# Size matters: analyzing bank profitability and efficiency under the Basel III framework

**Gržeta, Ivan; Žiković, Saša; Tomas Žiković, Ivana**

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# Size matters: analyzing bank profitability and efficiency under the Basel III framework

Ivan Gržeta*, Saša Žiković and Ivana Tomas Žiković

*Correspondence:
ivan.grzeta@efri.hr

Faculty of Economics
and Business, University of Rijeka,
51000 Rijeka, Croatia

**Abstract**

The latest regulatory framework, which has been introduced globally in the form of Basel III, and its implementation in the legislation of the member states of the European Union has generated much interest in the impact of regulation on the efficiency and profitability of banks. This study aims to examine the impact of the introduction of two major regulatory changes (Basel II and Basel III) on bank performance, in terms of bank size and bank-specific and macroeconomic variables. A two-stage empirical analysis was conducted on a sample of 433 European commercial banks over the 2006–2015 period. In the first stage, relative efficiency was calculated using non-parametric data envelopment analysis. In the second stage, the generalized method of moments was used to examine the impact of bank-specific and macroeconomic variables as well as regulation on bank performance, that is, profitability and efficiency. Considering bank size, the results show a diverse impact of regulation on bank performance. Regarding large- and medium-sized banks, regulation positively affects both efficiency and profitability, whereas, for small banks, it negatively affects performance. The results suggest that larger banks have skillfully adapted to the new regulatory environment. In contrast, small banks have problems with profitability and efficiency because the new regulatory framework has imposed additional administrative and regulatory burdens. This could result in future failure or mergers with larger banks, resulting in a higher concentration in the banking sector and increased systemic risk. Our results strongly suggest that regulation should not be implemented equally for all banks; that is, on a one size fits all terms. A distinction between small and large banks when introducing new regulatory frameworks should be made if a reasonable level of competition is to be preserved.

**Keywords:** Bank profitability, Bank efficiency, Bank size, Basel III regulatory framework

**JEL Classification:** C33, C67, G21, G28

## Introduction

A well-functioning financial system is a prerequisite for economic growth and serves as the backbone of economic development. The amount of funds available in the market depends on the banking skill of converting excess funds into placements, that is, their efficiency (Barth et al. 2013). The strength of the banking system is crucial for safeguarding the interests of investors, individuals, and the financial market altogether (Bouheni et al. 2014). Financial intermediaries play an important role in the functioning of any

modern economy. As the lack of financial supervision eventually results in the spread of systemic risk (Kou et al. 2019), strong banking regulation and supervision create a stable and safe banking environment aimed at preventing the negative impact that a bank failure can have on the entire economy. However, the impact of the banking regulatory framework remains a thought-provoking research topic as its refinements and changes have significant implications on bank performance.

This study primarily aims to examine whether Basel II and III legislative packages have similar impacts on banks of different sizes. Banks in the EU represent an interesting research case as they are subject to the same regulations enacted at the EU level. Although essentially all commercial banks are engaged in similar businesses, uniform regulations have different impacts on banks, depending on size. A well-functioning financial system is critical for economic growth. Accordingly, this study aims to analyze bank efficiency and profitability, as well as the impact of banking regulation on the performance of commercial banks. Additionally, this study aims to test the efficient structure hypothesis and the relative market power hypothesis following Berger (1995), who tested it based on United States (US) bank data. Guillén et al. (2014) tested this hypothesis for banks in Latin America. The efficient structure hypothesis suggests that bank size affects profits owing to scale dependence, whereas the market power hypothesis states that firms and banks with large market shares have monopolistic influence and subsequent high profits. Following Bucevska and Hadzi Misheva (2017), we analyzed the structure-conduct-performance (SCP) hypothesis versus the efficiency hypothesis. The structure-conduct-performance (SCP) paradigm states that concentration results in market power, which consequently affects performance and profitability, whereas the efficiency hypothesis states that higher operating efficiency results in concentration and consequently higher performance.

The database of EU commercial banks from 28 countries during the period from 2006 through 2015 serves as a valuable and unique pool, as it includes the introduction of the two largest regulatory changes in banking, namely Basel II and Basel III. The empirical analysis is conducted in two stages: the results for relative efficiency are obtained using non-parametric data envelopment analysis (DEA), whereas the effects of bank-specific and macroeconomic variables, along with regulatory framework changes on profitability and efficiency, are examined using dynamic panel data analysis.

Only a few authors have used a similar approach to analyze the impact of regulations on bank profitability and efficiency. However, while analyzing the impact of regulation on bank performance, the authors examine the impact of introducing only one major regulatory framework (Pasiouras et al. 2009; Bouheni et al. 2014; Căpraru and Ihnatov 2014).

This study aims to examine the impact of the introduction of two major regulatory changes (Basel II and Basel III) on bank performance over a longer observation period with respect to bank size and bank-specific and macroeconomic variables. Furthermore, most studies use arbitrary criteria to select the sample by country of origin (Bouheni et al. 2014; Căpraru and Ihnatov 2014) and distinguish banks by size (Terraza 2015). We use the European Central Bank (ECB) methodology as a more objective criterion for classifying bank size and focus on the analysis of EU banks as they are required to follow the same directives set out by the EU Commission.

The empirical analysis is conducted for different bank size categories to determine whether there is a difference in the impact of regulatory changes and other determinants on bank performance, that is, profitability and relative efficiency. The obtained results indicate, among other things, that larger banks have successfully adapted to the new regulatory framework, whereas small banks have experienced a decline in their performance, suggesting that bank regulation should be size-dependent. When introducing new regulatory frameworks, small and large banks should be distinguished to maintain a reasonable level of competition.

To the best of the authors' knowledge, there is no study on the impact of EU regulations (derived from Basel II and III) for the entire sample of the member countries of the EU. Although the existing literature extensively analyzes the profitability and efficiency determinants in the banking sector, only a few studies have examined the impact of regulation along with bank-specific and macroeconomic variables in relation to different bank size categories (Terraza 2015; Triki et al. 2017). It is safe to attribute this to the short observation period and difficulties in defining the proxies for the new regulation as well as the proxies for the bank size groups.

Regarding these issues, this study's contribution to the existing body of literature is to fill the gap by examining the impact of regulation along with bank-specific and macroeconomic variables on the performance of banks operating in 28 EU countries.

This paper proceeds as follows. "Supervision of commercial banks in the European Union" section discusses the supervision and structure of commercial banks in the EU. "Literature review" section reviews the literature on the relative efficiency and profitability of commercial banks. "Methodology, sample characteristics, and variable selection" section describes the methodology, sample characteristics, and variable selection. "Empirical results" section elaborates on the empirical results and provides an economic interpretation. Concluding remarks Section further draws conclusions, discusses the study implications, and provides recommendations for future research.

## Supervision of commercial banks in the European Union

The impact of regulation on the financial sector, especially for commercial banks in the EU, is observed through the constant updating of global regulations in response to changes in the global economy and crises. Banks have always been considered sensitive institutions that require government oversight and support to develop in a secure environment (Tchana Tchana 2014). After the 2008 global financial crisis, the safety and stability of the banking system have become imperative for all stakeholders, beginning with regulators, academics, and policymakers. Maintaining stability by holding an adequate amount of capital buffers and liquidity has been emphasized. The result of this effort is the introduction of a new regulatory framework referred to as Basel III, which emphasizes the importance of capital in both qualitative and quantitative terms, as well as the importance of stable funding and liquidity of bank assets. It has emerged from a belief that banks with adequate capital, liquid assets, and stable funding can maintain their operations more efficiently in the face of adverse and sudden economic shocks (Kim and Sohn 2017). Basel III represents a set of measures aimed at advancing regulation, supervision, and risk management in the banking sector (Schmaltz et al. 2014). The previous standards were not abolished with the introduction of Basel III but were

revised, reinforced, and expanded in several areas. A former chairman of the Federal Reserve, Ben Bernanke stated: "This framework would require banking organizations to hold more and higher quality capital, improving the resilience of the U.S. banking system in times of stress, thus contributing to the overall health of the U.S. economy." Reforms under the Basel III framework have two main objectives: reinforcing capital and liquidity, which should make banks more resilient to market fluctuations, and improving the banking sector's ability to withstand shocks resulting from financial and economic market stress.

EU rulebooks on prudential regulation are mainly derived from Basel guidelines and concern the amount and quality of liquidity and capital adequacy. Similar to the Basel Committee, such EU rulebooks are aimed at maintaining the stability of banks during economic downturns while ensuring that banks continue financing the corporate sector during economic downturns. The current regulatory package focuses on capital and liquidity, as banks were vulnerable during the financial crisis owing to the quality and quantity of capital and the lack of short- and long-term liquidity (European Commission, Prudential Requirements 2019). The recent EU legislative package attempts to mend this by imposing stricter prudential requirements for banks in terms of capital reserves and liquidity.

Basel III significantly affects banks' organizational structure and mainly affects the risk department. The regulatory framework sets boundaries and directions to enhance risk management and stimulate the development of internal risk management models. Although tighter regulations ensure sound management and improve safety in general, they also reduce credit growth (Cerutti et al. 2015).

## Literature review

Despite the positive intentions of the regulatory framework to maintain the stability of the financial system, its introduction should be evaluated in the context of the performance of individual banks. Commercial banks mainly aim to maximize profits and operate efficiently, two aspects that should be considered when evaluating the impact of regulation on business. To evaluate profitability, most researchers use return on assets (ROA) and/or return on equity (ROE) as profitability proxies in banks (Naceur and Omran 2011; Rezende and Wu 2012; Bouheni et al. 2014; Căpraru and Ihnatov 2014; Dietrich et al. 2014; Imbierowicz and Rauch 2014; Ozkan et al. 2014; Terraza 2015; Borio et al. 2017; Roulet 2017; Bucevska and Hadzi Misheva 2017; Kim and Sohn 2017; Antoun et al. 2021).

