks' efficiency is crucial for enhancing the overall performance of the banking system. One primary rationale is that banks serve as financial intermediaries, thereby exerting an indirect influence on the entire national economy. Moreover, given the intense competition in the banking industry, only the efficient banks can sustainably reap the advantages and remain successful.

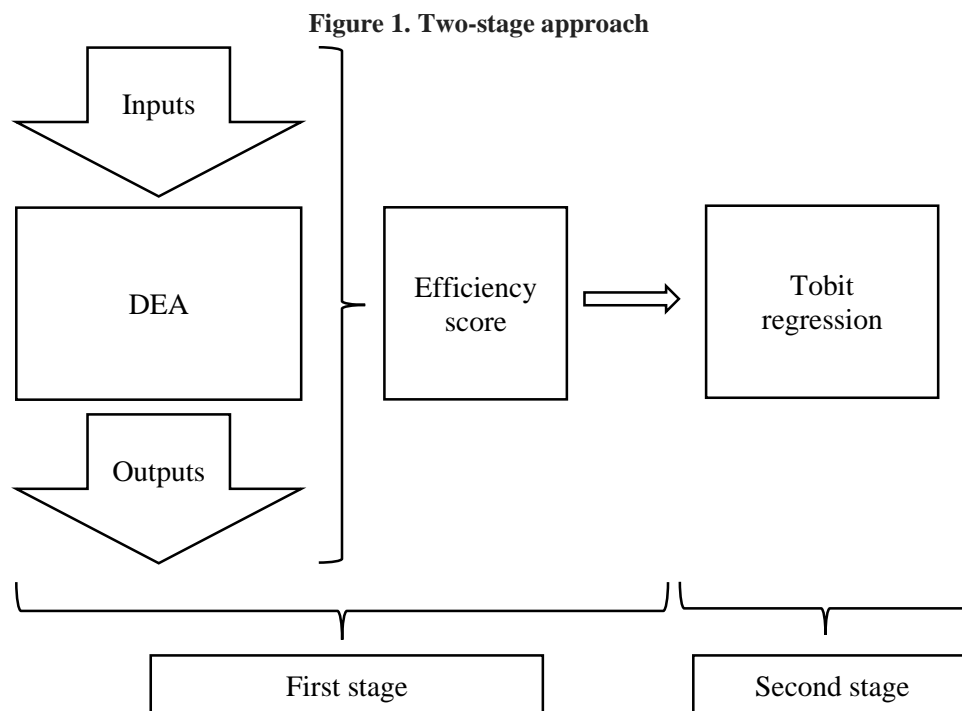
On the country level, the assessment of banks' efficiency serves multiple purposes. At the macro level, it enables the differentiation between the successful and the unsuccessful banks, facilitating the identification of best practices. On a micro level, quantifying business performance provides insights into areas that

require improvement, allowing for timely adjustments in strategic policies. Consequently, the analysis of business success yields diverse applications (Berger & Humphrey, 1997): (a) evaluating the impacts of macro policy changes, such as deregulation; (b) conducting research on business performance and identifying best practices; or (c) enhancing management performance by identifying strengths and weaknesses associated with varying levels of business success. Efficiency analysis of banks at the national level has been conducted by numerous researchers (Berger & Humphrey, 1997; Boubaker et al., 2022; Henriques et al., 2018; Jelassi & Delhoumi, 2021; Patra et al., 2023; Yu et al., 2021).

The research conducted on the banking sector in the Republic of Serbia has primarily focused on analyzing bank performance measures and assessing the determinants of profitability, with limited attempts to develop efficiency scores or other synthetic measures of business success (Domanović et al., 2018; Marinković & Radović, 2010; Marinković & Radović, 2014; Marjanović et al., 2018; Radojčić et al., 2018; Ristić & Jemović, 2021). Based on the comprehensive literature review conducted, there is a notable gap in the literature concerning Serbian banks regarding the assessment of efficiency and its determinants which this study aims to bridge.

### 3. Methodology, Data, and Model Development

To obtain a comprehensive analysis of bank efficiency in the Republic of Serbia and assess its determinants, a two-stage approach was employed (Figure 1).



In the first stage, DEA is utilized to estimate the efficiencies of the banks under consideration. This allows for the identification of efficient banks and the calculation of their efficiency scores. Subsequently, these efficiency estimates are subjected to regression analysis using the Tobit model, with the aim of elucidating the factors that contribute to the observed efficiencies.

### 3.1. Data Envelopment Analysis

DEA is a non-parametric method widely used in the banking sector to measure business performance. The term "data envelopment analysis" was first coined by a group of researchers (Charnes et al., 1978) based on the earlier work of Farrell (1957). DEA offers a powerful optimization capability, allowing the management to objectively identify both best practices and areas that require improvement. The DEA model can be formulated in two ways: as an input-oriented or an output-oriented model. Regarding the input-oriented model, the focus is on optimizing the inputs' level while preserving outputs' levels constant. On the other hand, the output-oriented model aims to optimize outputs' level while preserving the inputs' levels constant. In the efficiency studies of banking sector, mainly the input-oriented model is used (Eyceyurt Batir et al., 2017).

Another important issue regarding DEA is the selection of the type of returns to scale where the lack of consensus among researchers is still present. The DEA model, known as the CCR model, was built under the assumption of constant returns to scale (CRS) by Charnes et al. (1978). CRS assumes that a proportional increase in inputs will lead to a proportional increase in outputs (Titko et al., 2014). Subsequent modifications of the model by Banker et al. (1984) introduced the assumption of variable returns to scale (VRS). VRS assumes that equilateral increases in inputs may be greater or lesser than equilateral increases in outputs (Heffernan, 2005). In the existing literature, it is widely acknowledged that CRS assumption is applicable only to companies operating at an optimal level (Fethi & Pasiouras, 2010). However, the banking sector, due to factors like government regulations and imperfect competition, tends to deviate from this optimal scale (Titko et al., 2014). Consequently, as a more suitable assumption VRS is adopted for efficiency assessments in the banking sector. The mathematical model of input-oriented DEA model with VRS in its envelopment form can be represented as follows (Núñez et al., 2020):

$$\min \theta_0 - \varepsilon (\sum_{i=1}^m s_{i0}^- + \sum_{r=1}^p s_{r0}^+) \quad (1)$$

s.t.

