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2015

WORKING PAPER SERIES 10

2015

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Does Greater Capital Hamper the Cost Efficiency of Banks?

Jitka Lešanovská and Laurent Weill*

Abstract

The aim of our research is to analyze the relation between capital and bank efficiency by considering both directions of the Granger causality for the Czech banking industry. We use an exhaustive dataset of Czech banks from 2002 to 2013. We measure the cost efficiency of banks using stochastic frontier analysis. We perform Granger-causality tests to check the sign and significance of the causal relation between capital and efficiency. We embed Granger-causality estimations in the GMM dynamic panel estimator. We find no relation between capital and efficiency, as neither the effect of capital on efficiency, nor the effect of efficiency on capital is significant. The financial crisis does not influence the relation between capital and efficiency. Our findings suggest that tighter capital requirements like those under Basel III do not affect financial stability through the efficiency channel. Policies favoring capital levels and efficiency of the banking industry can therefore be designed separately.

Abstrakt

Cílem výzkumu je analyzovat vztah mezi kapitálem a efektivitou bank. Zkoumáme obousměrnou Grangerovu kauzalitu mezi těmito proměnnými pro český bankovní sektor na kompletním souboru dat od roku 2002 do roku 2013. Nákladovou efektivitu bank měříme pomocí stochastické hraniční analýzy. Provádíme testy Grangerovy kauzality s cílem ověřit znaménko a význam kauzálního vztahu mezi kapitálem a efektivitou. Odhady Grangerovy kauzality provádíme s využitím GMM dynamických panelových odhadů. Vztah mezi kapitálem a efektivitou nebyl identifikován, neboť ani vliv kapitálu na efektivitu, ani vliv efektivity na kapitál není významný. Finanční krize vztah mezi kapitálem a efektivitou nezměnila. Naše zjištění tak naznačují, že přísnější kapitálové požadavky, jako jsou ty v rámci regulace Basel III, neovlivní finanční stabilitu přes kanál efektivity. Opatření ovlivňující úrovně kapitálu nebo míry efektivity bankovního sektoru tak lze tvořit samostatně.

JEL Codes: G21, G28.

Keywords: Bank capital, Basel III, efficiency.

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This work was supported by Czech National Bank Research Project No. C3/13. Jitka Lešanovská acknowledges support from the Grant Agency of Charles University (grant No. 1682214). Laurent Weill acknowledges support from the Grant Agency of the Czech Republic 13-11983S.
The authors would like to thank Eva Hromádková, Philip Molyneux, Pierre Pessarossi, Marek Rusnák, and Kateřina Šmídková.
The views expressed in this paper are those of the authors and not necessarily those of the Czech National Bank.

Nontechnical Summary

The new capital rules commonly known as the Basel III reforms have led to a wide debate. These reforms include tighter capital requirements aimed at improving the resilience of the banking industry. However, they may also contribute to reducing bank lending and might therefore hamper growth. A couple of studies have thus analyzed how bank lending and then output will be affected by the Basel III reforms. However, the investigation of the effects of tighter capital requirements on bank performance and through this channel on financial stability remains limited. This lack of interest is surprising, as there are theoretical arguments for the existence of a relation between capital and performance and as there is empirical evidence that the efficiency of banks influences financial stability. Thus, if capital exerts an impact on financial stability through bank efficiency, it is of utmost interest to consider the influence of capital on bank efficiency to have a broad view of the consequences of capital requirements for financial stability.

The aim of our research is to analyze the relation between capital and bank efficiency by considering both directions of the Granger causality for the Czech banking industry. The findings of this paper are therefore of major interest for regulators. If capital reduces (increases) cost efficiency, capital requirements can potentially have negative (positive) consequences for financial stability through the cost efficiency channel.

To investigate this issue, we use an exhaustive dataset of Czech banks from 2002 to 2013 provided by the Czech National Bank. We measure cost efficiency using stochastic frontier analysis. We then perform Granger-causality tests to check the sign and significance of the causal relation between capital and efficiency. We embed Granger-causality estimations in the GMM dynamic panel estimator to address the econometric issues resulting from the use of lagged dependent variables.

Our investigation to identify a link between capital and efficiency showed no significant relation. Neither the effect of capital on efficiency, nor the effect of efficiency on capital is significant. These findings are robust to different specifications. In addition, the financial crisis does not influence the relation between capital and efficiency.

From a normative perspective, our findings suggest that tighter capital requirements do not affect financial stability through the efficiency channel. The implementation of Basel III should not affect the efficiency of Czech banks. Our results also support the view that changes in efficiency do not influence capital. In other words, policies favoring capital levels and efficiency of the banking industry can be designed separately.

1. Introduction

The new capital rules commonly known as the Basel III reforms have led to a wide debate about their overall impact on the financial sector and the real economy. These reforms, which include tighter capital requirements, are aimed at improving the resilience of the banking industry. However, there are also concerns about their potential negative impacts, particularly about their contribution to a reduction of bank lending and, in turn, to slower economic growth. A couple of studies have thus analyzed how bank lending and then output will be affected by the Basel III reforms (e.g., BCBS, 2010; Angelini et al., 2011). Horvath, Seidler, and Weill (2014) also contribute to this debate by showing that higher capital levels worsen liquidity creation by banks in the context of the Czech banking industry.

What is striking, however, is that the vast majority of studies looking at the effects of tighter capital requirements ignore the possibility of an impact on bank performance and hence on financial stability. This lack of interest is surprising both for a theoretical and for an empirical reason. The theoretical reason is that the agency costs literature has clearly shown that conflicts of interest between categories of agents (managers, shareholders, debtholders) which are related to the level of capital in the total balance sheet create agency costs which worsen firm performance (Jensen and Meckling, 1976).

The empirical reason is that bank performance, specifically the cost efficiency of banks, has been shown to influence financial stability. Podpiera and Weill (2008) have shown that deteriorations in cost efficiency precede increases in non-performing loans in a study of Czech banks. By also using cost efficiency scores for the Czech banking industry, Podpiera and Podpiera (2005) have found that cost inefficient management predicts bank failures. Thus, if capital exerts an impact on financial stability through bank efficiency, it is of utmost interest to consider the influence of capital on bank efficiency to have a broad view of the consequences of capital requirements for financial stability.