Efficiency broadly refers to efficiency in the production, consumption, and allocation of resources. Regarding relative efficiency, it is not possible to improve the economic position of an entity without simultaneously reducing that of the other entity. An entity is fully efficient if it is not possible to improve any of its inputs or outputs without affecting other inputs or outputs. In other words, an entity is efficient if the output is maximal, given the inputs (Cooper et al. 2004). The roots of the relative efficiency methodology can be found in the late 1970s by Sealey and Lindley (1977). It was later further developed by Banker et al. (1984). Sherman and Gold (1985) conducted the first calculation of the relative efficiency of bank branches using DEA. Subsequently, many researchers have

used DEA to evaluate bank efficiency (e.g. Pasiouras et al. 2009; Barth et al. 2013; Psillaki and Mamatzakis 2017).

Although the existing literature extensively analyzes profitability and efficiency determinants, only a few studies have examined the impact of regulation on them. This is predominantly due to the short observation period and difficulties in defining proxies for regulation. Pasiouras (2008) examines the impact of Basel II on bank efficiency and provides evidence in favor of the Basel II pillars, showing that banks actually increased their technical efficiency after its implementation. In their later work (Pasiouras et al. 2009) found that Basel II (i.e., market discipline mechanisms, official supervisory powers, and capital adequacy requirements) reinforced the authorities' supervisory control and improved market discipline, which consequently increased both bank profitability and cost efficiency. Simultaneously, stricter capital requirements reduced profit efficiency but increased cost efficiency. Partially contrary to this, Căpraru and Ihnatov (2014) analyze the main determinants of bank profitability in Central Eastern European countries and find that higher capital adequacy (an element emphasized in the recent regulatory framework) results in higher bank profitability. Bouheni et al. (2014), Neyapti and Dincer (2014), and Ozkan et al.(2014) conclude the same, proving that supervision and regulation improve bank profitability. In contrast, Chortareas et al. (2012) examine the dynamics between key supervisory and regulatory policies. Their results show that reinforcing official supervisory powers and capital restrictions can improve the efficiency of commercial banks, whereas interventionist regulatory policies, such as prohibiting banking activities in certain sectors or monitoring certain activities, can lower their efficiency. Barth et al. (2013) come to mixed conclusions regarding regulation, with tighter restrictions on bank activities negatively impacting bank efficiency, while tighter capital regulation has a marginally positive impact on bank efficiency. This is of particular interest to researchers in the current state of affairs, as future regulations will probably result in further policy tightening.

According to Deli and Hasan (2017), capital is among the leading indicators of bank profitability and can offset the negative effects of regulation. They conclude that strict capital regulation has a negative but weak effect on credit growth but is eliminated when banks have sufficient capital levels. They find that capital requirements associated with Basel standards are easily manageable for well-capitalized banks, especially when implemented during normal economic development. Kim and Sohn (2017) analyze the impact of capital on lending, depending on the level of commercial banks' liquidity for US banks. They find a positive relationship between bank capital and liquidity, with capital positively affecting lending when holding a sufficient level of liquidity. However, this is significant only for large banks. In contrast to Deli and Hasan (2017), Kim and Sohn (2017) find that the interaction between capital and lending is insignificant, or even negligibly negative, for small- and medium-sized banks.

Rezende and Wu (2012) provide an early definition of the threshold for bank size and the impact of regulation. Using banks with asset thresholds of 250 and 500 million USD, they show that on-site safety and soundness checks by regulators improve bank performance because more frequent checks increase the ROE and lower loan losses and delinquencies. However, in their analysis, they use only large banks, similar to Pasiouras et al. (2009) and Barth et al. (2013), who mainly focus on large banks.

Terraza (2015) was among the first to highlight the importance of bank size in profitability. He examines the effects of bank capital and liquidity ratios on profitability and finds that bank capital positively affects profitability, whereas the effects of liquidity ratios differ with respect to bank size. Their findings suggest that there are substantial differences in bank behavior depending on their size. Kale et al. (2015) find that after the 2001 Turkish crisis, large and small banks were not equally affected by different macroeconomic conditions; that is, small banks performed better than large banks in a volatile period, while large banks performed better in a stable period. Triki et al. (2017) analyze the impact of regulation on bank efficiency in 42 African countries and find that the impact of bank regulation was significantly related to bank size and risk profile. Their results support the theory that regulation should not be designed to apply the same rules to all banks but should be adapted to the characteristics and risk profiles of individual banks. Consistent with the findings of Pasiouras et al. (2009) and Barth et al. (2013), they also emphasize that imposed restrictions on activities and banking operations reduce and limit the diversity of income streams, which is reflected in decreased banking efficiency. McNulty et al. (2001) and Mercieca et al. (2007) also addressed research related to small banks and their peculiarities. However, to the best of the authors' knowledge, none of these studies address the impact of regulation on bank performance depending on their size across EU member countries.

For this reason, this study aims to fill the gap in the existing literature by examining the impact of regulation along with bank-specific and macroeconomic (monetary) variables on the performance of banks operating in EU member states.

Table 1 provides an overview of the main findings and datasets of influential studies on bank performance (profitability and efficiency).

## Methodology, sample characteristics, and variable selection

### Methodology

The impact of the new regulatory framework on banking operations (Basel implementation in EU legislation) was examined in a two-stage analysis. In the first stage, relative efficiency was calculated based on non-parametric DEA. As most economic variables exhibit dynamic behavior, in the second stage, we employ dynamic panel data analysis, where the efficiency scores from the first stage are used as a banking operation proxy in the second-stage analysis, along with the previously mentioned ROA.

Sherman and Gold (1985) conducted one of the first analyses of the relative efficiency of bank branches using the DEA methodology. They found useful information about inefficient branches and areas in which they could improve their efficiency. Their findings suggest that the DEA methodology is more advanced than other techniques for analyzing bank branch efficiency. Subsequently, the application of the DEA methodology to evaluate the relative efficiency of banks has increased (Pasiouras 2008; Chortareas et al. 2012; Barth et al. 2013; Gržeta 2020). Barth et al. (2013) state that DEA has several advantages as a non-parametric method for evaluating efficiency compared to parametric methods, such as stochastic frontier analysis (SFA). DEA calculates the multiple input/output data of the sample banks, which do not suffer from functional form dependency. Functional form dependency is present in parametric methods, where one must assume a particular functional form and impose a certain

**Table 1** Studies on bank performance (profitability and efficiency)

| **Bank profitability analysis** | | | |
|---|---|---|---|
| **Authors** | **Period** | **Dataset** | **Main findings** |
| Bouheni et al. (2014) | 2005–2011 | 6 EU countries (Germany, UK, France, Greece, Spain, Italy) | Regulation improves profitability |
| Căpraru and Ihnatov (2014) | 2004–2011 | 5 Central and Eastern Europe (CEE) countries (Romania, Hungary, Poland, Czech Republic, Bulgaria) | Banks with higher capital adequacy are more profitable |
| | | | Size of the banks has negative impact on profitability |
| Guillén et al. (2014) | 1989–2005 | Latin America | Testing hypothesis of relative market power, structure conduct performance and efficient structure |
| | | | Profit depends on size as well as power and both together make structure conduct performance hypothesis to hold |
| Ozkan et al. (2014) | 1998–2009 | Turkey | Regulation in Turkey had positive effect on lending, asset quality and profitability |
| Petria et al. (2015) | 2004–2011 | Europe (EU 27) | Credit risk, liquidity risk, management efficiency and concentration have negative influence on bank profitability |
| Terraza (2015) | 2005–2012 | Europe | No evidence of a positive relationship between greater efficiency and bank profitability |
| | | | Capitalization levels increase bank profitability |
| Bucevska and Hadzi Misheva (2017) | 2005–2009 | 6 Balkan countries | Efficiency is positively associated with profitability, unlike industry concentration, supporting efficiency hypothesis instead of structure-conduct-performance (SCP) paradigm |
| Hamdi et al. (2017) | 2005–2012 | Tunisia | Positive relationship between gross domestic product (GDP) and inflation with bank performance |
| Asongu and Odhiambo (2019) | 2001–2011 | Africa | Bank size increases bank interest rate margins |
| | | | Market power and economies of scale do not increase or decrease the interest rate margins significantly |
| Pasiouras (2008) | 2003 | 95 countries worldwide | All three pillars of Basel II provide evidence in favor of efficiency |
| | | | Larger size result in higher efficiency |
| | | | Concentration leads to higher efficiency |
| Pasiouras et al. (2009) | 2000–2004 | 74 countries worldwide | Regulation related to three pillars increase cost and profit efficiency |
| Chortareas et al. (2012) | 2000–2008 | 22 EU countries | Capital restriction and supervision increase efficiency |

**Table 1** (continued)

| Bank profitability analysis | | | |
|---|---|---|---|
| **Authors** | **Period** | **Dataset** | **Main findings** |
| | | | Larger banks operating in countries with less concentrated and more developed systems tend to have relatively higher levels of efficiency |
| Barth et al. (2013) | 1999–2007 | 72 countries worldwide | Regulation (Basel II pillars) is positively associated with efficiency |
| Lee and Chih (2013) | 2004–2011 | China | Policymakers and banks face a trade-off between financial risk and efficiency |
| | | | Stricter regulation may be good for bank stability, but not for bank efficiency |
| Kale et al. (2015) | 1997–2013 | Turkey | Regulation has a positive impact on efficiency |
| Triki et al. (2017) | 2005–2010 | 42 countries in Africa | More stringent capital requirements enhance the efficiency of large banks |
| | | | Regulation should be adapted to the risk and size level of the institutions that are being regulated |
| Jelassi and Delhoumi (2021) | 1995–2017 | Tunisia | Noticeable increase in banking technical efficiency, largely due to bank supervision |
| | | | Size of the banks and loans-to-asset ratio negatively affects efficiency |
| | | | Profitability is not significant |
| | | | Inflation positively affects efficiency |

Source: authors

structure on the shape of the efficient frontier. The accuracy of the results depends on the accuracy of the assumption. The second advantage of DEA is that it focuses on an individual unit (bank, firm, etc.) rather than the population average, which increases the accuracy of predicting individual efficiency. Another advantage is that individual units are compared to the best-practice frontier rather than the central tendency properties. The main advantage of DEA as a non-parametric method is simultaneously a disadvantage, as it is impossible to estimate model parameters, and it depends largely on the choice and number of input variables.