$$\sum_{j=1}^n \lambda_j x_{ij} = \theta_0 x_{i0} - s_{i0}^-, i = 1, \dots, m \quad (2)$$

$$\sum_{j=1}^n \lambda_j y_{rj} = y_{r0} + s_{r0}^+, r = 1, \dots, p \quad (3)$$

$$\sum_{j=1}^n \lambda_j = 1 \quad (4)$$

$$\lambda_j \geq 0, j = 1, \dots, n \quad (5)$$

$$s_{i_0}^-, s_{r_0}^+ \geq 0, i = 1, \dots, m; r = 1, \dots, p \quad (6)$$

Where  $n$  denotes the number of DMUs,  $p$  represents the number of outputs, and  $m$  indicates the number of inputs. The consumption of input  $i$  in DMU  $j$  is denoted as  $x_{ij}$ , while the production of output  $r$  by DMU  $j$  is represented by  $y_{rj}$ .  $\theta_0$  signifies the radial reduction of all inputs consumed by DMU<sub>0</sub>, given a specific level of outputs. On the other hand,  $s_{i_0}^-$  and  $s_{r_0}^+$  denote the additional reductions of inputs and increases in outputs, respectively, following the radial reduction. Furthermore, variables  $\lambda_j$  represent the optimal weights for the convex linear combination of the observed DMU<sub>0</sub>.

Although DEA has advantages compared to parametric approaches, a problem known as discrimination arises when the number of variables is relatively large compared to the number of decision-making units (DMUs). This can lead to most observations being classified as efficient, even if they are inefficient. To address this issue, it is recommended that the number of DMUs should be at least three times greater than the number of variables to be analyzed (Aytekin et al., 2022). This ensures an appropriate balance and adequate statistical power in the analysis. Therefore, the most debatable question in the formulation of DEA model is the selection of input and output variables (Henriques et al., 2020). In the literature, three fundamental approaches are commonly used regarding the variables selection banking (Milenković et al., 2022): the production approach, the intermediation approach, and the profitability approach. In the production approach, banks are seen as producers of various banking products utilizing resources such as capital, labour, and materials (Heffernan, 2005). On the other hand, the intermediation approach observes banks as intermediaries that transform funds and deposits into loans and other assets (George Assaf et al., 2013). Regarding the profitability approach, it focuses on outputs that are profit-oriented, such as interest income and non-interest income. Berger and Humphrey (1997) consider the intermediation approach to be more suitable for the efficiency assessment of banks compared to other approaches.

The pioneering study that applied DEA to evaluate the performance of financial institutions was conducted by Sherman and Gold (1985), where they assessed the efficiency of 14 bank branches. Since then, the banking sector has been a prominent area for DEA application. Numerous other studies have addressed the issue of assessing bank efficiency or the banking sector, highlighting the importance of obtaining a comprehensive quantitative assessment of business processes.

### **3.2. Tobit Regression Approach**

The outcomes obtained from traditional DEA analysis primarily focus on the internal factors of a business, which can lead to some managers disregarding improvement guidelines. This scepticism arises from the belief that the results are influenced by

external environmental factors not accounted for in the model (Paradi et al., 2011). Consequently, in the second phase, regression techniques are employed, wherein the efficiency index derived from the DEA model serves as the dependent variable, while the exogenous variables act as independent variables (Henriques et al., 2020). Those exogenous variables mainly reflect the macroeconomic environment and some industry specific characteristics. Tobit models, originally proposed by Tobin (1958), are regression models commonly used when the dependent variable is subject to constraints or limitations (Amemiya, 1984) and are frequently combined with DEA. For the analysis of panel data using the Tobit regression, two models are commonly employed: fixed effects and random effects. However, when utilizing a fixed effects model, the estimated values obtained through maximum likelihood estimation tend to be biased and inconsistent (Zhu et al., 2021). Consequently, to address this issue, the random effects model is often preferred.

### ***3.3. Data and Model Development***

The banking sector in the Republic of Serbia has undergone significant transformations in the past two decades, driven by structural reforms, financial liberalization, and international integration. These changes have facilitated the consolidation of the banking sector, with the entry of foreign banks playing a crucial role in strengthening the previously undercapitalized financial industry of Serbia. In recent years, the banking sector in the Republic of Serbia has experienced a consolidation trend, resulting in improved profitability and liquidity on average. However, a thorough evaluation of banking sector efficiency requires a comprehensive analysis. To perform the efficiency assessments, this paper utilizes the balance sheet and income statement data from a sample of 20 Serbian banks spanning the period from 2005 to 2022. The quarterly accounting data of these banks are obtained from the National bank of Serbia (2023a), while macroeconomic variables are sourced from the National bank of Serbia (2023) and the Statistical Office of the Republic of Serbia (2023).

To estimate the efficiency of Serbian banks, in the first stage, an intermediation approach is employed. Consistent with previous research and the characteristics of the intermediation approach, the selected input variables are deposit, equity, and interest expenses, while the output variables include loans and interest income. Regarding the efficiency frontier, instead of a common frontier across time, the efficiency frontiers are estimated quarterly, to obtain better understanding of the sources of inefficiency over time.

The second stage of the analysis focuses on the determinants of the efficiency. Previous studies have commonly employed Tobit regression in conjunction with DEA research (Eyceyurt Batir et al., 2017; Milenković et al., 2022; Patra et al., 2023). Some of these studies examine the influence of: (a) bank-specific factors such as profitability (Blanco-Oliver, 2021; El Moussawi & Mansour, 2022; Patra et al.,

2023) or bank's size (Anagnostopoulos et al., 2022; Harimaya & Ozaki, 2021; Martens et al., 2021); (b) industry-specific factors such as ownership (Gulati, 2022; Henriques et al., 2018; Patra et al., 2023), market share and concentration (El Moussawi & Mansour, 2022; Harimaya & Ozaki, 2021) or (c) macroeconomic factors such as inflation rate (Jelassi & Delhoumi, 2021; Raphael, 2013) and GDP (Dimitras et al., 2023; Jelassi & Delhoumi, 2021).