A few studies have analyzed this question. Berger and Bonaccorsi di Patti (2006) analyze the impact of capital on profit efficiency in the US banking industry for the period 1990–1995. They find that higher capital ratios are associated with lower efficiency. Fiordelisi, Marques-Ibanez, and Molyneux (2011) provide a broader perspective by considering the intertemporal relationships between capital, risk, and efficiency for a sample of European banks between 1995 and 2007. They find a positive bi-directional relation between capital and efficiency, while these results are just derivative findings of their estimations. Pessarossi and Weill (2015) examine the effect of capital on efficiency for Chinese banks by considering the first implementation of capital requirements in China in 2004. They also show a positive impact of capital on cost efficiency.

The aim of our research is to analyze the impact of Basel III on Czech banks, specifically the impact of tighter capital requirements on the cost efficiency of Czech banks, which is directly connected to the financial stability issue. The findings of this paper are therefore of major interest for regulators. If capital reduces (increases) cost efficiency, capital requirements can potentially have negative (positive) consequences for financial stability through the cost efficiency channel.

The contribution of this paper to the literature is threefold. First, our paper analyzes the relation between capital and bank efficiency by considering both directions of the Granger causality.

Previous studies only consider the impact of capital on efficiency, even though there are theoretical reasons why efficiency can influence capital. The exception is the study by Fiordelisi, Marques-Ibanez, and Molyneux (2011), although they do not test hypotheses on this relation and consider a broader issue. Consequently, we assume in our study that tighter capital requirements can influence efficiency, which, in turn, affects capital, thereby creating a virtuous or vicious circle.

Second, we provide new evidence on the implications of tighter capital requirements for Czech banks. The relation between capital and efficiency has only been investigated in the context of large countries such as the US and China or advanced economies such as Western European countries. We can question this relation in the context of small emerging countries with their specific features, such as the importance of financial stability, given the occurrence of bank failures in these countries in both of the last two decades and the major market share of foreign-owned banks.

Third, we analyze how this impact might have been influenced by the recent financial crisis. This crisis may have influenced the relation between capital and efficiency, notably through a higher capital ratio, which has not been chosen strictly voluntarily by banks but under pressure from regulators and other bank stakeholders.

To investigate this issue, we use an exhaustive dataset of Czech banks from 2002 to 2013 provided by the Czech National Bank. We measure cost efficiency using stochastic frontier analysis. We then perform Granger-causality tests to check the sign and significance of the causal relation between capital and efficiency. We embed Granger-causality estimations in the GMM dynamic panel estimator to address the econometric issues resulting from the use of lagged dependent variables.

The paper is organized as follows. Section 2 presents the hypotheses, while Section 3 describes the evolution of the Czech banking sector. Section 4 outlines the methodology and presents the data. Section 5 displays the results. Section 6 concludes.

2. Hypotheses

In this paper we investigate the relation between capital and efficiency at the bank level. We start by presenting the hypotheses proposed by the literature for each direction of the causality.

2.1 From Capital to Efficiency

The hypotheses on the impact of capital on cost efficiency come from the agency costs literature, which demonstrates the existence of conflicts of interest between firm stakeholders, as mentioned by Jensen and Meckling (1976). These authors identify two types of conflicts, which have different implications leading to opposite hypotheses on the link between capital and cost efficiency.

Agency costs can arise from conflicts of interest between shareholders and managers. Here, the main problem is the moral hazard behavior of managers, who may minimize their effort or waste

firm resources instead of increasing firm value. Higher debt financing, and therefore a lower equity-to-assets ratio, raises the pressure on managers to perform, as it reduces the "free cashflow" at the disposal of managers (Jensen, 1986), as debt implies interest payment obligations, and as managers want to avoid the personal costs of bankruptcy (Grossman and Hart, 1982). So a higher equity-to-assets ratio should have a negative impact on efficiency (the *"agency costs shareholders-managers hypothesis"*).

However, agency costs also arise from conflicts of interest between shareholders and debtholders, as shareholders have incentives to take actions that benefit themselves at the expense of debtholders and consequently do not necessarily maximize firm value. They have incentives to invest in riskier projects than those preferred by debtholders ("asset substitution," as suggested by Jensen and Meckling, 1976). These conflicts can also lead to underinvestment, as demonstrated by Myers (1977). Since these agency costs are related to the importance of debtholders, they are associated with greater debt financing. In other words, a higher equity-to-assets ratio would reduce these agency costs and would thus be positively related to efficiency (the *"agency costs shareholders-debtholders hypothesis"*).

Both types of agency costs can emerge in the banking industry. However, the agency costs resulting from the relation between shareholders and debtholders are of particular interest in the context of this industry, in which regulation has to take care of the potential conflicts of interest between shareholders and depositors to protect this latter category. Nonetheless, we cannot ignore the possibility of conflicts of interest between shareholders and managers for Czech banks. Most of these institutions are foreign-owned and several studies have pointed out that foreign banks might be more difficult to monitor from a distance by shareholders (e.g., Berger et al., 2000). Monitoring by a foreign shareholder might be even more challenging if the shareholder owns several banks in different countries (i.e., the case of large international banking groups). On the other hand, many Czech banks have concentrated ownership, which can contribute to reducing the agency problem between shareholders and managers. All these arguments lead to the particular interest in analyzing this issue specifically for Czech banks.

Basel III can influence both hypotheses by resulting in greater and stricter requirements regarding capital from shareholders. It will contribute to increasing the moral hazard behavior of managers, but will reduce the moral hazard behavior of shareholders. The latter consequence is a key motivation behind this regulation, but it is important to check whether it is outweighed by the former. Hence, we have to empirically test for the sign of the relation between capital and efficiency.

2.2 From Efficiency to Capital

The causality might also run from cost efficiency to capital. Berger and Bonaccorsi di Patti (2006) have proposed two conflicting hypotheses for this sense of causality. The *"efficiency-risk hypothesis"* suggests that greater efficiency is associated with lower capital, as it reduces the costs of financial distress for bank managers. Indeed, more efficient firms are less likely to fail and are therefore more willing to use debt. We should thus expect a negative impact of cost efficiency on capital.