In the DEA framework, a "bank with an efficiency score of 1 (100%) is located on the efficient frontier in the sense that its outputs cannot be further expanded without increasing its inputs" (Řepková 2015). A bank with an efficiency score below 100% is relatively inefficient, suggesting that it can achieve its current output level with fewer inputs. Each bank or decision-making unit (DMU) has a certain number of inputs (i) and outputs (o), implying that each DMU "consumes" a certain amount of input to obtain a certain output.

The productivity of DMU can be written as (Řepková 2015):

$$max\ h_0(u,v) = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}} \tag{1}$$

$$\text{subject to} \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1,\ \text{j} = 1, 2 \ldots j_0, \ldots, n,$$
$$u_r \geq 0,\ \text{r} = 1, 2, \ldots,\ \text{s}$$
$$v_i \geq 0,\ \text{i} = 1, 2, \ldots,\ \text{m}$$

where $u$ and $v$ are weights assigned to each input and output.

DEA assigns weights in such a way that no other DMU has higher efficiency. The objective function of the DMU is the ratio of the total weighted output to the total weighted input. where $h_0$ is the technical efficiency of $DMU_o$ to be estimated, $v_i$ and $u_r$ are weights to be optimized, $x_{ij}$ represents the amount of input of the *i th* type for the *j th* DMU, $y_{rj}$ is the observed amount of output of the *r th* type for the *j th* DMU, $i$ denotes the $m$ different inputs, $r$ indicates the $s$ different outputs, and $j$ indicates the $n$ different DMUs. As the traditional approach of computing the DEA frontier suffers from several problems,[1] Fernandes et al. (2018) proposed a bias-corrected approach implemented in the procedure of Simar and Wilson (see Simar and Wilson 1998 for more details). Their procedure uses a bootstrap approach that provides bias-corrected efficiency scores, where known bootstrap distributions mimic the original unknown sampling distributions of the estimators of interest.[2]

Given that most economic variables exhibit dynamic behavior, the second stage of the analysis is conducted using dynamic panel models. They consider the dynamic nature of the relationship among economic variables by including the lags of both dependent and independent variables. The most commonly used estimators in empirical research are the difference generalized method of moments (GMM) estimator proposed by Arellano and Bond (1991) and the System GMM estimator proposed by Arellano and Bover (1995) and Blundell and Bond (1998). GMM estimators achieve consistent and unbiased estimations of the parameters and solve the problem of endogeneity that may arise owing to the relationship between the dependent and independent variables by using the lags of the endogenous variables as instruments.

The empirical analysis is conducted separately for bank profitability and bank efficiency such that the results of the first stage of the analysis, that is, the efficiency scores obtained from DEA, are used in the panel data analysis. Moreover, the use of efficiency scores is twofold. First, we use efficiency scores as an independent bank-specific variable to examine its impact, along with other independent variables, on bank profitability (ROA). Second, in a separate analysis, we examine the drivers of bank efficiency using DEA efficiency scores as the dependent variable for bank efficiency. To avoid endogeneity problems, panel data analysis includes variables that are not used to estimate the efficiency scores obtained from DEA.

[1] DEA input/output data may contain random errors, so the efficient frontier may be distorted by statistical noise.

[2] Package "rDEA" in programming language "R" is used for the calculation of bias-corrected efficiency scores.

Like most economic variables, ROA (in examining bank profitability determinants) and efficiency scores (EFF—dependent variable for bank efficiency) exhibit dynamic behavior; that is, the current values of bank profitability depend on their past values. The linear dynamic panel data model used to explain bank profitability (first model specification) and subsequent bank efficiency (second model specification) can be expressed as follows:

$$y_{it} = \mu + \gamma y_{i,t-1} + \beta X_{it} + \delta Z_t + \alpha_i + \varepsilon_{it};\ \ i = 1, \ldots N,\ \ t = 1, \ldots, T \tag{2}$$

$$y_{it} - y_{i,t-1} = \gamma\left(y_{i,t-1} - y_{i,t-2}\right) + \beta\left(X_{it} - X_{i,t-1}\right) + \delta(Z_t - Z_{t-1}) + \left(\varepsilon_{it} - \varepsilon_{i,t-1}\right);\ i = 1, \ldots N,\ \ t = 1, \ldots, T \tag{3}$$

The different forms of the equation cancel out the individual effects. Furthermore, the correlation between the difference lagged dependent variable and the difference error term $\left(\varepsilon_{it} - \varepsilon_{i,t-1}\right)$ is solved using instrumental variables. Instrumental variables are expected to be highly correlated with the difference lagged dependent variable. Simultaneously, they should be uncorrelated with the difference error term. However, the difference GMM exhibits weaknesses when the dependent variable is highly persistent and when the ratio of individual effect variance and the remaining part of the error term variance increases ($\sigma_\alpha^2/\sigma_\varepsilon^2$). Therefore, (Arellano and Bover 1995; Blundell and Bond 1998) propose a system GMM estimator using both the equation in first differences (3) and the equation in levels (2). As this estimator showed better properties than the Arellano and Bond estimator, we provide empirical evidence using the system GMM. Moreover, the two-step GMM estimator is estimated using corrected standard errors and t-tests, which is consistent with the procedure proposed by Windmeijer (2005).

Along with the weak instrument problem that arises when using the difference GMM estimator for highly persistent variables, another concern is the use of too many instruments. Too many instruments can cause overfitting of the endogenous variables and fail to eliminate their endogenous components. The number of instruments increases relative to the sample size as the number of periods, T, increases (Roodman 2009). This problem is particularly pronounced for small samples. Therefore, the validity of the chosen instruments is tested using the Hansen J-test, which is a standard specification test for the two-step GMM, while the consistency of the model estimates is tested using the Arellano-Bond second-order autocorrelation AR (2).

Additionally, a separate analysis is performed with respect to bank size, with a separate calculation of relative efficiency within different categories of banks. This is done to ascertain whether there is a difference in profitability and efficiency determinants between the small and large bank categories. Additionally, we aimed to examine whether regulation differently affects bank profitability and efficiency in terms of their size, as smaller banks are expected to have limited resources for additional administrative burdens and lower resilience to external shocks. Regarding the robustness check, we performed separate analyses for all, large, medium, and small banks, controlling for the European Monetary Union (EMU) and Old European Union (EU15) country variables.

### Sample characteristics

To avoid the problems of comparing different types of banks, we used only commercial banks for our sample. The financial data were collected from the BankScope database of Bureau van Dijk, which contains 1309 commercial banks from 2000 to 2015. The banks left out of the sample included banks classified as "bankrupt" or "liquidated," banks involved in mergers and acquisitions, and banks with missing financial data consistent with the research of Dietrich et al. (2014) and Bucevska and Hadzi Misheva (2017). Following a similar approach to Bouheni et al. (2014), our observation period covers data from 2006 to 2015 owing to the introduction of the new International Financial Reporting Standards (IFRS) for banks in 2005, so the data were collected at the individual level, that is, for each bank in the EU-28 countries, for the 10-years period (annual data from 2006 to 2015). Consequently, the final sample includes 433 commercial banks, of which 281 banks are classified as large and medium-sized banks, and the remaining 152 banks are classified as small banks.[3] Table 2 shows the distribution of observations according to the country of origin and bank size.

The largest share of the sample comprises banks in Germany, France, and Italy. The same applies to large- and medium-sized banks,[4] while Germany, Italy, and the United Kingdom have the highest share of small banks.

### Variable selection

The impact of regulatory requirements has largely been analyzed either for selected countries at the global level (Barth et al. 2013), selected countries at the European level (Dietrich et al. 2014), or for individual countries. However, to the best of the authors' knowledge, there is no scientific research on the impact of EU regulation for the 28 EU member states.

As the global financial crisis significantly affected bank profitability, the profitability of banks, regardless of their size is evaluated using ROA, which represents the ratio of profit before taxes to total assets. Following previous research on bank efficiency (Sealey and Lindley 1977; Sherman and Gold 1985; Bauer et al. 1998; Athanasoglou et al. 2006; Pasiouras 2008; Chortareas et al. 2012; Barth et al 2013; Boda and Zimková 2015; Kale et al. 2015; Řepková, 2015; Triki et al 2017), the proposed model for assessing relative efficiency has four inputs and three outputs. As the main limitation of DEA is that the results are potentially sensitive to the selection of inputs and outputs, the importance of variables is thoroughly analyzed prior to their selection. The inputs used to calculate the relative efficiency of a bank are funding, personnel expenses, fixed assets, and loan loss provisions, whereas loans, other earning assets, and net fees are used as outputs. As the number of firms on the efficient frontier tends to increase with the number of input and output variables, the

[3] Bank size is determined in accordance with the European Central Bank methodology (ECB, Consolidated banking data 2018), where bank is defined as a) large if the ratio of individual bank assets to total consolidated assets of EU banks is greater than 0.5%, b) medium-sized if the ratio of individual bank assets to total consolidated assets of EU banks is between 0.5 and 0.005%, and c) small if the ratio of individual bank assets to total consolidated assets of EU banks is below 0.005%. After applying European Central Bank methodology, the threshold for small banks is EUR 1.550.000, for medium sized banks between EUR 1.550.000 and EUR 155.000.000, while large banks are those with value of their assets above EUR 155.000.000.

[4] Large and medium-sized banks are analyzed together because the number of large banks in the sample is only 37, which is insufficient for separate statistical analysis.