This study focuses only on industry-specific and macroeconomic factors (Table 1). Regarding industry-specific factors concentration ratio (CR3) is selected. CR3 is calculated as the sum of the market shares of the three entities that have the largest market share, whereby the market share is determined considering the book value of the assets. Regarding the influence of concentration in the banking sector on the efficiency, the Structure-Conduct-Performance theory suggests that a higher concentration in the banking sector can lead to a reduced competition, resulting in the presence of inefficient banks and overall instability (El Moussawi & Mansour, 2022). In concentrated markets, the lack of competitive pressure may discourage managers from striving for maximum efficiency in their firms (Nguyen et al., 2016). This negative relationship is further reinforced if the "quiet life" hypothesis holds, which means that an increased concentration creates a relaxed banking environment with little motivation to minimize costs (Berger & Humphrey, 1997). In essence, a monopolistic environment is considered less efficient compared to a competitive one, indicating a negative relation between the concentration and the efficiency. However, Sufian (2016) highlights that banks which operate in highly concentrated markets have a tendency to engage in collusion, which allows them to generate monopoly profits, and hence improve the efficiency.

**Table 1. Description of bank-specific and macroeconomic factors**

Variable	Description	Expected impact
CR3	Concentration ratio of three entities	+/-
Inflation	Consumer price index	+/-
GDP	GDP growth rate	+/-
FinCrisis	Global financial crisis – dummy variable	-
CovCrisis	Coronavirus pandemics – dummy variable	-

When considering macroeconomic factors, inflation is commonly used as an indicator of the overall economic environment. The effect of inflation on bank efficiency largely depends on the bank's ability to anticipate future inflation. If the inflation can be anticipated, banks can adjust their interest rates accordingly to generate higher revenues than costs, thereby maintaining or increasing their profits. However, if the inflation is unforeseen, banks may struggle to adjust interest rates appropriately, leading to the possibility of costs growing faster than revenue



(Athanasoglou et al., 2008). Another macroeconomic indicator is the GDP growth rate. The research suggests that strong economic growth positively impacts the intermediation efficiency as it stimulates the increased deposits and demand for loans for various investments (Raphael, 2013). Most studies indicate a positive relationship between economic growth and bank efficiency (Chen & Lu, 2021; Dimitras et al., 2023). However, some studies, have found a negative influence of GDP on bank efficiency (Eyceyurt Batir et al., 2017). The global financial crisis is one more factor of the macroeconomic environment that will be assessed for its influence. Its widespread impact and significance for the global economy are evident from the numerous banks and financial institutions that experienced collapse, bailouts, or major restructuring in its aftermath (Andrieş & Ursu, 2016). Luo et al. (2011) suggest that financial crises have had a detrimental impact on banking activities, both in terms of funding and lending, leading to a significant decrease in bank efficiency. During such crises, banks have experienced a reduction in lending activities and faced pressure due to the risk of deposit withdrawals by customers (Boubaker et al., 2022). Some studies have reported a negative influence of the global financial crisis on the efficiency of banks (Andrieş & Ursu, 2016; Wanke et al., 2022) indicating a decrease in efficiency. However, other studies suggest that the global financial crisis did not have a significant adverse effect on the efficiency levels of banks (Gulati, 2022). Furthermore, the impact of the coronavirus pandemic will also be evaluated. The pandemic, being an exogenous shock, has caused various disturbances for the banking industry, often leading to an increase in bank failure rates. The evidence suggests that the efficiency of banks has been negatively affected by the coronavirus pandemic (Li et al., 2021).

Tobit regression model can be specified as follows:

$$\begin{aligned} \text{Bank efficiency}_{it} = & \beta_0 + \beta_1 CR3_{it} + \beta_2 FinCrisis_{it} + \\ & \beta_3 CovCrisis_{it} + \beta_4 Inflation_{it} + \beta_5 GDP_{it} + \varepsilon_{it} \end{aligned} \quad (7)$$

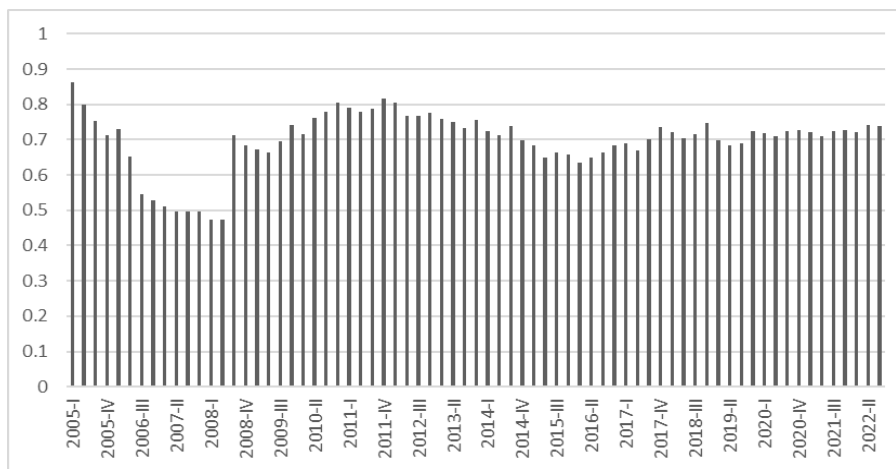
#### 4. Results and Discussion

In the first stage of the analysis, the efficiency scores for each period were computed. Figure 2 shows the average trend of quarterly efficiency over the period 2005-2022.