The *"franchise value hypothesis"* considers that a more efficient bank is more willing to use capital to protect the economic rents or franchise value resulting from its efficiency from the threat of liquidation. So, this hypothesis predicts a positive role of cost efficiency in capital.

The financial crisis might have played a role in the relation between cost efficiency and capital. For instance, the crisis might have exacerbated the threat of liquidation for efficient banks suggested by the *"franchise value hypothesis"* and might therefore have fostered a positive impact of cost efficiency on capital.

So, there are opposite theoretical predictions for both senses of the causality, which may furthermore have been influenced by the financial crisis.

3. Developments in the Czech Banking Sector

The Czech financial system is a banking-based system, in the sense that the banking industry is the main source of funding for the real economy. Like its peers in Central and Eastern Europe, the Czech banking industry is still of a reasonable size; its assets represented roughly 130% of GDP in 2013. Also, the banking business in the Czech Republic is of a conservative nature, based mainly on collecting deposits and providing loans to the real economy. In addition to that, banks hold investment assets, the majority of which are domestic government bonds.

In the late 1990s, the Czech banking system experienced a banking crisis. This was followed in the early 2000s by a clean-up of bank balance sheets and by acquisitions of major banks by foreign investors. As a result, the quasi-totality of the assets of the banking industry is currently controlled by foreign owners. Also, large European banking groups such as Erste Group, Société Générale, KBC, UniCredit Group, and Raiffeisen Group are present in the Czech Republic. Their subsidiaries in the Czech Republic rank among the largest domestic banks, with a market share of around 60% in terms of assets. Over the last decade, the number of banks has varied between 40 and 44. Several banks have been converted into branches of foreign banks operating in the Czech Republic under the EU single passport. The Czech banking sector consisted of 18 banks, 21 foreign bank branches, and 5 special-purpose building societies as of 2013.

In comparison to the 1990s crisis, Czech banks came through the recent financial crisis relatively unscathed thanks to their good capital position and conservative business models. They did not receive any government capital support during the crisis, unlike some of their foreign parent banks, and performed well overall (Frait, Geršl, and Seidler, 2011). The aggregate capital adequacy of Czech banks in fact increased during the crisis and totaled 17% in 2013. The banking sector's resilience to the crisis was also positively influenced by the responsible lending policy of domestic banks in the pre-crisis period, with almost no use of innovative instruments such as CDS and no material dependence on financing from interbank markets.

The Czech banking system exhibits favorable values of key prudential indicators on the aggregate level and was even able to maintain its profitability during the crisis, which, in turn, helped banks improve their capitalization using retained earnings. The profitability of the Czech banking sector in the crisis period was positively influenced by its large and stable deposit base on the liability

side. Domestic banks benefit from the conservative preferences of households, who favor bank deposits over alternative forms of financial assets. The significant overhang of deposits over loans in the sector (a deposit-to-loan ratio of about 130%) contributed to the ability of banks to lower interest rates paid on deposits, hence effectively reducing financing costs on the sector level.

On the asset side, credit risk materialized and non-performing loans increased in the initial years of the crisis. Increased provisioning for bad loans and some write-offs of junk foreign government bonds negatively impacted banks' net profits. However, non-performing loans stabilized in 2010 at the reasonable level of around 6%, which has led to a lower need to create significant additional provisions since then.

Although the key prudential indicators exhibit favorable values on the sector level, there are differences across banks in the Czech banking sector in terms of both riskiness, profitability, and capital position and their approach to the banking business.

The stability of Czech banks and the way they operate have been influenced by the regulatory environment in the Czech Republic, which has undergone important changes over time. In mid-2007 the Basel II rules were implemented into local law, and as early as 2007 some banks, mainly the largest ones, started to use the internal rating-based approach, an advanced and more sophisticated method for calculating capital requirements. Smaller banks kept the standardized approach for calculating capital requirements they were using under Basel I. The Basel III approach was implemented in the EU in mid-2013 via CRR/CRD IV, which took effect at the beginning of 2014. Basel III therefore influenced the 2009–2013 period only indirectly, as banks had been expecting stricter regulation to be introduced in reaction to the global financial crisis even though the final shape of CRR/CRD IV had not yet been finalized.

4. Methodology

This section is devoted to the presentation of the methodology used to obtain the results. We first present the data we used in our investigation. The empirical analysis is based on two building blocks, namely, the calculation of efficiency scores and Granger-causality testing of the relationship between the capital and efficiency of banks. Hence, we explain how we estimate the efficiency scores before describing how we study the relation between capital and efficiency.

4.1 Data

As the source of the data for the empirical analysis, we use the internal regulatory database of the Czech National Bank (CNB) to obtain data of a financial and regulatory nature. Despite the monthly frequency of the data reported to the CNB, we opt for the use of quarterly data for our analysis for two reasons. Firstly, quarterly data might be of higher quality than monthly data, as banks also publish their financial results on a quarterly basis. Secondly, it is reasonable to believe that it potentially takes longer than a few months, and even several quarters, for capital to influence efficiency. As a result, monthly data might introduce additional noise into the analysis instead of additional informative value. It might also be reasonable to do the analysis on yearly data. However, this would lead to a significant decrease in the number of available observations,

potentially to a level insufficient for reliable statistical testing, as the number of cross sections (banks in the Czech Republic excluding branches of foreign banks) is also not very large.

The data used comprise bank balance sheet and income statement items. The dataset covers 29 banks operating during the period 2002–2013, thus capturing pre-crisis and crisis effects. The dataset is unbalanced, as some banks came into being or stopped operating as standalone banks during the period.[1] As of 2013 there were 21 active banks in the sample, excluding two state-owned banks.[2] Branches of foreign banks were excluded from the dataset, as they are not independent of their parent banks, do not have registered capital, and therefore are not subject to capital regulation on a standalone basis.