**Table 2** Distribution of banks according to the country of origin and bank size

| Country | Total num. of banks | % | Large and medium sized banks | % | Small banks | % |
|---|---|---|---|---|---|---|
| Austria | 29 | 6.70 | 18 | 6.41 | 11 | 7.24 |
| Belgium | 9 | 2.08 | 6 | 2.14 | 3 | 1.97 |
| Bulgaria | 9 | 2.08 | 7 | 2.49 | 2 | 1.32 |
| Cyprus | 5 | 1.15 | 5 | 1.78 | 0 | 0.00 |
| Czech | 10 | 2.31 | 7 | 2.49 | 3 | 1.97 |
| Germany | 65 | 15.01 | 39 | 13.88 | 26 | 17.11 |
| Denmark | 23 | 5.31 | 15 | 5.34 | 8 | 5.26 |
| Estonia | 4 | 0.92 | 3 | 1.07 | 1 | 0.66 |
| Spain | 14 | 3.23 | 9 | 3.20 | 5 | 3.29 |
| Finland | 3 | 0.69 | 2 | 0.71 | 1 | 0.66 |
| France | 53 | 12.24 | 42 | 14.95 | 11 | 7.24 |
| Greece | 5 | 1.15 | 2 | 0.71 | 3 | 1.97 |
| Croatia | 19 | 4.39 | 12 | 4.27 | 7 | 4.61 |
| Hungary | 9 | 2.08 | 7 | 2.49 | 2 | 1.32 |
| Ireland | 4 | 0.92 | 4 | 1.42 | 0 | 0.00 |
| Italy | 43 | 9.93 | 23 | 8.19 | 20 | 13.16 |
| Lithuania | 6 | 1.39 | 3 | 1.07 | 3 | 1.97 |
| Luxemburg | 14 | 3.23 | 11 | 3.91 | 3 | 1.97 |
| Latvia | 11 | 2.54 | 5 | 1.78 | 6 | 3.95 |
| Malta | 3 | 0.69 | 2 | 0.71 | 1 | 0.66 |
| Netherlands | 6 | 1.39 | 5 | 1.78 | 1 | 0.66 |
| Poland | 13 | 3.00 | 8 | 2.85 | 5 | 3.29 |
| Portugal | 10 | 2.31 | 8 | 2.85 | 2 | 1.32 |
| Romania | 10 | 2.31 | 7 | 2.49 | 3 | 1.97 |
| Sweden | 11 | 2.54 | 6 | 2.14 | 5 | 3.29 |
| Slovenia | 7 | 1.62 | 5 | 1.78 | 2 | 1.32 |
| Slovakia | 6 | 1.39 | 3 | 1.07 | 3 | 1.97 |
| United Kingdom | 32 | 7.39 | 17 | 6.05 | 15 | 9.87 |
| Total | 433 | 100.00 | 281 | 100.00 | 152 | 100.00 |

Source: Author's calculations based on BankScope data

appropriate number is selected based on previous research. Although DEA allows the use of inputs and outputs in different units of measurement for the evaluation of relative efficiency, all inputs and outputs are expressed in the same currency, that is, the euro. Funding represents the sources of funds used by banks for their operations and is calculated as the sum of deposits with short- and long-term funding. Fixed assets include land, buildings, equipment, and long-term investments, and refer to the type of assets that cannot be regularly converted into cash without affecting business operations. Personnel expenditures represent expenses incurred by banks on their employees, and encompass net salaries, taxes, and contributions to and from salaries. Lastly, loan loss provisions represent the risk of banks, which, according to Laeven and Majnoni (2003) and Barth et al. (2013), should be treated as costs that are certain to be incurred over time, but uncertain when they will occur. Provision is used to cover several factors that affect credit losses, such as customer default, difficulties in credit collection, and loan refinancing on worse than originally agreed terms. Loans, net fees, and other earning assets are used as outputs because they primarily describe

**Table 3** List, definition, and source of variables used in the DEA analysis

| Variable | Definition | Source |
|---|---|---|
| *Bank relative efficiency* | | |
| Funding (FUNDING = DSTFUNDING + LTFUNDING) | The sum of total deposits, short term funding and total long term funding (000 EUR) | BankScope |
| Personnel expenses (PEREXP) | Personnel expenses (000 EUR) | BankScope |
| Fixed assets (FA) | Fixed assets (000 EUR) | BankScope |
| Loan loss provision (LLPROVISION) | Loan loss provision (000 EUR) | BankScope |
| Loans (LOANS) | Total loans (000 EUR) | BankScope |
| Other earning assets (OEA) | Total other earning assets (000 EUR) | BankScope |
| Net fees (NETFEES) | Total net fees (000 EUR) | BankScope |

Source: Authors

banks' interest and non-interest income. Most commercial banks' income is derived from the loans issued. As loans were classified as a separate output for the efficiency calculation, other earning assets were used to capture the rest of the assets that contribute to revenue generation. Table 3 provides the list, definitions, and sources of the variables used in the DEA analysis.

To avoid endogeneity problems, the variables used in the estimation of relative efficiency are not considered in the panel data analysis. The independent variables used in the panel data analysis are bank-specific, macroeconomic (monetary) variables, and a dummy variable for regulation, indicating alignment with the Basel framework. The first set of explanatory variables (bank-specific variables) captures banks' financial strength and accounts for idiosyncratic risk. To control for potential outliers common in bank-level data, observations below the 5th percentile and above the 95th percentile are replaced with their winsorized values. The second set of variables includes macroeconomic and monetary variables that account for systematic risk, while the dummy variable for regulation is constructed to take the value of one for the periods from 2006 through 2007 and 2013 through 2015, and zero otherwise. We added dummy variables indicating banks operating in EMU countries and a dummy variable for banks operating in the old EU-15 member states. This is done to control for possible differences in the profitability and efficiency of banks operating in developed EU countries and in countries with a common currency, the euro. Table 4 lists the variables included in the panel data analysis.

Regarding bank-specific variables, ROA is expected to positively affect relative efficiency, and vice versa. Bank liquidity indicates the ability of a bank to cover its current and upcoming expenses. The bank achieves adequate liquidity by matching the amounts and maturities of liabilities with receivables, and maintaining an adequate liquidity reserve. Many authors such as Ozkan et al. (2014) use cash, trading securities, deposits, money market securities, and other variables as liquidity proxies. Liquidity is evaluated consistent with Athanasoglou et al. (2006), Mercieca et al. (2007), Kundid et al. (2011), and Borio et al. (2017) as the ratio of total loans to total assets. The higher the percentage of loans to total assets, the higher the expected profitability and relative efficiency. Bank size is calculated as the natural logarithm of total assets (Pasiouras 2008; Dietrich and Wanzenried 2009; Chortareas et al. 2012; Barth et al 2013; Căpraru and Ihnatov 2014; Petria et al. 2015; Borio et al. 2017; Kim

**Table 4** List, definition, and source of variables used in dynamic panel data analysis

| Variable | Definition | Source |
|---|---|---|
| *Dependent variables* | | |
| Return on assets (ROA) | Return on assets: pre-tax profit/total assets | Authors calculation |
| Efficiency for the entire sample of banks (EFF_A)<br>Efficiency for large and medium-sized banks (EFF LM)<br>Efficiency for small sized banks (EFF_S) | Bias-corrected efficiency scores for each bank *i* in time *t* (Simar Wilson correction) | Authors calculation |
| *Independent variables* | | |
| Bank specific variables | | |
| Return on assets (ROA) | Return on assets: pre-tax profit/total assets | Authors calculation |
| Efficiency (EFF) | Relative efficiency of the bank within the 0–1 range | Authors calculation |
| Liquidity (LIQ) | Liquidity: total loans/total assets | Authors calculation |
| Bank size (LBSIZE) | Bank size: logarithm of total assets | Authors calculation |
| Macro (monetary) variables | | |
| Long-term interest rate (LTR) | Long-term interest rates are used as a convergence criterion for the European Monetary Union, based on the Maastricht Treaty. Yearly interest rates are calculated based on the monthly averages | Eurostat |
| Real gross domestic product growth (GDPG) | Percentage change from previous year | Eurostat |
| Herfindahl–Hirschman Index (LHHI) | Herfindahl–Hirschman Index—sum of the squared fraction of bank's total assets to the total assets within a given country multiplied by 10.000<br>LHHI = logarithm of HHI | Authors calculation |
| Inflation (HICP) | Harmonized Index of Consumer Prices is a measure of change over time in the prices of consumer goods and services | Eurostat |
| Regulatory variable | | |
| Regulatory variable (REG_DUMMY) | Dummy variable, years 2006 and 2007 (for Basel II), 2013, 2014, 2015 (for Basel III) equal 1, while other years equal 0 | Authors calculation |
| Control variables | | |
| European Monetary Union (EMU) | Dummy variable:<br>equals 1 if a country is a member of European Monetary Union (19 countries) and 0 otherwise | Authors calculation |
| Old EU member countries (EU15) | Dummy variable:<br>equals 1 if a country is a member of old 15 EU countries and 0 otherwise | Authors calculation |

Source: Authors calculations

and Sohn 2017; Škrabić Perić et al. 2018; Antoun et al. 2021). Bank size is usually assumed positively affect both return on assets and relative bank efficiency. Contrary to Petria et al. (2015) indicate that bank size can negatively affect performance. They emphasize that a larger size can generate economies of scale and improve business performance. However, simultaneously, bureaucracy, inertia, and rigidity can affect larger organizations and reduce business performance. This is also interesting from the perspective of the new regulatory environment, as the newly imposed regulatory framework also affects small banks. As mentioned by Kale et al. (2015), small banks may perform better than large banks during periods of instability.