The overall efficiency of Serbian banks during the analyzed timeframe is 70%, suggesting that there is a room for improvement. On average, banks could enhance their efficiency by 30%, meaning they could have achieved the same level of outputs using only 70% of the resources (inputs) they employed. Therefore, the results indicate that inefficient banks can improve their efficiency by reducing inputs while maintaining their output levels. Specifically, inefficient banks should consider reducing their equity, interest expenses, and total deposits, while keeping their total loans and interest incomes constant in order to move closer to the efficient frontier, which represents the best practices of the analyzed group. Although it may not be

immediately obvious, reducing equity or total deposits can be beneficial for a bank's efficiency. The rationale behind this is provided by Henriques et al. (2018) who state that investments in assets should only be made if they are expected to generate future economic returns. According to them, accumulating a large volume of deposits does not necessarily translate into a corresponding increase in loans and the potential operating revenues from interest rate spreads may not justify the maintenance of high levels of deposits.

**Figure 2. Average quarterly efficiencies for all sample banks, 2005–2022**



In the second step, Tobit regression was applied on a set of a panel data. The panel data analysis assumes the use of stationary data, so it is important to test the stationarity of the time series. To assess the presence of unit roots, the Levin, Lin, and Chu test was employed. The test results indicate that all variables are stationary at a significance level of 1%. The results of the estimated model are presented in Table 2.

Regarding the impact of banking sector concentration, the concentration ratio (CR3) shows a statistically significant negative relationship, which is in accordance with the previous literature. Concentrated banking systems, where a small number of banks dominate the market, often result in higher interest rates on loans. This can incentivize banks to take on a greater risk, leading to an increased volume of non-performing loans and a higher likelihood of bank failure (Boyd & De Nicoló, 2005). In such systems, banks may lack the motivation to establish sound credit practices, resulting in a higher proportion of non-performing loans (Fu et al., 2014). As a result, the concentration of the banking sector, combined with banks' risky behaviour, can have implications for the stability of the banking system, potentially increasing the risk of bank failure (Fungáčová & Weill, 2013). To mitigate the potential negative effects of concentration on bank performance, it is recommended that regulators adopt a more stringent evaluation process for assessing and approving mergers and acquisitions at the national level (Fu et al., 2014).

**Table 2. Estimated model results**

Explanatory variables	Estimated values
CR	-0.491*** (0.178)
Inf	0.00544*** (0.000990)
GDP	-0.0134*** (0.00158)
FinCrisis	-0.108*** (0.0134)
CovCrisis	0.0101 (0.0198)
Constant	0.509*** (0.0767)
Observations	1,420
Number of banks	20

Standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

Turning to the impact of macroeconomic conditions, a negative coefficient for the GDP variable can be observed. This finding indicates that an increase in economic activity is associated with a decrease in efficiency of banks and this negative relationship can be attributed to banks choosing to invest in riskier assets during the periods of growth (El Moussawi & Mansour, 2022). Such a strategy exposes them to a higher risk of capital loss if borrowers fail to meet their debt obligations. More specifically, banks do not experience benefits from periods of economic growth due to higher loan defaults, which in turn decrease banking efficiency under the VRS assumption (Ofori-Sasu et al., 2019).

On the other hand, an inflation has a positive effect on bank efficiency. The impact of inflation is closely tied to the interest rate structure. If bank management can accurately anticipate the inflation, they can adjust interest rates in a way that doesn't harm the net interest margin (Ofori-Sasu et al., 2019). In the case of the Republic of Serbia, it appears that banks were able to effectively manage the inflation and even experienced a positive impact on their efficiency.

Regarding the influence of the global financial crisis, it had a negative impact on banks' efficiency levels. Its effects were widespread, including Central and Eastern European countries where there was a shift in the loan portfolios of banks. Additionally, there was a decrease in loan demand, leading to a reduced profitability as banks struggled to find attractive investment opportunities or had to lower net

interest margins to make loans more appealing (Dietrich & Wanzenried, 2011). Despite its relatively small market size, the Republic of Serbia experienced the transmission of the global financial crisis due to the integration of the world economic system. This transmission occurred through the depreciation of the exchange rate, which posed risks to the credit portfolios of the banks in Serbia (Vunjak et al., 2014). As a result, the overall efficiency of banks deteriorated during the global financial crisis.

Unlike the global financial crisis, which started in the financial sector and then spread to the real economy, the crisis caused by the coronavirus pandemic was faced by the financial sector in a better position. Banks had a sufficient liquidity and capital reserves, enabling them to weather the economic downturn and continue serving their clients (Vasić, 2020). Central banks and governments worldwide implemented various policy measures to ensure an ample liquidity and facilitate the flow of credit. The National Bank of Serbia, along with many other central banks, adjusted the monetary policy by reducing the interest rates, creating favourable financing conditions to support economic recovery (Vasić, 2020). Additionally, the financial sector received an additional liquidity in local and foreign currencies to maintain the lending activities. Nevertheless, the overall impact of the coronavirus pandemic on the efficiency of banks in the Republic of Serbia is not statistically significant, however, there remains a need for further analyses of the impact of the pandemic by incorporating more recent data as they become available.

## **5. Conclusion**

The banks play a crucial role in economic development by exerting control over the money supply and influencing the overall economic growth. Given its status as a pivotal component of the modern economy, the banking sector's efficiency assumes a paramount importance. By efficiently intermediating between the depositors and the borrowers, banks contribute to the efficient allocation of the capital, enabling funds to flow to sectors with high growth potential and fostering economic prosperity. In that sense, the analysis results reveal that, during the examined period, the average efficiency of Serbian banks stood at 70%, indicating a room for improvement in their intermediation processes. As for the determinants of bank efficiency in Serbia, factors such as the concentration ratio (CR3), GDP growth rate, and the global financial crisis have shown a negative and statistically significant influence on the efficiency levels. Conversely, the inflation rate has demonstrated a positive and statistically significant impact. No evidence was found regarding the influence of the coronavirus pandemic on the bank efficiency.

This paper contributes to the existing research on the bank efficiency twofold. Theoretical contributions include providing a comprehensive overview of the models used for assessing efficiency and identifying key determinants. Empirically, the study focuses on investigating the influence of industry-specific and macroeconomic factors on the bank efficiency, specifically within the Serbian banking sector.

