Charles University

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MASTER'S THESIS

Bank credit risk management in the low-interest rate environment

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Declaration of Authorship

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Prague, May 9, 2019

Signature

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Abstract

The thesis examines the relation of the low-interest rate environment to the banks' selected credit risk measures with a panel dataset on banks in Eurozone, Denmark, Japan, Sweden, and Switzerland covering the period 2011–2017. It employs a system GMM framework and a combination of bank-related and macroeconomic variables. This study builds on recent literature on effects of low-interest rates on banks' profitability and estimates the following three hypotheses: The potential effects of the low-interest rate on non-performing loans (NPL) ratio, risk-weighted assets (RWA) to total assets ratio, and changes in Tier 1 capital ratio. There are three main results: Firstly, the results suggest that a prolonged period of negative monetary interest rate can affect the NPL ratio and reveal a possible relationship between the 3M-interbank interest rate and NPL ratio. Thus, the thesis does not reject the first hypotheses. However, it rejects these hypotheses in case of the other two ratios. Secondly, the study finds a bank heterogeneity to be a significant determinant of the credit risk. Finally, using recent data, this thesis contributes to the literature focusing on the drivers of the NPL ratio, RWA to total assets ratio and Tier 1 capital ratio, where in case of the latter two the existing research is limited compared to the NPL.

JEL Classification	C33, E43, E52, E58, G21
Keywords	banks, credit risk, low interest rates, monetary policy, non-performing loans

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Abstrakt

Tato diplomová práce zkoumá vztah prostředí nízkých úrokových sazeb k bankovním ukazatelům kreditního rizika pomocí panelových dat pokrývajícími banky zemí Eurozóny, Dánska, Japonska, Švédska a Švýcarska během období let 2011–2017. Práce využívá metody system-GMM se zapojením bankovně-specifických a makroekonomických proměnných. Tato práce navazuje na existující literaturu zkoumající efekty nízkých úrokových sazeb na profitabilitu bank a pokouší se odhadnout tyto následující hypotézy: Eventuální vliv nízkých úrokových sazeb na ukazatel ohrožených úvěrů (NPL), míru rizikově vážených aktiv (RWA) k celkovým aktivům a vliv na změnu ukazatele Tier 1 kapitálu. Práce má tyto tři hlavní závěry: Zaprvé, výsledky naznačují, že setrvání v období záporných úrokových sazeb může ovlivnit ukazatel NPL a odhalují potenciální vztah 3měsíčních mezibankovních sazeb k ukazateli NPL. Tato práce nicméně zamítá hypotézy ohledně ostatních dvou ukazatelů. Zadruhé, studie odhaluje bankovní heterogenitu jako signifikantní faktor kreditního rizika. Závěrem, práce přispívá s využitím aktuálních dat k literatuře zaměřené na zkoumání určujících vlivů NPL, RWA a ukazatele Tier 1 kapitálu, kde v případě posledních dvou zmíněných je výzkum méně rozvinutý v porovnání s NPL.

Klasifikace JEL	C33, E43, E52, E58, G21
Klíčová slova	banky, kreditní riziko, nízké úrokové sazby, monetární politika, ohrožené úvěry

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Acronyms

BoJ Bank of Japan

DN Danmarks Nationalbank

ECB European Central Bank

GDP Gross domestic product

GMM Generalized method of moments

IFS IMF International Financial Statistics, International Monetary Fund

OLS Ordinary least squares

NPL Non-performing loan

RWA Risk weighted assets

SNB Swiss National Bank

SR Sveriges Riksbank

List of countries

AT Austria

BE Belgium

CH Switzerland

CY Cyprus

DE Germany

DK Denmark

EE Estonia

ES Spain

FI Finland

FR France

GR Greece

IE Ireland

IT Italy

JP Japan

LT Lithuania

LU Luxembourg

LV Latvia

MT Malta

NL Netherlands

PT Portugal

SE Sweden

SI Slovenia

SK Slovakia

Master's Thesis Proposal

Author	Bc. Matěj Maivald
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Proposed topic	Bank credit risk management in the low-interest rate environment

Motivation In theory, low interests will incentivize investments in economy and boost consumer spending by providing inexpensive loans. Central banks' motivation to set interest rates close to zero (or even below in some cases) can vary they may wish to provide additional monetary easing or to stabilize exchange rates (Demiralp et al., 2017).

However, these actions can have direct implications on the retail and commercial banks. With a combination of other unprecedented factors, such as new regulation, periods of stagnation, they can result in a lower profit or affect the riskiness of banks. These effects will vary for different capital and ownership structures and the size of these effects will be country specific.

This thesis will try to contribute to the strand of recent literature focusing on the effects of low interest rates environment. Kerbl and Sigmund (2017) found out a significant impact of close to zero rates to Austrian banks' profitability by employing a time series model of banks' items in profit and loss statements. Ampudia and Van den Heuvel (2017) investigated the relationship between changes in Eurozone interest rates and banks' stock prices. Bikker and Vervliet examined the effect of low interest rate environment on the US banking sector profitability and changes in risk behavior.

Lopez et al. (2018) inspected a dataset of banks in 27 countries and focused on a possible relationship of negative nominal interest rates and interest income and expenses. Lucas et al. (2018) suggest that bank business model adapt over time as the banks are facing post-financial crisis environment shaped not only by low interest rates but accompanied by changes in yield curve as well.

The added value of this thesis is in using of a cross-country dataset incorporating information from all countries where monetary authorities had decided to employ negative interest rates and examining the effects on the risk management of the banks.