In addition to bank-specific characteristics, we consider the macroeconomic conditions that account for systematic risk. Bank lending behavior in response to the central bank monetary policy is depicted by movements in market interest rates (Shehzad and De Haan 2009; Roulet 2017). We used the Maastricht criterion bond yields that significantly dropped after the financial crisis, a trend that was also observed for all other reference interest rates, such as Euro Interbank Offered Rate (EURIBOR). Economic activity is evaluated using the annual gross domestic (GDP) growth rate, as it allows comparison of the economic development dynamics between economies of different sizes over time, and is expected to be positively related to bank profitability and efficiency (Pasiouras 2008; Dietrich and Wanzenried 2009; Pasiouras et al. 2009; Shehzad and De Haan 2009; Chortareas et al. 2012; Borio et al. 2017; Bucevska and Hadzi Misheva 2017; Deli and Hasan 2017; Roulet 2017). Market competition is evaluated using the Herfindahl–Hirschman Index (HHI), which is a commonly used measure of market concentration (McNulty et al. 2001; Athanasoglou et al. 2006; Naceur and Omran 2011; Chortareas et al. 2012; Barth et al 2013; Căpraru and Ihnatov 2014; Ozkan et al. 2014; Petria et al. 2015; Řepková, 2015; Triki et al. 2017; Bucevska and Hadzi Misheva 2017), and it is expected to positively affect ROA and negatively affect relative efficiency. Inflation is evaluated using the harmonized index of consumer prices (HICP). According to Fernandes et al. (2018), when inflation is anticipated, banks can adjust their interest rates and, consequently, increase revenues faster than costs, and vice versa.

To evaluate the impact of Basel II/III and the new EU regulations on bank performance, we use a dummy variable, similar to the work of Ozkan et al. (2014). In 2006 and 2007, we controlled for the introduction of the Basel II regulatory framework, while in 2013, 2014, and 2015, we controlled for the introduction of the Basel III regulatory framework. Banks adapted to the Basel II regulatory framework between 2004 and 2007 (Košak et al. 2015), while the dummy variables for 2013 to 2015 represent the introduction of the Basel III regulatory framework, which came into force in January 2014, but for which banks had to prepare earlier.

## Empirical results

A total of 433 commercial banks from 28 EU member states were used to evaluate their relative efficiency for the entire period from 2006 to 2015. Of the original 1309 commercial banks, 433 commercial banks had available input/output over the observed period. The precondition for including variables in the calculation of DEA relative efficiency is the existence of a positive correlation between the variables.[5]

The results of relative efficiency are expected to vary depending on bank size. Relative efficiency is evaluated for each bank (433 banks in total) for a period of 10 years, which corresponds to 4330 observations of relative efficiency. Our analysis provides an opportunity to examine the changes and trends in relative efficiencies over time for each decision-making unit i.e. each bank. Table 5 shows the descriptive statistics of the inputs, outputs, and bank-specific variables.

[5] Correlation matrix with input and output variables used in the DEA is available upon request.

**Table 5** Descriptive statistics of input/output variables

| | Mean | Median | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| *Variables used as DEA inputs* | | | | | |
| Total funding | 43,900,000 | 2,640,403 | 138,000,000 | 300 | 1,340,000,000 |
| Personnel expenditure | 428,172 | 30,250 | 1,544,161 | 460 | 16,100,000 |
| Fixed assets | 391,973 | 16,367 | 1,618,013 | 0 | 21,600,000 |
| Loan loss provision | 247,623 | 9,526 | 1,067,948 | − 1,891,052 | 20,500,000 |
| *Variables used as DEA outputs* | | | | | |
| Loans | 28,600,000 | 1,536,069 | 89,100,000 | 0 | 759,000,000 |
| Other earning assets | 29,400,000 | 814,913 | 125,000,000 | 0 | 1,760,000,000 |
| Net fees | 347,376 | 22,771 | 1,236,808 | − 238,612 | 12,800,000 |
| *Bank-specific variables* | | | | | |
| Return on assets (ROA) | 0.006 | 0.01 | 0.022 | − 0.375 | 0.215 |
| Relative efficiency of all banks (EFFa) | 0.794 | 0.91 | 0.136 | 0.250 | 0.999 |
| Liquidity (LIQ) | 0.564 | 0.73 | 0.233 | 0 | 0.993 |
| Log of bank size (LBSIZE) | 15.228 | 16.54 | 2.266 | 9.701 | 21.513 |

Source: Authors calculations

The total dataset consists of 433 banks for a 10-years period, which is equal to 4330 observations for every variable. Bank-specific variables are winsorised at the 95th and 5th percentile

Because the sample comprises commercial banks, it is expected that the main input is funding (the sum of deposits and other forms of funding sources), while the main output is bank loans. It is interesting to note that other earning assets stand out as the output with the highest mean value, but the median is almost twice as low as that for loans. This suggests that some commercial banks are engaged in other less traditional types of commercial banking, such as securities, whereas most other banks primarily handle loans. Regarding other input/output variables, there is a difference between the mean and median values for personnel expenses and fixed assets. This can be attributed to the significant difference among commercial banks in the sample, with large banks pushing up the arithmetic mean, whereas the median is significantly lower. Positive values for loan loss provisions represent the amount of allowance added to reserves, as some banks replenish their reserves based on negative economic expectations. Thus, banks act in a cyclical manner by increasing their reserves in times of recession and decreasing them when economic conditions are favorable. The negative values of net fees can be attributed to accounting policies, where individual banks are likely to record the costs associated with fees under the cost of fees. Negative values and values equal to zero are not suitable for DEA. According to DEA methodology, all values must be greater than zero. This was achieved by adding the lowest value of a given variable to the other values within that variable. Thus, the negative or zero values of the variables were eliminated, and the positive values were used to evaluate relative efficiency.

Regarding bank-specific variables, the ROA mean is generally low at 0.6%. Several significant declines in bank profitability occurred between 2006 and 2009. The average ROA was nearly 1.5% before the 2008 crisis, which is considered a "normal" level, and approximately 0.4% after 2009. Despite the significant decline in profitability, the majority of the banks remained above the mean, with a median of 1%, but profitability

**Table 6** Relative efficiency of banks by size categorization and time

| Relative efficiencies (efficiency scores) | Years | Mean | Median | Std. dev | Minimum | Maximum |
|---|---|---|---|---|---|---|
| *All banks (EFF_A)* | | | | | | |
| | 2006 | 0.87 | 0.89 | 0.08 | 0.58 | 0.99 |
| | 2007 | 0.85 | 0.87 | 0.10 | 0.51 | 0.99 |
| | 2008 | 0.62 | 0.62 | 0.12 | 0.25 | 0.91 |
| | 2009 | 0.7 | 0.71 | 0.10 | 0.39 | 0.93 |
| | 2010 | 0.72 | 0.72 | 0.10 | 0.47 | 0.96 |
| | 2011 | 0.83 | 0.84 | 0.08 | 0.54 | 0.96 |
| | 2012 | 0.76 | 0.76 | 0.10 | 0.42 | 0.96 |
| | 2013 | 0.73 | 0.73 | 0.11 | 0.35 | 0.95 |
| | 2014 | 0.93 | 0.95 | 0.07 | 0.62 | 1 |
| | 2015 | 0.92 | 0.94 | 0.07 | 0.67 | 1 |
| *Medium and large banks only (EFF_LM)* | | | | | | |
| | 2006 | 0.82 | 0.84 | 0.07 | 0.56 | 0.93 |
| | 2007 | 0.80 | 0.81 | 0.10 | 0.51 | 0.99 |
| | 2008 | 0.67 | 0.68 | 0.11 | 0.37 | 0.91 |
| | 2009 | 0.72 | 0.74 | 0.09 | 0.42 | 0.92 |
| | 2010 | 0.76 | 0.77 | 0.10 | 0.52 | 0.96 |
| | 2011 | 0.79 | 0.82 | 0.08 | 0.54 | 0.97 |
| | 2012 | 0.81 | 0.83 | 0.10 | 0.53 | 0.98 |
| | 2013 | 0.81 | 0.83 | 0.09 | 0.45 | 0.97 |
| | 2014 | 0.90 | 0.91 | 0.07 | 0.62 | 1 |
| | 2015 | 0.88 | 0.90 | 0.07 | 0.66 | 1 |
| *Small banks only (EFF_S)* | | | | | | |
| | 2006 | 0.88 | 0.90 | 0.06 | 0.65 | 0.96 |
| | 2007 | 0.73 | 0.75 | 0.09 | 0.51 | 0.90 |
| | 2008 | 0.73 | 0.74 | 0.11 | 0.30 | 0.93 |
| | 2009 | 0.74 | 0.75 | 0.11 | 0.44 | 0.95 |
| | 2010 | 0.73 | 0.73 | 0.12 | 0.46 | 0.94 |
| | 2011 | 0.71 | 0.73 | 0.10 | 0.39 | 0.90 |
| | 2012 | 0.79 | 0.81 | 0.09 | 0.52 | 0.96 |
| | 2013 | 0.84 | 0.86 | 0.09 | 0.40 | 0.98 |
| | 2014 | 0.76 | 0.79 | 0.09 | 0.43 | 0.91 |
| | 2015 | 0.70 | 0.72 | 0.11 | 0.33 | 0.87 |

Source: Authors calculations

The total dataset consists of 433 banks for the 10-years period, which is equal to 4330 observations for every variable. When considering large and medium banks only there are 2810 observations for large and medium sized banks, and 1520 for small banks

remained below the pre-crisis levels. Generally, banks show high average efficiency. However, this varies significantly over the years and across different bank size categories (details in Table 6). The higher the value of the liquidity ratio (i.e., the ratio of total loans to total assets), the less liquid the bank is (in our sample, most assets comprise less liquid loans). The mean and median values confirm that banks have adequate liquidity and manage their assets carefully. Similar to the personnel expenses and fixed assets variables, bank size shows that we deal with a heterogeneous sample in terms of size, which is why we performed a specific analysis focusing on bank size.

Table 6 shows the relative efficiencies according to bank size categorization and years.