The research presented in this paper has certain limitations that need to be acknowledged. Firstly, the reliance on balance sheet data has influenced the selection and accuracy of the indicators used in the study. Secondly, while the chosen indicators were selected based on a thorough review of the literature and aligned with the established frameworks for measuring the bank performance, it is worth noting that there are additional indicators that could have been considered. The inclusion of alternative indicators may have yielded different insights and potentially influenced the overall results of the analysis.

Future studies could address these limitations by incorporating a broader range of data sources and considering additional indicators to provide a more comprehensive assessment of the bank performance.

## References

- Alqahtani, F., Mayes, D. G., & Brown, K. (2017). Islamic bank efficiency compared to conventional banks during the global crisis in the GCC region. *Journal of International Financial Markets, Institutions and Money*, 51, 58–74. <https://doi.org/10.1016/j.intfin.2017.08.010>
- Amemiya, T. (1984). Tobit models: A survey. *Journal of Econometrics*, 24(1–2), 3–61. [https://doi.org/10.1016/0304-4076\(84\)90074-5](https://doi.org/10.1016/0304-4076(84)90074-5)
- Anagnostopoulos, Y., Husa, K. A., & Noikokyris, E. (2022). A three-phase comparative efficiency analysis of US and EU banks. *International Review of Economics and Finance*, 81(January 2021), 113–127. <https://doi.org/10.1016/j.iref.2022.04.009>
- Andrieș, A. M., & Cocriș, V. (2010). A comparative analysis of the efficiency of Romanian banks. *Romanian Journal of Economic Forecasting*, 13(4), 54–75.
- Andrieș, A. M., & Ursu, S. G. (2016). Financial crisis and bank efficiency: An empirical study of European banks. *Economic Research-Ekonomska Istrazivanja*, 29(1), 485–497. <https://doi.org/10.1080/1331677X.2016.1175725>
- Asimakopoulou, G., Chortareas, G., & Xanthopoulos, M. (2018). The eurozone financial crisis and bank efficiency asymmetries: Peripheral versus core economies. *Journal of Economic Asymmetries*, 18(July), e00099. <https://doi.org/10.1016/j.jeca.2018.e00099>
- Athanasoglou, P. P., Brissimis, S. N., & Delis, M. D. (2008). Bank-specific, industry-specific and macroeconomic determinants of bank profitability. *Journal of International Financial Markets, Institutions and Money*, 18(2), 121–136. <https://doi.org/10.1016/j.intfin.2006.07.001>
- Aytekin, A., Ecer, F., Korucuk, S., & Karamaşa, Ç. (2022). Global innovation efficiency assessment of EU member and candidate countries via DEA-EATWIOS multi-criteria methodology. *Technology in Society*, 68(January). <https://doi.org/10.1016/j.techsoc.2022.101896>
- Bătae, O. M., Dragomir, V. D., & Feleagă, L. (2021). The relationship between environmental, social, and financial performance in the banking sector: A European study. *Journal of Cleaner Production*, 290. <https://doi.org/10.1016/j.jclepro.2021.125791>
- Berger, A. N., & Humphrey, D. B. (1997). Efficiency of financial institutions: International survey and directions for future research. *European Journal of Operational Research*, 98(2), 175–212. [https://doi.org/10.1016/S0377-2217\(96\)00342-6](https://doi.org/10.1016/S0377-2217(96)00342-6)

- Blanco-Oliver, A. (2021). Banking reforms and bank efficiency: Evidence for the collapse of Spanish savings banks. *International Review of Economics and Finance*, 74(December 2020), 334–347. <https://doi.org/10.1016/j.iref.2021.03.015>
- Boubaker, S., Do, D. T., Hammami, H., & Ly, K. C. (2022). The role of bank affiliation in bank efficiency: a fuzzy multi-objective data envelopment analysis approach. *Annals of Operations Research*, 311(2), 611–639. <https://doi.org/10.1007/s10479-020-03817-z>
- Boyd, J. H., & De Nicoló, G. (2005). The theory of bank risk taking and competition revisited. *Journal of Finance*, 60(3), 1329–1343. <https://doi.org/10.1111/j.1540-6261.2005.00763.x>
- Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2(6), 429–444. <https://doi.org/10.1016/j.rser.2016.12.030>
- Chen, X., & Lu, C. C. (2021). The impact of the macroeconomic factors in the bank efficiency: Evidence from the Chinese city banks. *North American Journal of Economics and Finance*, 55, 101294. <https://doi.org/10.1016/j.najef.2020.101294>
- Delis, M. D., & Papanikolaou, N. I. (2009). Determinants of bank efficiency: evidence from a semi-parametric methodology. *Managerial Finance*, 35(3), 260–275. <https://doi.org/10.1108/03074350910931771>
- Dietrich, A., & Wanzenried, G. (2011). Determinants of bank profitability before and during the crisis: Evidence from Switzerland. *Journal of International Financial Markets, Institutions and Money*, 21(3), 307–327. <https://doi.org/10.1016/j.intfin.2010.11.002>
- Dimitras, A. I., Dokas, I., Mamou, O., & Spyromitros, E. (2023). Investigating the performance of European banks using non-parametric techniques: the role of performing loans efficiency. *EuroMed Journal of Business*. <https://doi.org/10.1108/EMJB-11-2022-0202>
- Domanović, V., Todorović, V., & Savović, S. (2018). Internal factors of bank profitability in the republic of Serbia. *Business and Economic Horizons*, 14(3), 659–673. <https://doi.org/10.15208/beh.2018.46>
- El Moussawi, C., & Mansour, R. (2022). Competition, cost efficiency and stability of banks in the MENA region. *Quarterly Review of Economics and Finance*, 84, 143–170. <https://doi.org/10.1016/j.qref.2021.12.005>
- Eyceyurt Batir, T., Volkman, D. A., & Gungor, B. (2017). Determinants of bank efficiency in Turkey: Participation banks versus conventional banks. *Borsa Istanbul Review*, 17(2), 86–96. <https://doi.org/10.1016/j.bir.2017.02.003>
- Farahani, Y. G., & Dastan, M. (2013). Analysis of Islamic banks' financing and economic growth: a panel cointegration approach. *International Journal of Islamic and Middle Eastern Finance and Management*, 6(2), 156–172. <https://doi.org/10.1108/17538391311329842>
- Farrell, M. J. (1957). The Measurement of Productive Efficiency <http://www.jstor.org/stab>. *Journal of the Royal Statistical Society. Series A (General)*, 120(3), 253–290. <http://goo.gl/AFhm2N>
- Ferreira, F. A. F., Santos, S. P., & Rodrigues, P. M. M. (2011). Adding value to bank branch performance evaluation using cognitive maps and MCDA: A case study. *Journal of the Operational Research Society*, 62(7), 1320–1333. <https://doi.org/10.1057/jors.2010.111>
- Fethi, M. D., & Pasiouras, F. (2010). Assessing bank efficiency and performance with operational research and artificial intelligence techniques: A survey. *European Journal of Operational Research*, 204(2), 189–198. <https://doi.org/10.1016/j.ejor.2009.08.003>
- Fu, X. (Maggie), Lin, Y. (Rebecca), & Molyneux, P. (2014). Bank competition and financial stability in Asia Pacific. *Journal of Banking and Finance*, 38(1), 64–77. <https://doi.org/10.1016/j.jbankfin.2013.09.012>