4.2 Estimation of Efficiency Scores

Bank efficiency is measured using frontier efficiency techniques, which are the standard way to measure bank performance in empirical banking studies (e.g. Bonin, Hasan, and Wachtel, 2005; Podpiera and Weill, 2008). We consider cost efficiency as defined by the ability of a bank to produce a given product with the minimum of costs. Frontier efficiency techniques provide sophisticated measures of performance—efficiency scores, which have two major advantages over other measures. First, they are synthetic measures of performance: efficiency scores allow several input and output dimensions to be included in the evaluation of performance. Second, they are relative measures of performance. A cost frontier is estimated, allowing each bank to be compared with the best-practice bank. Thus, the cost efficiency scores assess how close a bank is to what its optimal cost would be for producing the same bundle of outputs.

We use the stochastic frontier approach to estimate efficiency scores. This technique is commonly applied in studies of bank efficiency (Bonin, Hasan, and Wachtel, 2005; Karas, Schoors, and Weill, 2010). It disentangles the distance from the efficiency frontier into an inefficiency term and a random error, which represent random disturbances reflecting luck or measurement errors.[3] To do so, we assume a normal distribution for the random error and a half-normal distribution for the inefficiency term. Following Jondrow et al. (1982), bank-specific estimates of inefficiency terms can then be calculated using the distribution of the inefficiency term conditional on the estimate of the composite error term (i.e., the sum of the inefficiency term and the random error).

[1] These banks either closed down, changed their status to a branch of a foreign bank, or merged with another bank in the domestic banking system. As only two closures occurred at the beginning of the period analyzed, we do not consider any significant survival bias in our results. If a significant merger occurred in the system, i.e., a merger which resulted in an increase of more than 50% in the total assets of the acquiring bank, the banks concerned were treated as two separate entities (i.e., the bank before the merger and the bank after the merger) in the dataset used for the empirical investigation, as the way of doing business might also have changed as a result of the merger.

[2] Banks owned by the Czech state were excluded from the dataset, as the principles and incentives under which they operate are different from those of standard commercial banks.

[3] The alternative approach to measuring bank efficiency is data envelopment analysis (DEA). However, unlike the stochastic frontier approach, it does not allow inefficiency to be disentangled from random shocks. As a consequence, the total distance between the cost frontier and the bank's effective total cost is viewed as inefficiency. This tends to overestimate the inefficiency and explains why the stochastic frontier approach is more commonly used in the context of transition countries (e.g., Bonin, Hasan, and Wachtel, 2005; Karas, Schoors, and Weill, 2010).

Following Fries and Taci (2005) and Weill (2009), among others, we follow the intermediation approach for the specification of banking inputs and outputs. This approach assumes that the bank collects deposits to transform them into loans with capital and labor. We consider two outputs in the cost function: loans and investment assets.[4] Loans comprise loans provided to households, non-financial corporations, government, and the central bank. Investment assets consist of debt securities and shares held by banks. We also employ three input prices. The price of funds is calculated as the interest rate paid on borrowed funds, the price of labor is defined as labor costs divided by the number of bank employees, and the price of capital is calculated as the costs incurred by banks for fixed assets such as buildings, equipment, and software relative to the value of those assets. All the costs are measured on an annual basis. Total cost is then simply the sum of the costs incurred for funds, labor, and capital. Following Bonin, Hasan, and Wachtel (2005) and Karas, Schoors, and Weill (2010), we employ a translog form to model the cost frontier of banks. The cost frontier is then the following one:

$$\ln\left(\frac{TC}{w_3}\right) = \beta_0 + \sum_m \alpha_m \ln y_m + \sum_n \beta_n \ln\left(\frac{w_n}{w_3}\right) + \frac{1}{2}\sum_m \sum_j \alpha_{mj} \ln y_m \ln y_j + \frac{1}{2}\sum_n \sum_k \beta_{nk} \ln\left(\frac{w_n}{w_3}\right)\ln\left(\frac{w_k}{w_3}\right) + \sum_n \sum_m \gamma_{nm} \ln\left(\frac{w_n}{w_3}\right)\ln y_m + \varepsilon \quad (1)$$

where TC is total cost, y_m is the m^{th} bank's output (m=1,2), w_n is the n^{th} input price (n=1,2), and w_3 is the price of borrowed funds. For simplicity of presentation, the indices for each bank have been dropped.

The model estimates one common cost frontier over the period, with dummy variables for each year to control for the specifics of individual years and dummy variables for each quarter to take into account the potential end-of-quarter effect and especially end-of-year effect in the case of the dummy variable for each fourth quarter. We also include a dummy variable for building societies due to the specifics of their business model (excluding them from the dataset would be costly in terms of the number of observations lost).

4.3 The Relation between Capital and Efficiency

The efficiency scores obtained from the stochastic frontier analysis are then used in the Granger-causality framework to test our hypotheses regarding the relationship between capital and efficiency in both directions: from capital to efficiency and from efficiency to capital. Since Granger causality is based on examining the lags of both efficiency and capital on the dependent variable efficiency/capital, we face a dynamic panel. The dynamic panel is estimated via the General Method of Moments (GMM), which, unlike the standard estimation method via fixed effects, is not liable to dynamic panel bias and handles the potential problem of endogeneity via the use of valid instruments.

[4] We do not consider off-balance sheet items because we want to stick to a standard definition of banking inputs and outputs in our approach and because they represent a relatively small activity for Czech banks.

Specifically, we use the two-step GMM system developed by Arellano and Bover (1995) and Blundell and Bond (1998). In comparison to the difference GMM framework, the GMM system should be more appropriate when the variables examined are relatively persistent, which is the case with both capital and efficiency, as both of them are dependent on their past values given their nature. In addition to the differenced equation being instrumented with instruments in levels (as in the difference GMM), the GMM system uses instruments in differences for the level equation, which might be more relevant when the variables are rather persistent.

The capital used for testing the Granger causality between efficiency and capital is simply the accounting capital represented by own funds. The capital ratio is calculated as the share of own funds in the balance sheet of the bank. In addition to the accounting definition, the capital ratio is alternatively defined with regulatory capital and is then calculated as the share of regulatory capital in the balance sheet of the bank. The reason for this alternative definition of capital is that the aim of this paper is to assess the potential impact of the higher regulatory capital requirements resulting from the Basel III framework on the efficiency of Czech banks. We do not consider risk-weighted assets when measuring our capital variable, because the theoretical arguments regarding the relation between capital and efficiency are all based on the relative importance of equity in comparison to total debt in the total balance sheet. It is therefore not relevant from this perspective to consider the ratio of capital to risk-weighted assets.