Table 6 shows the summary statistics of relative efficiency scores for the entire sample, large and medium banks, and a sample of only small banks. Although the efficiency scores of different bank size categories cannot be directly compared, it is clear that large and medium-sized banks experienced a sharper decline in efficiency during the 2008 financial crisis, while small banks experienced a sharper decline 1 year earlier, corresponding to the introduction of the Basel II regulatory framework. Although the efficiency of both bank size categories was similarly affected by the 2008 through 2010 financial crisis, larger and medium-sized banks recovered earlier than small banks. The results also indicate that small banks experienced a sharper decline in efficiency during the period from 2013 through 2015, which coincides with the introduction of the Basel III regulatory framework. On the side, medium and large banks did not experience a decrease in their efficiency over the same period. Overall, we find that small banks have lower efficiency, similar to the findings of Lee and Chih (2013).

The panel data analysis shows that a high correlation between the variables can result in a multicollinearity problem that can affect the significance of the parameters. The correlation matrix shows that there is no high collinearity between the independent variables as all variables have a correlation coefficient below 0.7. The presence of multicollinearity among the independent variables is also tested using variance inflation factors (VIF), where the total variance of the model is set in proportion to the variance of the model containing only one independent variable. The VIF also confirms that there is no high correlation and that the selected variables are suitable for panel data analysis.[6]

With each financial crisis or major market disruption, regulatory reforms have increased efforts to reduce bank failure risk. New regulatory frameworks are aimed at finding solutions that work best and promote the sustainability of a banking system, that is, a system that increases bank efficiency (Barth et al. 2013). Table 7 shows the results of the bank profitability determinants for the entire sample of banks, and separately for the categories of banks with respect to their size. Model diagnostics are examined using the Hansen test and Arellano-Bond test for first- and second-order serial autocorrelation. The null hypothesis of the Hansen test is that the selected instruments are valid. According to the Hansen test, over-identification restrictions are not rejected in any of the observed models, confirming the validity of the chosen instruments. The null hypothesis for the Arellano-Bond first-order autocorrelation AR(1) assumes the absence of first-order autocorrelation in the differenced residuals, while AR(2) assumes the absence of second-order autocorrelation (bottom rows of the table). The presence of first-order autocorrelation AR(1) is expected, whereas a second- or higher-order correlation implies inconsistent model estimates. The results show that the null hypothesis for the absence of first-order serial correlation AR(1) is rejected at the 1% significance level, whereas the absence of second-order serial correlation in the differenced residuals AR(2) is not rejected.

The lagged dependent variable has a positive and statistically significant effect in all the model specifications, implying that profitability in the previous period also determines profitability in the current period. The positive and significant sign of the variable

[6] Correlation matrix on bank-specific variables is available upon request.

**Table 7** Bank profitability determinants (for all banks jointly and separately for categories of banks with respect to their size)

| ROA—dep. var | All banks | | | Large and medium banks only | | | Small banks only | | |
|---|---|---|---|---|---|---|---|---|---|
| | [1] | [2] | [3] | [4] | [5] | [6] | [7] | [8] | [9] |
| Variables | ROA_all_B_baseline | ROA_all_B_EMU | ROA_all_B_EU15 | ROA_LM_B_baseline | ROA_LM_B_EMU | ROA_LM_B_EU15 | ROA_SMALL_B_baseline | ROA_SMALL_B_EMU | ROA_SMALL_B_EU15 |
| L.ROA | 0.444*** | 0.478*** | 0.478*** | 0.193*** | 0.235*** | 0.211*** | 0.504*** | 0.532*** | 0.520*** |
| | [4.403] | [4.962] | [4.962] | [3.392] | [4.377] | [2.736] | [4.859] | [4.286] | [4.377] |
| | (0.101) | (0.096) | (0.096) | (0.057) | (0.054) | (0.077) | (0.104) | (0.124) | (0.119) |
| EFF_all_banks | 0.007* | 0.013*** | 0.013*** | | | | | | |
| | [1.646] | [4.009] | [4.009] | | | | | | |
| | (0.004) | (0.003) | (0.003) | | | | | | |
| EFF_L&M_banks | | | | 0.024*** | 0.023*** | 0.024*** | | | |
| | | | | [4.002] | [4.123] | [3.892] | | | |
| | | | | (0.006) | (0.006) | (0.006) | | | |
| EFF_small_banks | | | | | | | 0.051*** | 0.041*** | 0.039*** |
| | | | | | | | [3.227] | [2.951] | [3.119] |
| | | | | | | | (0.016) | (0.014) | (0.012) |
| LIQ | 0.005 | 0.016** | 0.016** | 0.002 | 0.002 | 0.003 | 0.020 | 0.012 | 0.010 |
| | [0.880] | [1.994] | [1.994] | [0.873] | [0.799] | [1.130] | [1.075] | [0.941] | [0.718] |
| | (0.006) | (0.008) | (0.008) | (0.003) | (0.002) | (0.003) | (0.019) | (0.013) | (0.014) |
| LTR | −0.001** | −0.001*** | −0.001*** | −0.002*** | −0.002*** | −0.002*** | −0.000 | −0.000 | −0.001 |
| | [−2.069] | [−3.413] | [−3.413] | [−5.961] | [−5.533] | [−5.387] | [−0.021] | [−0.058] | [−0.812] |
| | (0.001) | (0.0004) | (0.0004) | (0.000) | (0.000) | (0.000) | (0.001) | (0.001) | (0.001) |
| GDPG | 0.001** | 0.0004** | 0.0004** | 0.001*** | 0.001*** | 0.001*** | 0.000 | 0.000 | 0.000 |
| | [2.555] | [2.310] | [2.310] | [3.411] | [3.933] | [3.779] | [0.157] | [1.132] | [0.672] |
| | (0.0002) | (0.0002) | (0.0002) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| LHHI | −0.001 | −0.005 | −0.005 | −0.011*** | −0.011*** | −0.011*** | 0.015 | 0.011 | 0.012 |
| | [−0.528] | [−0.862] | [−0.862] | [−3.338] | [−3.537] | [−3.636] | [1.292] | [1.128] | [1.173] |
| | (0.002) | (0.005) | (0.005) | (0.003) | (0.003) | (0.003) | (0.011) | (0.009) | (0.010) |
| HICP | −0.0004* | −0.0002 | −0.0002 | −0.001** | −0.001** | −0.001** | −0.000 | −0.000 | −0.000 |
| | [−1.936] | [−0.479] | [−0.479] | [−2.382] | [−2.122] | [−2.158] | [−0.333] | [−0.732] | [−0.192] |
| | (0.0002) | (0.0003) | (0.0003) | (0.000) | (0.000) | (0.000) | (0.001) | (0.001) | (0.001) |
| LBSIZE | −0.0002 | 0.004 | 0.004 | −0.002*** | −0.001*** | −0.001*** | 0.013** | 0.011** | 0.015*** |
| | [−0.451] | [1.013] | [1.013] | [−3.241] | [−2.891] | [−3.174] | [2.396] | [2.168] | [3.015] |
| | (0.0005) | (0.004) | (0.004) | (0.000) | (0.000) | (0.000) | (0.005) | (0.005) | (0.005) |
| REG_DUMMY | 0.047 | 0.003 | −0.009 | 0.152*** | 0.142*** | 0.145*** | −0.301** | −0.234* | −0.320** |
| | [1.485] | [1.000] | [−0.084] | [3.903] | [3.705] | [3.577] | [−2.014] | [−1.661] | [−2.127] |
| | (0.032) | (0.003) | (0.112) | (0.039) | (0.038) | (0.041) | (0.149) | (0.141) | (0.150) |
| 1.EMU | | −0.011 | | | −0.003 | | | 0.007 | |
| | | [−0.094] | | | [−1.070] | | | [0.838] | |
| | | (0.112) | | | (0.003) | | | (0.008) | |
| 1.EU15 | | | −0.005 | | | 0.002 | | | 0.007 |
| | | | [−0.706] | | | [0.378] | | | [0.594] |
| | | | (0.008) | | | (0.005) | | | (0.012) |
| Nb. of banks [id] | 433 | 433 | 433 | 281 | 281 | 281 | 152 | 152 | 152 |
| Nb. of observations | 3879 | 3879 | 3879 | 2521 | 2521 | 2521 | 1358 | 1358 | 1358 |

**Table 7** (continued)

| ROA—dep. var | All banks | | | Large and medium banks only | | | Small banks only | | |
|---|---|---|---|---|---|---|---|---|---|
| | [1] | [2] | [3] | [4] | [5] | [6] | [7] | [8] | [9] |
| **Variables** | **ROA_all_B_baseline** | **ROA_all_B_EMU** | **ROA_all_B_EU15** | **ROA_LM_B_baseline** | **ROA_LM_B_EMU** | **ROA_LM_B_EU15** | **ROA_SMALL_B_baseline** | **ROA_SMALL_B_EMU** | **ROA_SMALL_B_EU15** |
| Hansen test [p-value] | 0.12 | 0.09 | 0.09 | 0.31 | 0.98 | 0.87 | 0.26 (0.57) | 0.13 | 0.13 |
| AR1 test [*p*-value] | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| AR2 test [*p*-value] | 0.21 | 0.21 | 0.21 | 0.79 | 0.95 | 0.87 | 0.25 | 0.26 | 0.26 |

***, **, * denote significance at the 1%, 5%, and 10% significance level. Numbers in brackets are z-statistics, while robust standard errors are in parenthesis. Models also include temporal and country dummy variables

Source: Authors calculations

indicating bank relative efficiency shows that more efficient banks achieve higher ROA across all size categories. This is consistent with the findings of Guillén et al. (2014) and Bucevska Hadzi Misheva (2017), who show that efficiency is positively related to profitability, hence supporting the efficiency hypothesis. Commercial banks are expected to be more profitable if they are more efficient in converting inputs (funding, personnel costs, fixed assets, and provisions) into outputs (loans, other profit-earning assets, and net fees). Liquidity has a positive and significant effect when all banks are considered and controlled for EMU/EU membership, indicating that EMU and old EU member states have synchronized business cycles stemming from, among other things, synchronized monetary policy (Kotarac et al. 2017). The significance of liquidity disappears when separate bank size categories are analyzed, similar to the results of Bouheni et al. (2014). The disappearance of the significance of liquidity when separately considering large, medium, and small banks compared to the total sample can be attributed to the emergence of other variables that are better at explaining the variance in ROA for the subsamples. In the case of small banks, it is their size and regulatory dummy, and for large and medium banks, it is bank concentration and inflation. The long-term interest rate has a significant and negative impact on the profitability of large and medium banks, whereas the long-term interest rate for small banks does not have a significant impact. A possible explanation for this result is the specialization of the activities of small banks such that their profitability does not depend significantly on interest rate movements.