- Fungáčová, Z., & Weill, L. (2013). Does competition influence bank failures? Evidence from Russia. *Economics of Transition*, 21(2), 301–322. <https://doi.org/10.1111/ecot.12013>
- Gardener, E., Molyneux, P., & Nguyen-Linh, H. (2011). Determinants of efficiency in South East Asian banking. *Service Industries Journal*, 31(16), 2693–2719. <https://doi.org/10.1080/02642069.2010.512659>
- George Assaf, A., Matousek, R., & Tsionas, E. G. (2013). Turkish bank efficiency: Bayesian estimation with undesirable outputs. *Journal of Banking and Finance*, 37(2), 506–517. <https://doi.org/10.1016/j.jbankfin.2012.09.009>
- Goyal, J., Singh, M., Singh, R., & Aggarwal, A. (2019). Efficiency and technology gaps in Indian banking sector: Application of meta-frontier directional distance function DEA approach. *Journal of Finance and Data Science*, 5(3), 156–172. <https://doi.org/10.1016/j.jfds.2018.08.002>
- Gulati, R. (2022). Global and local banking crises and risk-adjusted efficiency of Indian banks: Are the impacts really perspective-dependent? *Quarterly Review of Economics and Finance*, 84, 23–39. <https://doi.org/10.1016/j.qref.2022.01.004>
- Harimaya, K., & Ozaki, Y. (2021). Effects of diversification on bank efficiency: Evidence from Shinkin banks in Japan. *International Review of Economics and Finance*, 71, 700–717. <https://doi.org/10.1016/j.iref.2020.10.008>
- Heffernan, S. (2005). *Modern banking*. John Wiley & Sons. <https://doi.org/10.3406/reco.1992.409350>
- Henriques, I. C., Sobreiro, V. A., Kimura, H., & Mariano, E. B. (2018). Efficiency in the Brazilian banking system using data envelopment analysis. *Future Business Journal*, 4(2), 157–178. <https://doi.org/10.1016/j.fbj.2018.05.001>
- Henriques, I. C., Sobreiro, V. A., Kimura, H., & Mariano, E. B. (2020). Two-stage DEA in banks: Terminological controversies and future directions. *Expert Systems with Applications*, 161, 113632. <https://doi.org/10.1016/j.eswa.2020.113632>
- Holod, D., & Lewis, H. F. (2011). Resolving the deposit dilemma: A new DEA bank efficiency model. *Journal of Banking and Finance*, 35(11), 2801–2810. <https://doi.org/10.1016/j.jbankfin.2011.03.007>
- Jackson, P. M., & Fethi, M. D. (2000). Evaluating the efficiency of Turkish commercial banks: an application of DEA and Tobit Analysis. *EPRU Discussion Papers*, 2–4. <http://hdl.handle.net/2381/369%5Cnhttp://www.le.ac.uk/ulsm/research/epru/dispaper.html>
- Jelassi, M. M., & Delhoumi, E. (2021). What explains the technical efficiency of banks in Tunisia? Evidence from a two-stage data envelopment analysis. *Financial Innovation*, 7(1). <https://doi.org/10.1186/s40854-021-00282-w>
- Kallel, H., Ben Hamad, S., & Triki, M. (2019). Modeling the efficiency of Tunisian and Moroccan banks using the SFA approach. *International Journal of Productivity and Performance Management*, 68(5), 879–902. <https://doi.org/10.1108/IJPPM-03-2018-0099>
- Kao, C., & Liu, S. T. (2016). A parallel production frontiers approach for intertemporal efficiency analysis: The case of Taiwanese commercial banks. *European Journal of Operational Research*, 255(2), 411–421. <https://doi.org/10.1016/j.ejor.2016.04.047>
- Li, X., Xie, Y., & Lin, J. H. (2021). COVID-19 outbreak, government capital injections, and shadow banking efficiency. *Applied Economics*, 53(4), 495–505. <https://doi.org/10.1080/00036846.2020.1808183>
- Luo, D., Yao, S., Chen, J., & Wang, J. (2011). World Financial Crisis and Efficiency of Chinese Commercial Banks. *World Economy*, 34(5), 805–825. <https://doi.org/10.1111/j.1467->