We perform Granger-causality tests to check the sign and causality of the relationship between capital and cost efficiency. We embed Granger-causality estimations in the GMM dynamic panel estimator to address the econometric issues induced by the use of lagged dependent variables. We then follow recent empirical studies on banking that similarly investigate Granger causality in various banking issues, such as the relationship between non-performing loans and efficiency (e.g., Berger and DeYoung, 1997; Podpiera and Weill, 2008), the link between competition and efficiency (e.g., Pruteanu-Podpiera, Weill, and Schobert, 2007; Casu and Girardone, 2009), and the relationship between capital and liquidity creation (Horvath, Seidler, and Weill, 2014).

We thus estimate the following equations to examine the relationships between bank capital and cost efficiency:

$$Efficiency_{i,t} = f(Capital_{i,lag}, Efficiency_{i,lag}, Z_{i,t}) + e_{i,t} \qquad (2)$$

$$Capital_{i,t} = f(Efficiency_{i,lag}, Capital_{i,lag}, Z_{i,t}) + e_{i,t} \qquad (3)$$

where the subscript t denotes the time dimension, i represents the cross-sectional dimension across banks, Z are the control variables, and $e_{i,t}$ is the error term. *Efficiency* is the cost efficiency score. *Capital* is the ratio of bank equity to total assets.

Equation (2) tests if changes in capital temporally precede variations in efficiency, while equation (3) evaluates if changes in efficiency temporally precede variations in capital.

We use four lags based on quarterly frequency. We consider this choice to be reasonable given the time needed to exert an influence and given the frequency of our data. In their analyses of the causal relation between non-performing loans and bank efficiency, Podpiera and Weill (2008) use

three lags and Fiordelisi, Marques-Ibanez, and Molyneux (2011) use two, but both studies use yearly data.

We then estimate an AR(4) process in which the Granger causality is tested by a joint test in which the sum of all the lagged coefficients of the explained variable in question is significantly different from zero. Podpiera and Weill (2008), Fiordelisi, Marques-Ibanez, and Molyneux (2011) and Horvath, Seidler, and Weill (2014) use similar frameworks.

We add two control variables in the estimations. First, we consider *Size*, as measured by the log of total assets, as bank size can influence the relation between capital and efficiency. Second, we include *GDP*, representing GDP growth, to take into account the macroeconomic environment. The source of the data is the Czech Statistical Office.

Table A1 displays the summary statistics for all of the variables used in the estimations.

5. Results

This section displays our results. We first present the main estimations of the relation between capital and efficiency. We then display some robustness checks.

5.1 Main Estimations

With respect to the first direction of the causality, from *Capital* to *Efficiency*, our results show that capital does not Granger-cause efficiency, as the sum of the coefficients of the lagged variable *Capital* is insignificantly negative when *Efficiency* is the dependent variable (Table A2). This finding is inconsistent with both the "agency costs shareholders-managers hypothesis" that capital has a negative impact on efficiency and the "agency costs shareholders-debtholders hypothesis," where the impact should be positive. This finding differs from the positive impact found by Fiordelisi, Marques-Ibanez, and Molyneux (2011) for European banks and by Pessarossi and Weill (2015) for Chinese banks, and from the negative influence pointed out by Berger and Bonaccorsi di Patti (2006) for US banks, but with profit efficiency.

We interpret our result in the following way. Both studies using cost efficiency like us (Fiordelisi, Marques-Ibanez, and Molyneux, 2011; Pessarossi and Weill, 2015) find a positive impact. They therefore support the key influence of agency costs between shareholders and debtholders. As we find no significant impact of capital, it means that the two types of agency costs offset each other in the context of the Czech banking industry. In other words, agency costs between shareholders and managers exert a greater influence for Czech banks than they do for European or Chinese banks, as they are strong enough to offset the influence of agency costs between shareholders and debtholders for the impact of capital on efficiency. This may stem from the fact that the vast majority of Czech banks are owned by foreign investors and, as such, are more difficult to monitor from a distance by shareholders (as shown by Berger et al., 2000), which leads to greater agency costs between shareholders and managers.

For the reverse causality, we find that efficiency does not Granger-cause capital, because the sum of the coefficients of the lagged variable *Efficiency* is not significant when explaining *Capital*. In

other words, efficiency does not influence capital (Table A2). From a theoretical perspective, this finding does not accord with the "efficiency-risk hypothesis," which predicts a negative influence of efficiency on capital, or with the "franchise value hypothesis," which expects a positive one. We therefore have a different finding for Czech banks than Fiordelisi, Marques-Ibanez, and Molyneux (2011) have for European banks, as they conclude that efficiency has a positive impact on capital. Our conclusion supports the view that the "efficiency-risk hypothesis" and the "franchise value hypothesis" offset each other for Czech banks, or else both exert no influence in the context of the Czech banking industry.

In a nutshell, our estimations support the absence of any relation between capital and efficiency for Czech banks.

5.2 Robustness Checks

To check the robustness of our findings, we perform alternative specifications to our main estimations. First, we examine whether the results are the same if we consider a longer time for capital or efficiency to have an impact on one another. Specifically, we consider the potential influence over the previous two years instead of one year as in our main estimations. We then redo the estimations by considering eight lags for *Capital* and *Efficiency*, capturing the previous two years with quarterly data. The results with eight lags show a similar pattern in the relation between capital and efficiency (Table A3). The total effect of capital on efficiency is again insignificant, while we observe no significant influence of efficiency on capital. In other words, our findings are not influenced by the number of lags.

Second, we rerun all estimations without control variables (*Size*, *GDP*) to check whether their inclusion influences our results, for instance by changing the significance of the key variables. We again find that the sum of the coefficients of the lagged variable *Capital* when explaining *Efficiency* is insignificant, and the sum of the coefficients of the lagged variable *Efficiency* when explaining *Capital* is also insignificant (Table A4). In other words, we again find no evidence of Granger-causation in either direction.