GDP growth positively affects profitability when all banks, as well as large and medium-sized banks, are considered, similar to the work of Căpraru and Ihnatov (2014), Guillén et al. (2014), and Hamdi et al. (2017). As large- and medium-sized banks tend to operate in a greater number of countries and their overall exposure to national economies is greater, their sensitivity to business cycles appears to be more pronounced. Contrary to expectations, bank concentration evaluated by the Herfindahl–Hirschman index only affects the profitability of large- and medium-sized banks. This insignificantly affects profitability when all banks are observed, consistent with the findings of Guillén et al. (2014) and Bucevska Hadzi Misheva (2017). Although higher concentration in the banking sector is expected to be positively associated with bank profitability (Berger 1995), this does not hold for large- and medium-sized banks, where higher

concentrations result in a decline in profitability, which is inconsistent with the relative market power hypothesis and the structure-conduct-performance (SCP) paradigm. Inflation significantly and negatively impacts the profitability of large and medium banks, as well as on the baseline model, which considers all banks, as in the results of Bouheni et al. (2014) and Căpraru and Ihnatov (2014). One possible explanation for this result could be that rising inflation reduces banks' profit margins and makes it difficult for them to adjust quickly to market conditions predominately due to competition concerns. One additional explanation for the disappearance of the significance of inflation when controlling for EMU and EU 15 members is the homogeneity of inflation movement within the Euro and EU old member states area because other variables such as size and regulatory dummy are significant, which is consistent with the findings of Kotarac et al. (2017).

Bank size was found to be insignificant when all banks were considered, consistent with Ozkan et al. (2014). The efficient structural hypothesis states that size is an important determinant of bank profitability. Our results suggest that size is important for small banks, implying that larger banks within the small-bank category achieve higher profitability. However, when the analysis was conducted for large banks, bank size emerged as significant and negatively affected the profitability of large and medium-sized banks, which contradicts the findings of Asongu and Odhiambo (2019), who found that size positively impacts interest margins and, therefore, should positively affect their profitability. This result is consistent with the findings of Petria et al. (2015) and can be explained by the inertia of large banks, as opposed to the more flexible smaller banks within the large and medium-sized bank category.

The variable indicating the introduction of the new regulatory framework insignificantly affects profitability when all banks are considered. However, interesting results emerge when the analysis is conducted separately for different size categories, with regulations positively affecting the profitability of large and medium-sized banks and negatively affecting the profitability of small banks. Andrle et al. (2018) concluded that higher capital requirements led to balance sheet shrinkage and affected banks that struggled with profitability only. This finding implies that profitability problems are more prevalent among small banks. The negative relationship between regulation and profitability in small banks can be attributed to the new regulatory requirements that cause a higher administrative burden and related costs associated with new job creation and more complex IT and compliance services. Owing to lower profit margins and fewer employees in small banks, the new regulatory requirements have a significantly greater impact on their costs compared with large and medium-sized banks that have successfully adapted. Moreover, the results show that there are no differences in profitability between EMU countries and those with their own national currency. The same applies to the EU15 control variable, which shows that there are no significant differences in the profitability determinants between the original 15 developed EU members and the rest of the EU countries.

Table 8 shows the bank efficiency determinants for all banks jointly and separately for the different bank size categories.

The results indicate that the lagged dependent variable is positive and statistically significant for all the model specifications. This finding implies that the previous level of

**Table 8** Bank relative efficiency determinants (for all banks jointly and separately for categories of banks with respect to their size)

| EFF—dep. var | All banks | | | Large and medium banks only | | | Small banks only | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| VARIABLES | EFF_All_banks_baseline | EFF_All_banks_EMU | EFF_All_banks_EU15 | EFF_L&M_banks_baseline | EFF_L&M_banks_EMU | EFF_L&M_banks_EU15 | EFF_Small_banks_baseline | EFF_Small_banks_EMU | EFF_Small_banks_EU15 |
| L.EFF_all_banks | 0.281*** | 0.292*** | 0.283*** | | | | | | |
| | [15.737] | [14.883] | [16.022] | | | | | | |
| | (0.018) | (0.020) | (0.018) | | | | | | |
| L.EFF_L&M_banks | | | | 0.336*** | 0.335*** | 0.336*** | | | |
| | | | | [11.900] | [11.713] | [11.900] | | | |
| | | | | (0.028) | (0.029) | (0.028) | | | |
| L.EFF_small_banks | | | | | | | 0.350*** | 0.273*** | 0.271*** |
| | | | | | | | [8.021] | [5.713] | [5.744] |
| | | | | | | | (0.044) | (0.048) | (0.047) |
| ROA | 0.420*** | 0.423*** | 0.429*** | 0.719*** | 0.722*** | 0.719*** | 0.612*** | 0.552*** | 0.572*** |
| | [4.145] | [2.651] | [4.127] | [3.774] | [3.757] | [3.775] | [3.510] | [3.373] | [3.356] |
| | (0.101) | (0.160) | (0.104) | (0.190) | (0.192) | (0.190) | (0.174) | (0.164) | (0.170) |
| LIQ | 0.059*** | 0.053** | 0.056*** | 0.029 | 0.023 | 0.029 | 0.032 | 0.095*** | 0.095*** |
| | [3.827] | [2.133] | [3.743] | [1.310] | [0.994] | [1.310] | [0.966] | [2.950] | [2.884] |
| | (0.015) | (0.025) | (0.015) | (0.022) | (0.023) | (0.022) | (0.033) | (0.032) | (0.033) |
| LTR | −0.002* | −0.002 | −0.002 | −0.001 | −0.001 | −0.001 | 0.000 | 0.000 | 0.000 |
| | [−1.647] | [−1.296] | [−1.619] | [−0.642] | [−0.611] | [−0.642] | [0.101] | [0.177] | [0.037] |
| | (0.001) | (0.002) | (0.001) | (0.001) | (0.001) | (0.001) | (0.003) | (0.003) | (0.003) |
| GDPG | 0.001 | 0.001 | 0.001 | 0.002*** | 0.002*** | 0.002*** | 0.003 | 0.003* | 0.003 |
| | [1.546] | [1.317] | [1.508] | [2.950] | [2.926] | [2.950] | [1.591] | [1.654] | [1.538] |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.002) | (0.002) | (0.002) |
| LHHI | 0.004 | 0.003 | 0.004 | 0.026 | 0.026 | 0.026 | −0.043 | −0.028 | −0.024 |
| | [0.266] | [0.115] | [0.252] | [1.559] | [1.547] | [1.558] | [−1.277] | [−0.811] | [−0.686] |
| | (0.014) | (0.027) | (0.014) | (0.017) | (0.017) | (0.017) | (0.034) | (0.034) | (0.034) |
| HICP | 0.001 | 0.001 | 0.001 | 0.002*** | 0.002** | 0.002*** | −0.000 | 0.001 | 0.001 |
| | [1.361] | [1.163] | [1.386] | [2.581] | [2.568] | [2.581] | [−0.279] | [0.853] | [0.919] |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.002) |
| LBSIZE | −0.001 | −0.000 | −0.001 | 0.007* | 0.007 | 0.007* | 0.004 | 0.008 | 0.009 |
| | [−0.662] | [−0.073] | [−0.532] | [1.782] | [1.552] | [1.781] | [0.388] | [0.625] | [0.738] |
| | (0.002) | (0.006) | (0.002) | (0.004) | (0.004) | (0.004) | (0.009) | (0.013) | (0.013) |
| REG_DUMMY | 0.584*** | 0.191*** | 0.094*** | 0.117*** | 0.198*** | 0.197*** | −0.070*** | −0.061*** | −0.064*** |
| | [3.951] | [15.201] | [18.343] | [12.253] | [16.535] | [16.427] | [−4.527] | [−3.241] | [−3.290] |
| | (0.148) | (0.013) | (0.005) | (0.010) | (0.012) | (0.012) | (0.016) | (0.019) | (0.019) |
| | (0.015) | (0.187) | (0.015) | (0.022) | (0.191) | (0.022) | (0.030) | (0.042) | (0.029) |
| 1.EMU | | 0.382 | | | −0.155 | | | 0.057*** | |
| | | [1.815] | | | [−0.802] | | | [1.479] | |
| | | (0.211) | | | (0.194) | | | (0.039) | |
| 1.EU15 | | | 0.487*** | | | −0.169 | | | 0.425 |
| | | | [3.346] | | | [−0.890] | | | [1.187] |
| | | | (0.146) | | | (0.190) | | | (0.358) |
| Nb. of banks [id] | 433 | 433 | 433 | 281 | 281 | 281 | 152 | 152 | 152 |

**Table 8** (continued)

| EFF—dep. var | All banks | | | Large and medium banks only | | | Small banks only | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| VARIABLES | EFF_All_banks_baseline | EFF_All_banks_EMU | EFF_All_banks_EU15 | EFF_L&M_banks_baseline | EFF_L&M_banks_EMU | EFF_L&M_banks_EU15 | EFF_Small_banks_baseline | EFF_Small_banks_EMU | EFF_Small_banks_EU15 |
| Nb. of observations | 3888 | 3888 | 3888 | 2525 | 2525 | 2525 | 1363 | 1363 | 1363 |
| Hansen test [*p*-value] | 0.09 | 0.12 | 0.12 | 0.15 | 0.15 | 0.14 | 0.61 | 0.64 | 0.61 |
| AR1 test [*p*-value] | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| AR2 test [*p*-value] | 0.15 | 0.19 | 0.16 | 0.75 | 0.76 | 0.75 | 0.56 | 0.95 | 0.96 |

***, **, *denote significance at the 1%, 5%, and 10% significance level. Numbers in brackets are z-statistics, while robust standard errors are in parenthesis. Models also include temporal and country dummy variables

Source: Authors calculations

efficiency positively affects the current value of bank efficiency. Profitability positively and significantly affects efficiency, regardless of bank size, implying that more profitable banks achieve higher relative efficiency. Liquidity, measured as the ratio of loans to assets, positively affects relative efficiency for all banks, as well as for small banks, while it has no effect on the relative efficiency of large and medium-sized banks. This can be attributed to the fact that, unlike small banks, large and medium banks do not rely primarily on loans as output, but on fees and other profitable assets.