- 9701.2011.01354.x
- Marinkovic, S., & Radovic, O. (2010). On the determinants of interest margin in transition banking: the case of Serbia. *Managerial Finance*, 36(12), 1028–1042. <https://doi.org/10.1108/03074351011088432>
- Marinković, S., & Radović, O. (2014). Bank net interest margin related to risk, ownership and size: An exploratory study of the serbian banking industry. *Economic Research-Ekonomska Istrazivanja*, 27(1), 134–154. <https://doi.org/10.1080/1331677X.2014.952114>
- Marjanović, I., Stanković, J., & Popović, Ž. (2018). Efficiency Estimation of Commercial Banks Based on Financial Performance: Input Oriented DEA CRS/VRS Models. *Economic Themes*, 56(2), 239–252. <https://doi.org/10.2478/ethemes-2018-0014>
- Martens, W., Yapa, P., Safari, M., & Watts, S. (2021). The influence of earnings management on bank efficiency: the case of frontier markets. *Heliyon*, 7(10), e08232. <https://doi.org/10.1016/j.heliyon.2021.e08232>
- Milenković, N., Radovanov, B., Kalaš, B., & Horvat, A. M. (2022). External Two Stage DEA Analysis of Bank Efficiency in West Balkan Countries. *Sustainability (Switzerland)*, 14(2). <https://doi.org/10.3390/su14020978>
- Moradi-Motlagh, A., & Babacan, A. (2015). The impact of the global financial crisis on the efficiency of Australian banks. *Economic Modelling*, 46, 397–406. <https://doi.org/10.1016/j.econmod.2014.12.044>
- National bank of Serbia. (2023a). *Bank's Balance Sheet/Profit statement*. <https://nbs.rs/sr/finansijske-institucije/banke/bilans-stanja/>
- National bank of Serbia. (2023b). *Inflation Report*. <https://nbs.rs/en/drugi-nivo-navigacije/publikacije-i-istrazivanja/IOI/index.html>
- Nguyen, M., Perera, S., & Skully, M. (2016). Bank market power, ownership, regional presence and revenue diversification: Evidence from Africa. *Emerging Markets Review*, 27, 36–62. <https://doi.org/10.1016/j.ememar.2016.03.001>
- Núñez, F., Arcos-Vargas, A., & Villa, G. (2020). Efficiency benchmarking and remuneration of Spanish electricity distribution companies. *Utilities Policy*, 67(December 2019). <https://doi.org/10.1016/j.jup.2020.101127>
- Ofori-Sasu, D., Abor, J. Y., & Mensah, Lord. (2019). Funding structure and technical efficiency: A data envelopment analysis (DEA) approach for banks in Ghana. *International Journal of Managerial Finance*, 15(4), 425–443. <https://doi.org/10.1108/IJMF-01-2018-0003>
- Paradi, J. C., Rouatt, S., & Zhu, H. (2011). Two-stage evaluation of bank branch efficiency using data envelopment analysis. *Omega*, 39(1), 99–109. <https://doi.org/10.1016/j.omega.2010.04.002>
- Patra, B., Padhan, P. C., & Padhi, P. (2023). Efficiency of Indian Banks—private versus public sector banks: A two-stage analysis. *Cogent Economics and Finance*, 11(1). <https://doi.org/10.1080/23322039.2022.2163081>
- Radojicic, M., Savic, G., & Jeremic, V. (2018). Measuring the efficiency of banks: The bootstrapped i-distance gar dea approach. *Technological and Economic Development of Economy*, 24(4), 1581–1605. <https://doi.org/10.3846/tede.2018.3699>
- Raphael, G. (2013). Bank-specific, industry-specific and macroeconomic determinants of bank efficiency in Tanzania: A two stage analysis. *European Journal of Business and Management*, 5(2), 2222–2839. [https://s3.amazonaws.com/academia.edu.documents/30633015/Bank-specific\\_\\_industry-specific\\_and\\_macro-economic\\_determinants\\_of\\_bank\\_efficiency\\_in\\_Tanzania.pdf?AWS](https://s3.amazonaws.com/academia.edu.documents/30633015/Bank-specific__industry-specific_and_macro-economic_determinants_of_bank_efficiency_in_Tanzania.pdf?AWS)



- AccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1512193867&Signature=DgTGvGtNqQo6EBj2778b8KfMk98%3D&res
- Řepková, I. (2015). Banking Efficiency Determinants in the Czech Banking Sector. *Procedia Economics and Finance*, 23(October 2014), 191–196. [https://doi.org/10.1016/s2212-5671\(15\)00367-6](https://doi.org/10.1016/s2212-5671(15)00367-6)
- Ristić, K., & Jemović, M. (2021). Analysis of Non-Performing Loans' Determinants in the Banking Sector of the Republic of Serbia. *Economic Themes*, 59(1), 133–151. <https://doi.org/10.2478/ethemes-2021-0008>
- Sharma, A. K., Sharma, D., & Barua, M. K. (2012). Efficiency and Productivity of Indian Banks : An Application of Data Envelopment Analysis and Tobit Regression. *National Conference on Emerging Challenges for Sustainable Business, January 2016*, 81–90. <https://doi.org/10.13140/RG.2.1.2827.6886>
- Sherman, H. D., & Gold, F. (1985). Bank branch operating efficiency. Evaluation with Data Envelopment Analysis. *Journal of Banking and Finance*, 9(2), 297–315. [https://doi.org/10.1016/0378-4266\(85\)90025-1](https://doi.org/10.1016/0378-4266(85)90025-1)
- Singh, P. K., & Thaker, K. (2020). Profit efficiency and determinants of Indian banks; A truncated bootstrap and data envelopment analysis. *Cogent Economics and Finance*, 8(1). <https://doi.org/10.1080/23322039.2020.1724242>
- Statistical Office of the Republic of Serbia. (2023). *Quarterly national accounts*. <https://www.stat.gov.rs/en-US/oblasti/nacionalni-racuni/kvartalni-nacionalni-racuni>
- Sufian, F. (2016). Determinants of Efficiency in the Malaysian Banking Sector: Evidence from Semi-parametric Data Envelopment Analysis Method. *Studies in Microeconomics*, 4(2), 151–172. <https://doi.org/10.1177/2321022216636443>
- Sufian, F., & Abdul Majid, M.-Z. (2007). Deregulation, consolidation and banks efficiency in Singapore: Evidence from event study window approach and Tobit analysis. *International Review of Economics*, 54(2), 261–283. <https://doi.org/10.1007/s12232-007-0017-2>
- Sufian, F., Kamarudin, F., & Nassir, A. md. (2016). Determinants of efficiency in the Malaysian banking sector: Does bank origins matter? *Intellectual Economics*, 10(1), 38–54. <https://doi.org/10.1016/j.intele.2016.04.002>
- Titko, J., Stankevičienė, J., & Lāce, N. (2014). Measuring bank efficiency: DEA application. *Technological and Economic Development of Economy*, 20(4), 739–757. <https://doi.org/10.3846/20294913.2014.984255>
- Tobin, B. Y. J. (1958). Estimation of Relationships for Limited Dependent Variables. *Econometrica*, 26(1), 24–36.
- Ünlü, U., Yalçın, N., & Avsarlıgil, N. (2022). Analysis of Efficiency and Productivity of Commercial Banks in Turkey Pre- and during COVID-19 with an Integrated MCDM Approach. *Mathematics*, 10(13). <https://doi.org/10.3390/math10132300>
- Vasić, V. (2020). Bankarski sektor u borbi za ublažavanje efekata pandemije. *Bankarstvo*, 49, 4–9. <https://www.ceeol.com/content-files/document-905893.pdf>
- Vunjak, N., Davidović, M., & Stefanović, M. (2014). Uticaj globalne finansijske krize na performanse bankarskog sektora Srbije. *Teme*, 71, 1279–1298.
- Wanke, P., Skully, M., Wijesiri, M., Walker, T., & dalla Pellegrina, L. (2022). Does ownership structure affect firm performance? Evidence of Indian bank efficiency before and after the Global Financial Crisis. *International Transactions in Operational Research*, 29(3), 1842–1867. <https://doi.org/10.1111/itor.13072>
- Wu, H. Y. (2012). Constructing a strategy map for banking institutions with key performance indicators of the balanced scorecard. *Evaluation and Program Planning*, 35(3), 303–320.