Third, we use an alternative measure of the capital ratio in our estimations. We used the ratio of accounting capital represented by own funds to total assets as our measure of the capital ratio in the main estimations, following previous studies and the theoretical arguments regarding capital structure and performance and the conflicts between shareholders and other stakeholders (debtholders and managers). However, as the aim of this paper is to assess the potential effect of the new Basel III capital requirements, we replace accounting capital with regulatory capital and the capital ratio is then alternatively defined as the share of regulatory capital in the balance sheet of the bank. The results of the estimations with *Regulatory Capital* are in line with the main estimations (Table A5).

Fourth, we use an alternative measure of cost performance in our estimations. We consider a standard cost measure of performance to check if our results still stand. Specifically, one might wonder whether our results are influenced by the use of sophisticated cost efficiency measures and would survive the use of more basic cost measures. To this end, we create a measure *Cost* defined as the ratio of operating costs to total assets. Operating costs are the sum of costs incurred for labor and for fixed assets. The results of the estimations with *Cost* correspond with the main

estimations using cost efficiency scores (Table A6).[5] We can therefore observe that the lack of evidence of Granger-causation is not a consequence of the cost efficiency scores obtained from the stochastic frontier approach.

Fifth, we examine whether the relationship between capital and efficiency has changed as a result of the recent global financial crisis. Financial troubles can affect the link between capital and efficiency, notably through regulators exerting pressure to enhance capital, but also by affecting the behavior of bank managers in terms of efficiency. To address this issue, we rerun our estimations by adding interaction terms between lagged values of *Capital* and *Efficiency* and *Crisis*, a dummy variable which is equal to one if the observation belongs to the years 2009–2013 (Table A7). We consider this period to be the crisis period, given that the main effects of the financial crisis were amplified in the Czech Republic in 2009 by a strong fall in GDP. We also alternatively tried other periods, such as 2008–2013, and obtained similar results.

We observe, however, that the sums of the interaction terms for *Capital* and *Efficiency* are insignificant. At the same time, the total impact of capital on efficiency is still insignificant, while the total impact of efficiency on capital is also insignificant. As a consequence, our findings are not influenced by the period of study, as the financial crisis did not influence the relation between capital and efficiency, which remains insignificant in both directions.

6. Conclusion

This study investigates the relation between capital and efficiency in the Czech banking industry. This issue is of utmost interest for appraising the implications of tighter capital requirements such as those included in the Basel III rules. To this end, we perform Granger-causality tests on an exhaustive dataset of Czech banks from 2002 to 2013 to analyze the relation between capital and efficiency.

Our investigation to identify a link between capital and efficiency revealed no significant relation. Neither the effect of capital on efficiency, nor the effect of efficiency on capital is significant. These findings are robust to different specifications. In addition, the financial crisis does not influence the relation between capital and efficiency.

Our conclusion differs from the findings of former studies. However, our study differs by investigating the relation between capital and efficiency for a small emerging country characterized by a high presence of foreign-owned banks.

From a normative perspective, our findings suggest that tighter capital requirements do not affect financial stability through the efficiency channel. The implementation of Basel III should not affect the efficiency of Czech banks. Our results also support the view that changes in efficiency do not influence capital. In other words, policies favoring capital levels and efficiency of the banking industry can be designed separately.

[5] We also redid our estimations by considering two alternative cost measures: the ratio of operating costs to income, and the ratio of total costs to total assets, with similar results.

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Appendix

Table A1: Descriptive Statistics

This table provides the descriptive statistics for the variables used in the estimations.

Variable name	**N**	**Mean**	**S.D.**	**Min**	**Max**
Loans (CZK billions)	888	110.86	144.65	2.33	617.97
Investment assets (CZK billions)	888	43.11	76.62	0.05	402.81
Price of labor (CZK thousands)	888	836.88	267.91	394.10	2102.30
Price of physical capital (ratio)	888	1.594	1.749	0.214	14.271
Price of borrowed funds (%)	888	2.110	0.908	0.383	5.175
Total cost (CZK billions)	888	5.410	7.025	0.109	30.987
Efficiency (%)	888	69.41	18.92	10.81	98.07
Capital (as share of total assets, %)	888	8.11	4.52	1.35	27.25
Regulatory capital (as share of total assets, %)	888	7.49	4.12	1.86	26.14
GDP growth (%)	888	2.74	3.36	-5.47	7.59
Total assets (CZK billions)	888	163.03	224.80	2.39	921.15

Table A2: Main Estimations

Granger-causality tests: the dependent variable is at the top of the column. We use the two-step system GMM estimator with Windmeijer (2005) corrected standard errors. The Hansen test of overidentifying restrictions with the null hypothesis that the instruments used are not correlated with the residuals and the overidentifying restrictions are valid is reported. The Arellano–Bond (AB) test for the first and second-order serial correlation applied to the differenced residuals has the null hypothesis of no serial correlation. The variables $Capital_{total}$ and $Efficiency_{total}$ are the estimated coefficients for the test that the sum of lagged terms (for capital and efficiency, respectively) is not different from zero. *P*-values are reported in brackets and ***, **, and * indicate that *p* is less than 0.01, 0.05, and 0.1 respectively.

	Efficiency		Capital	
Efficiency (t-1)	0.382***	(0.000)	0.00823	(0.620)
Efficiency (t-2)	0.153***	(0.000)	-0.0147	(0.156)
Efficiency (t-3)	0.0898*	(0.052)	-0.0123	(0.193)
Efficiency (t-4)	0.292***	(0.000)	0.0169*	(0.088)
Efficiency TOTAL	**0.917*** **	**(0.000)**	**-0.002**	**(0.960)**
Capital (t-1)	-1.248**	(0.035)	0.831***	(0.000)
Capital (t-2)	0.363	(0.295)	-0.0100	(0.886)
Capital (t-3)	-0.296	(0.468)	0.0308	(0.521)
Capital (t-4)	0.554	(0.111)	0.0755	(0.459)
Capital TOTAL	**-0.627**	**(0.402)**	**0.928*** **	**(0.000)**
GDP	-0.0400	(0.768)	-0.0234	(0.581)
Size	0.00590*	(0.090)	-0.000212	(0.920)
Constant	0.0832	(0.402)	0.00959	(0.794)
Number of observations	736		736	
Number of banks	26		26	
Hansen test	5.193	(0.268)	4.948	(0.293)
AB test AR(1)	-3.551***	(0.000)	-3.114***	(0.002)
AB test AR(2)	0.452	(0.651)	0.357	(0.721)