The long-term interest rate does not significantly affect the relative efficiency of banks, except for the baseline model for the entire sample. However, it is highly dubious because they are significant at the 10% level. Similar to the profitability analysis and the results of Chortareas et al. (2012), GDP growth was found to be significant only for large and medium-sized banks that dominate national banking markets. This can be explained by the higher interlinkage of national economies and business sectors with higher exposure to national business cycle movements. GDP growth also appears to be significant for low bank efficiency when the model is controlled for the EMU dummy variable. This finding further coincides with the finding of Kotarac et al. (2017) of synchronous business cycles and shocks within EMU countries, indicating that small banks within EMU countries are more exposed to business cycle movements than those outside the EMU. The level of bank concentration measured using the Herfindahl–Hirschman index, insignificantly affects the relative efficiency of all observed bank size categories, similar to the results of Triki et al. (2017). Inflation was found to positively affect the efficiency of large and medium-sized banks only, as in Pasiouras et al. (2009), Kale et al. (2015), and Jelassi and Delhoumi (2021), implying that large and medium-sized banks are more efficient in managing inflation given their more sophisticated risk management practices and diversified portfolios of assets and liabilities.

Bank size plays a significant and positive role in relative efficiency only for large and medium-sized banks, meaning that larger banks within this category are more efficient, consistent with Pasiouras (2008), Barth et al. (2013), and Triki et al. (2017). In other words, the largest banks in the EU are the most efficient. However, size does not

significantly affect the small bank category, which is inconsistent with expectations that size is crucial in explaining the relative efficiency of small banks. Interestingly, bank size positively affects the relative efficiency of large and medium-sized banks and negatively affects profitability. Therefore, larger banks in this category are more efficient, but simultaneously realize lower returns on assets. One possible explanation for this paradox is that larger banks, notwithstanding their ability to adapt to their operations–that is, to improve their efficiency–tend to be less flexible in quickly responding to their customers' needs, resulting in relatively lower profitability. The lack of bank size significance for large and medium-sized banks when accounting for EMU membership, but its presence in total and only old member states, can be attributed to the influence of new EU states in the EMU subsample, which economically, but also in the organization, role, and perception of banks, differs from old member states, for the most part, owing to their socialist past.

Further, the most interesting results emerge in terms of the introduction of the new regulation in relation to the different bank size categories. The introduction of the new regulation positively affects efficiency when all banks are considered, similar to the results of Pasiouras (2008), Pasiouras et al. (2009), Chortareas et al. (2012), Barth et al. (2013), Kale et al. (2015), and Triki et al. (2017). However, when banks are examined separately by size, similar to the profitability analysis, the new regulation positively affects large and medium-sized banks only and negatively affects small banks. These results suggest that the more stringent requirements imposed by the new regulation significantly affect small banks, making it difficult for them to efficiently convert inputs (funding, staff costs, fixed assets, and loan loss provisions) into outputs (loans, other earning assets, and net fees). This seems to be a very strong indication that the global regulatory framework for banks (Basel II and Basel III) should be adjusted according to the size of the bank to maintain a certain level of banking competition in the EU.

The statistical significance of the EMU and EU15 variables is only present when all banks are considered. The results show that there are statistical differences in relative efficiency between countries belonging to the EMU and countries using their own national currency, in that banks operating in countries with euro currency have higher relative efficiency. Similarly, there is a higher relative efficiency for banks operating in the original 15 developed EU member countries compared with the rest of the EU.

## Concluding remarks

This study's results show that the EU banking market is not homogenous and that banks differ in their relative efficiency, among other things, depending on their size. This study primarily aims to examine the impact of the introduction of two major regulatory framework changes (Basel II and III), together with bank-specific and macroeconomic variables, on bank performance in different bank size categories. Additionally, we test the efficient structure hypothesis and relative market power hypothesis following Berger (1995). Our contribution to the existing body of literature fills this gap by examining the impact of regulation along with bank-specific and macroeconomic variables on the performance of banks operating in EU countries. As our results indicate, bank size is a key feature in examining the impact of regulation on banking performance. The global regulatory framework negatively affects profitability and relative efficiency for small banks and positively impacts large- and medium-sized banks.

Our empirical analysis has several important policy implications. First, because the regulatory framework is set uniformly for all banks in the EU and the empirical analysis shows that the regulatory framework has different implications for different bank size categories, regulators should consider this when creating or amending regulations. Our results show that regulators should adopt size-specific bank-related policies and regulations if a certain level of banking competition is to be preserved in the EU in the long term. Second, as the new regulatory framework attributes special importance to both liquidity and the quality of capital, commercial banks should improve the monitoring of risk factors associated with liquidity and diversify their funding sources. Third, small banks should have easier access to borrowing in financial markets during difficult times to avoid holding excess liquidity reserves in prosperity, which reduces their long-term profitability and sustainability. Fourth, regulators should clearly define and classify liquid assets and funding sources according to the nature of each bank's business while considering its size. To survive and become more efficient, small banks need to focus their strategy on finding specific market niches, such as developing inclusive finance supported by governments and/or humanitarian organizations, as well as devising models that integrate the opinions of participants with different preference formats to achieve specific social goals (Chao et al. 2021). Another avenue that small banks can pursue is cutting costs and improving their financial performance as well as the quality of their financial services by immersing themselves in financial technology (Fintech) (Kou et al. 2021a). When small banks operate in the traditional commercial market, they have a hard time competing with large banks, whose size allows them to achieve a wider margin spread, and consequently, greater efficiency and profitability.

Our main conclusion is that regulators should consider the diversity of commercial banks, especially their size. These findings provide an argument for creating a less restrictive regulatory framework for small banks, which makes it easier for them to operate, thereby improving their profitability and relative efficiency. Without such an approach, the future of smaller banks in the EU seems very bleak, as does the current level of banking competition within the EU. Small banks are expected to have problems with profitability because the new regulatory framework has imposed additional administrative and regulatory burdens. In contrast, we expect small banks to become more efficient as they can adapt to the new environment over the years or disappear to a larger extent through mergers and acquisitions (M&A) processes. Although from the regulators' point of view, this might even seem favorable because less work is needed to monitor a smaller number of banks, such an approach is shortsighted and will only weaken the EU banking infrastructure and increase the systemic risk within the banking sector. This warning echoes the findings of Kale et al. (2015), who show that smaller banks perform better than large banks during volatile periods.

Our study has several limitations. The first is the data used. A limitation of using secondary data is the accuracy of the data. Owing to the number of banks, it was not possible to take financial statements for each bank separately over the entire period observed. Second, although the dummy variable has been used as a proxy for regulation in several previous studies, the authors consider it an insufficiently adequate measure. However, owing to the lack of accounting data for earlier years in this study, we consider the relationship between the available data and the usability of the dummy variable a well-balanced proxy for regulation. One important avenue for future research is how to design and implement

policies and measures that would consider the differences in the impact of regulation on large and small banks or the other way of putting it would be systemically important and non-systemically important in the broader sense of the word. For future research, it is also important to determine whether small banks can endanger the financial system so that they are significantly interconnected through holding companies or other structures within individual countries. Indeed, if there is a high degree of interconnectedness among small banks through certain interconnected structures, another problem known as "too many to fail" may arise, in which the failure of a large number of small banks owing to a less stringent regulatory framework could cause difficulties for the financial system. It would be interesting to analyze bank efficiency using both financial and non-financial data, as payment and transactional data-based variables have been shown to improve bankruptcy predictions for small and medium-sized enterprises (SMEs) (Kou et al. 2021a, b). Once more detailed financial data are available, it would also be interesting to analyze the particular regulatory factors that affect bank performance (i.e., profitability and relative efficiency) and to what extent, whether they are large, medium-sized, or small banks.

**Abbreviations**

| | |
|---|---|
| EU | European Union |
| GMM | Generalized method of moments |
| SCP | Structure-conduct-performance |
| DEA | Data envelopment analysis |
| ECB | European Central Bank |
| ROA | Return on assets |
| ROE | Return on equity |
| US | United States |
| CEE | Central and Eastern Europe |
| GDP | Gross domestic product |
| SFA | Stochastic frontier analysis |
| DMU | Decision-making unit |
| EMU | European Monetary Union |
| EU15 | Old European Union |
| HHI | Herfindahl–Hirschman index |
| HICP | Harmonized index of consumer prices |
| VIF | Variance inflation factors |

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**Author contributions**
IG: Conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing original draft, writing—review and editing, visualization, project administration, funding acquisition. SŽ: conceptualization, validation, resources, supervision, writing—review and editing. ITŽ: Methodology, software, validation, formal analysis, supervision, writing—review and editing. All authors read and approved the final manuscript.

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**Availability of data and materials**
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

## Declarations

**Competing interests**
The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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