<https://doi.org/10.1016/j.evalprogplan.2011.11.009>

Xie, Q., Xu, Q., Chen, L., Jin, X., Li, S., & Li, Y. (2022). Efficiency evaluation of China's listed commercial banks based on a multi-period leader-follower model. *Omega (United Kingdom)*, 110, 102615. <https://doi.org/10.1016/j.omega.2022.102615>

Yu, M. M., Lin, C. I., Chen, K. C., & Chen, L. H. (2021). Measuring Taiwanese bank performance: A two-system dynamic network data envelopment analysis approach. *Omega (United Kingdom)*, 98, 102145. <https://doi.org/10.1016/j.omega.2019.102145>

Zheng, G. W., Siddik, A. B., Masukujjaman, M., & Fatema, N. (2021). Factors affecting the sustainability performance of financial institutions in Bangladesh: The role of green finance. *Sustainability (Switzerland)*, 13(18), 1–27. <https://doi.org/10.3390/su131810165>

Zhu, C., Zhu, N., & Shan, W. U. H. (2021). Eco-efficiency of industrial investment and its influencing factors in china based on a new SeUo-SBM-DEA model and tobit regression. *Mathematical Problems in Engineering*, 2021. <https://doi.org/10.1155/2021/5329714>

## O DETERMINANTAMA EFIKASNOSTI BANAKA U REPUBLICI SRBIJI: DVOSTEPENI DEA PRISTUP

**Apstrakt:** Značajna uloga bankarskog sektora u ekonomskom razvoju zemlje nameće potrebu kontinuiranog merenja i praćenja efikasnosti banaka. Pored toga, identifikovanje industrijskih i makroekonomskih faktora koji utiču na postignutu efikasnost je važan zadatak u cilju otkrivanja potencijalnih poremećaja, kao i davanja adekvatnih smernica za poboljšanje efikasnosti. Stoga je osnovni cilj ovog rada da se kvantifikuje postignuta efikasnost i otkriju njene determinante. Studija se sprovodi u dve faze. U prvoj fazi, primenom DEA metode, proceniće se efikasnost banaka za period od 2005. do 2022. godine, dok će se u drugoj fazi utvrđivati faktori efikasnosti primenom Tobit regresije. Rezultati ukazuju da kada su u pitanju faktori specifični za privrednu granu, veća koncentracija tržišta nepovoljno utiče na efikasnost banaka. U pogledu makroekonomskih faktora, rast bruto domaćeg proizvoda, stopa inflacije i svetska finansijska kriza imaju značajan uticaj na dostignuti nivo efikasnosti banaka u Republici Srbiji. Pored proširenja postojećih znanja o kvantifikaciji efikasnosti i definisanju determinanti efikasnosti na primeru banaka u Republici Srbiji, rezultati u ovom radu su relevantni i za kreatore politike i praktičare.

**Ključne reči:** DEA analiza, intermedijarni pristup, Tobit regresija, specifični faktori, makroekonomski faktori.

### **Authors' biographies**

**Ivana Marjanović** has a PhD in the field of Mathematics and Statistics in Economics. Currently she is a Teaching Assistant at the Faculty of Economics, University of Niš. Her research primarily revolves around the utilization of quantitative methods in economics, with a particular emphasis on employing operational research and decision theory methods and models. Additionally, she possesses substantial expertise in conducting both quantitative and qualitative research in the domain of urban studies and sustainable development. She actively participates as a researcher in multiple projects funded by the European Union.

**Jelena J. Stanković**, full professor at the Faculty of Economics, University of Niš, holding PhD in Mathematics and Statistics in Economics. Her scientific interests include quantitative economic analysis, particularly analytics in the context of smart, sustainable, and resilient urban and regional development. She is an active member of the Committee for Economic Sciences of the Serbian Academy of Science and Arts (SASA) and a PI of the projects conducted in the field of economics by SASA Branch in Niš. Also, she is PC of Horizon Europe UR-DATA project. She is engaged as a researcher on several projects funded by the Ministry of Education, Science and Technological Development of Republic of Serbia, as well as on international projects, with strong competencies in project management and wide experience of coordination and implementation of project activities.

**Georgios Tsaples** received his diploma as an Electrical and Computer Engineer, from the Engineering Faculty of the Aristotle University of Thessaloniki. He holds an MsC in Engineering in Policy Analysis from the Technical University of Delft and his PhD in Operational Research from the University of Macedonia. He is currently applying quantitative methods in various EU-funded projects. His research interests include operational research, simulation and optimization methods and their applications in a wide range of topics from racism to sustainability.