Table A3: Estimations with Eight Lags

Granger-causality tests: the dependent variable is at the top of the column. We use the two-step system GMM estimator with Windmeijer (2005) corrected standard errors. The Hansen test of overidentifying restrictions with the null hypothesis that the instruments used are not correlated with the residuals and the overidentifying restrictions are valid is reported. The Arellano–Bond (AB) test for the first and second-order serial correlation applied to the differenced residuals has the null hypothesis of no serial correlation. The variables $Capital_{total}$ and $Efficiency_{total}$ are the estimated coefficients for the test that the sum of lagged terms (for capital and efficiency, respectively) is not different from zero. *P*-values are reported in brackets and ***, **, and * indicate that *p* is less than 0.01, 0.05, and 0.1 respectively.

	Efficiency		Capital	
Efficiency (t-1)	0.287	(0.107)	0.0111	(0.601)
Efficiency (t-2)	0.201*	(0.066)	-0.0198	(0.124)
Efficiency (t-3)	0.0781	(0.366)	-0.00436	(0.691)
Efficiency (t-4)	0.184**	(0.031)	0.0125*	(0.098)
Efficiency (t-5)	-0.0385	(0.499)	-0.0120	(0.216)
Efficiency (t-6)	-0.0991	(0.228)	0.00539	(0.628)
Efficiency (t-7)	-0.117**	(0.038)	-0.00227	(0.689)
Efficiency (t-8)	0.177**	(0.020)	-0.00722	(0.402)
Efficiency TOTAL	**0.673***	**(0.051)**	**-0.017**	**(0.712)**
Capital (t-1)	-1.805	(0.134)	0.800***	(0.000)
Capital (t-2)	0.782	(0.279)	0.0484	(0.475)
Capital (t-3)	-0.146	(0.780)	0.0251	(0.648)
Capital (t-4)	0.233	(0.703)	0.144**	(0.021)
Capital (t-5)	-0.220	(0.339)	-0.127	(0.139)
Capital (t-6)	-0.0963	(0.893)	0.0940*	(0.060)
Capital (t-7)	-0.505	(0.386)	-0.0396	(0.652)
Capital (t-8)	0.332	(0.350)	0.0496	(0.647)
Capital TOTAL	**-1.426**	**(0.459)**	**0.995*****	**(0.000)**
GDP	-0.0710	(0.801)	-0.0179	(0.558)
Size	0.0171	(0.257)	0.000710	(0.727)
Constant	0.258	(0.428)	0.0101	(0.765)
Number of observations	616		616	
Number of banks	24		24	
Hansen test	7.640	(0.106)	5.288	(0.259)
AB test AR(1)	-2.796***	(0.005)	-2.992***	(0.003)
AB test AR(2)	-1.029	(0.304)	-0.0859	(0.932)

Table A4: Estimations without Control Variables

Granger-causality tests: the dependent variable is at the top of the column. We use the two-step system GMM estimator with Windmeijer (2005) corrected standard errors. The Hansen test of overidentifying restrictions with the null hypothesis that the instruments used are not correlated with the residuals and the overidentifying restrictions are valid is reported. The Arellano–Bond (AB) test for the first and second-order serial correlation applied to the differenced residuals has the null hypothesis of no serial correlation. The variables $Capital_{total}$ and $Efficiency_{total}$ are the estimated coefficients for the test that the sum of lagged terms (for capital and efficiency, respectively) is not different from zero. *P*-values are reported in brackets and ***, **, and * indicate that *p* is less than 0.01, 0.05, and 0.1 respectively.

	Efficiency		Capital	
Efficiency (t-1)	0.407***	(0.000)	0.0115	(0.459)
Efficiency (t-2)	0.159***	(0.001)	-0.0124	(0.179)
Efficiency (t-3)	0.103**	(0.039)	-0.0104	(0.227)
Efficiency (t-4)	0.300***	(0.000)	0.0191**	(0.038)
Efficiency TOTAL	**0.968*** **	**(0.000)**	**0.008**	**(0.812)**
Capital (t-1)	-1.019**	(0.015)	0.872***	(0.000)
Capital (t-2)	0.488	(0.208)	0.000602	(0.992)
Capital (t-3)	-0.274	(0.470)	0.0349	(0.443)
Capital (t-4)	0.490*	(0.084)	0.0853	(0.335)
Capital TOTAL	**-0.315**	**(0.643)**	**0.993*** **	**(0.000)**
Constant	0.0485	(0.716)	-0.00362	(0.918)
Number of observations	736		736	
Number of banks	26		26	
Hansen test	6.728	(0.151)	4.821	(0.306)
AB test AR(1)	-3.582***	(0.000)	-3.213***	(0.001)
AB test AR(2)	0.669	(0.504)	0.266	(0.791)

Table A5: Alternative Definition of Capital Variable

Granger-causality tests: the dependent variable is at the top of the column. We use the two-step system GMM estimator with Windmeijer (2005) corrected standard errors. The Hansen test of overidentifying restrictions with the null hypothesis that the instruments used are not correlated with the residuals and the overidentifying restrictions are valid is reported. The Arellano–Bond (AB) test for the first and second-order serial correlation applied to the differenced residuals has the null hypothesis of no serial correlation. The variables $Capital_{total}$ and $Efficiency_{total}$ are the estimated coefficients for the test that the sum of lagged terms (for capital and efficiency, respectively) is not different from zero. *P*-values are reported in brackets and ***, **, and * indicate that *p* is less than 0.01, 0.05, and 0.1 respectively.

	Efficiency		Regulatory capital	
Efficiency (t-1)	0.435***	(0.000)	0.00769	(0.300)
Efficiency (t-2)	0.175***	(0.001)	-0.00302	(0.617)
Efficiency (t-3)	0.113**	(0.020)	0.000199	(0.974)
Efficiency (t-4)	0.311***	(0.000)	0.0134*	(0.054)
Efficiency TOTAL	**1.034*** **	**(0.000)**	**0.018**	**(0.181)**
Regulatory capital (t-1)	-0.758***	(0.006)	0.904***	(0.000)
Regulatory capital (t-2)	0.766**	(0.016)	0.0240	(0.714)
Regulatory capital (t-3)	-0.272	(0.254)	0.129**	(0.018)
Regulatory capital (t-4)	0.315	(0.186)	-0.00958	(0.879)
Regulatory capital TOTAL	**0.051**	**(0.930)**	**1.047*** **	**(0.000)**
GDP	0.0436	(0.683)	-0.00159	(0.953)
Size	0.00175	(0.630)	-0.000167	(0.813)
Constant	-0.0349	(0.739)	-0.0151	(0.492)
Number of observations	736		736	
Number of banks	26		26	
Hansen test	6.488	(0.166)	4.381	(0.357)
AB test AR(1)	-3.548***	(0.000)	-3.29***	(0.001)
AB test AR(2)	0.698	(0.485)	1.004	(0.315)

Table A6: Alternative Definition of Cost Performance

Granger-causality tests: the dependent variable is at the top of the column. *Cost* is the ratio of operating costs (costs incurred for labor and for fixed assets) to total assets. We use the two-step system GMM estimator with Windmeijer (2005) corrected standard errors. The Hansen test of overidentifying restrictions with the null hypothesis that the instruments used are not correlated with the residuals and the overidentifying restrictions are valid is reported. The Arellano–Bond (AB) test for the first and second-order serial correlation applied to the differenced residuals has the null hypothesis of no serial correlation. The variables $Capital_{total}$ and $Cost_{total}$ are the estimated coefficients for the test that the sum of lagged terms (for *Capital* and *Cost*, respectively) is not different from zero. *P*-values are reported in brackets and ***, **, and * indicate that *p* is less than 0.01, 0.05, and 0.1 respectively.

	Cost		Capital	
Cost (t-1)	0.528**	(0.015)	-0.193	(0.360)
Cost (t-2)	0.348***	(0.000)	-0.206	(0.186)
Cost (t-3)	0.0517	(0.576)	0.0821	(0.539)
Cost (t-4)	0.342*	(0.089)	-0.121	(0.349)
Cost TOTAL	**1.269*** **	**(0.000)**	**-0.437**	**(0.243)**
Capital (t-1)	0.00799	(0.929)	0.829***	(0.001)
Capital (t-2)	-0.0546	(0.314)	-0.0114	(0.911)
Capital (t-3)	0.0494*	(0.070)	0.0791**	(0.039)
Capital (t-4)	-0.0714	(0.105)	0.0809	(0.302)
Capital TOTAL	**-0.069**	**(0.476)**	**0.978*** **	**(0.001)**
GDP	-0.0108	(0.662)	0.0112	(0.854)
Size	0.0000978	(0.916)	-0.000524	(0.711)
Constant	-0.000867	(0.906)	0.0134	(0.626)
Number of observations	734		734	
Number of banks	26		26	
Hansen test	3.252	(0.517)	3.943	(0.414)
AB test AR(1)	-2.092**	(0.036)	-2.860***	(0.004)
AB test AR(2)	1.125	(0.260)	1.045	(0.296)

Table A7: Results by Periods

Granger-causality tests: the dependent variable is at the top of the column. We use the two-step system GMM estimator with Windmeijer (2005) corrected standard errors. The Hansen test of overidentifying restrictions with the null hypothesis that the instruments used are not correlated with the residuals and the overidentifying restrictions are valid is reported. The Arellano–Bond (AB) test for the first and second-order serial correlation applied to the differenced residuals has the null hypothesis of no serial correlation. The variables $Capital_{total}$ and $Efficiency_{total}$ are the estimated coefficients for the test that the sum of lagged terms (for capital and efficiency, respectively) is not different from zero. *P*-values are reported in brackets and ***, **, and * indicate that *p* is less than 0.01, 0.05, and 0.1 respectively.

	Efficiency		Capital	
Efficiency (t-1)	0.414***	(0.000)	-0.000221	(0.983)
Efficiency (t-2)	0.183***	(0.000)	-0.0249***	(0.007)
Efficiency (t-3)	0.0772	(0.108)	-0.0149	(0.113)
Efficiency (t-4)	0.313***	(0.000)	0.00887	(0.227)
Efficiency TOTAL	**0.987*** **	**(0.000)**	**-0.031**	**(0.154)**
Capital (t-1)	-1.422***	(0.002)	0.712***	(0.004)
Capital (t-2)	0.560	(0.179)	-0.0582	(0.333)
Capital (t-3)	-0.337	(0.482)	0.0199	(0.568)
Capital (t-4)	0.589*	(0.088)	-0.00719	(0.950)
Capital TOTAL	**-0.610**	**(0.274)**	**0.667*** **	**(0.001)**
Capital*Crisis (t-1)	0.506	(0.173)		
Capital*Crisis (t-2)	-0.296	(0.153)		
Capital*Crisis (t-3)	0.212	(0.205)		
Capital*Crisis (t-4)	-0.148	(0.351)		
Capital*Crisis TOTAL	**0.273**	**(0.229)**		
Efficiency*Crisis (t-1)			-0.0126	(0.287)
Efficiency*Crisis (t-2)			0.00769**	(0.041)
Efficiency*Crisis (t-3)			0.00119	(0.738)
Efficiency*Crisis (t-4)			0.00440	(0.427)
Efficiency*Crisis TOTAL			**0.001**	**(0.898)**
GDP	0.236	(0.163)	-0.0778	(0.304)
Size	0.00327	(0.339)	0.000794	(0.600)
Constant	0.0237	(0.822)	0.0464**	(0.050)
Number of observations	736		736	
Number of banks	26		26	
Hansen test	7.977	(0.240)	7.452	(0.281)
AB test AR(1)	-3.453***	(0.001)	-2.362**	(0.018)
AB test AR(2)	0.154	(0.878)	0.653	(0.514)

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ISSN 1803-7070