Hypotheses

Hypothesis #1: Low interest rate environment will influence the banks' Risk Weighted Assets / Total Assets ratio after 1–3 years

Hypothesis #2: Low interest rate environment will delay influence the banks' Non-performing loans ratio after 1–3 years

Hypothesis #3: Low interest rate environment will result in a change of bank's capital structure

Methodology The thesis will be using a panel dataset from the Orbis Bank focus database, with a geographical scope limited to Denmark, Eurozone, Japan, Sweden, and Switzerland. The results will be derived by panel regression using fixed and random effects and generalized method of moments.

The dataset will consist of individual banks in analyzed countries and will include data on different risk measures, such as Risk Weighted Assets / Total Asset, or Non-performing loans. The analysis will try to determine the period, after which the low interest rate environment translated into the performance of banks, and to determine the size of such effect, this will be achieved by an addition of dummy explanatory variables to the models.

Expected Contribution By employing the most recent data from the Orbis Bank Focus database, this master thesis will present an empirical evidence of how the negative interest rates impact the risk management of the banking sector across the countries, where central banks decided to employ policies of the low (or even negative in some periods) interest rates.

The results will be useful for policymakers, as they will try to evaluate the time frame after which the close to a zero interest or even negative interest rate policy might translate into the balance sheet of banks and affect the overall riskiness as expressed in the ratios described in my hypotheses.

Outline

1. Introduction and motivation

2. Theoretical background

3. Literature review

4. Methodological background
5. Data and empirical analysis
6. Results and Discussion
7. Conclusion

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Author Supervisor

Chapter 1

Introduction

After the global financial crisis of 2007–2008, central banks in several advanced economies decided to ease the macroeconomic environment by reducing interest rates towards (and eventually below) the zero bound, a move that was not put into practice before. The motivation of the central banks differed, the European Central Bank's (ECB), Sveriges Riksbank's (SR, central bank of Sweden) (Demiralp, Eisenschmidt, & Vlassopoulos 2017) and Bank of Japan's (BoJ) (Hattori 2017). Decision was following the objective to arrange further monetary easing to boost the economy and to keep up with the inflation target, while other central banks employed the policy of negative interest rates to prevent the excessive inflow of capital (namely Danmarks Nationalbank (DN) and Swiss National Bank (SNB)) thus trying to prevent overheating of the local economies (Bech & Malkhozov 2016).

This thesis' objective is to model and to analyze the potential impact of too low or negative interest rate on the commercial banks and their risk management. Lowering overnight policy interest rates usually translates into bank offered deposit rates following the same trend—cutting interest rates under the zero bound should theoretically yield the same policy targets as lowering interest rates above zero. However, with negative interest rates, banks might become reluctant to charge its clients for deposits (this especially applies for retail clients)—this can be naturally channeled in changes in risk structure, with banks preferring riskier loans to compensate for the change in costs (Bech & Malkhozov 2016).

For the analysis, this thesis uses a data-set of Eurozone, Japan, Swedish, Swiss and Danish commercial banks originating from the Orbis BankScope database with observations for 827 different banks. The model controls for the effect of the negative interest rates, explains the bank-specific factors (for example size of the banks or a primary focus of business) and accounts for other macroeconomic variables in examined countries. The specific objective of this thesis is to test for the following three hypotheses:

> Hypothesis #1: Low-interest rate environment will influence the banks' Non-performing loans ratio after 1–3 years
>
> Hypothesis #2: Low-interest rate environment will influence the banks' Risk-Weighted Assets / Total Assets ratio after 1–3 years
>
> Hypothesis #3: Low-interest rate environment will result in a change of banks' capital structure.

The results can be found useful for policymakers, as they will try to evaluate the time frame after which the close to a zero interest or even negative interest rate policy might translate into the balance sheet of banks and affect the overall riskiness as expressed in the ratios described in our hypotheses.

The rest of the thesis is structured as follows: Chapter 2 summarizes recent literature focusing on the modeling of the banking environment influenced by low and negative interest rates and literature focused on modeling of credit risk indicators using panel microeconomic data. Then a theoretical background explaining key concepts important and theories relevant for the topic is explained in Chapter 3, with a critical focus on bank-specific factors, explaining credit risk measures and capital structure of the banks.

Subsequently, Chapter 4 discusses the tools and methodology used for the analysis. Chapter 5 clarifies sources and the nature of the collected data; then Chapter 6 finally uses the data-set to assess the possible impact of low-interest rates on the management of credit risk. Chapter 7 summarizes findings of this master thesis.

Chapter 2

Literature review

This thesis tries to capture the changes in credit risk management after the crisis observed in years 2007–2008. Therefore, this chapter in Section 2.1 tries to cover the development of recent studies focused on the impact of the low interest rates on the banking industry, and then in Section 2.2, it summarizes another strand of the literature focused on estimating determinants of the credit risk.

2.1 Low-interest rate environment

In a study Altunbas, Gambacorta, & Marques-Ibanez (2012) explored, how monetary policy can affect bank risk-taking. They examined the sample 3,000 banks in the euro area from the years 1999 to 2005 using the GMM model. In its specification, they controlled for standard macroeconomic variables as well as for bank-specific variables. The researchers applied one year expected default frequency as a proxy for credit risk measure. The study found the market interest rate to be a significant factor in explaining the risk position of the bank.

Borio, Gambacorta, & Hofmann (2017) investigated how the short term interest rate and the slope of the yield curve relate to the bank profitability measured by a return on assets ratio. Authors use an annual data-set from 1995 to 2012 (spanning over the financial crisis, which is included in the empirical model as a dummy variable) of more than 100 banks in 14 countries. Authors are using the generalized method of moments (GMM) estimator in order to control for excess endogeneity in the model. Their analysis shows that overall higher interest rates and steeper yield curve increase banks' profitability. They claim that the effect on the interest income is larger than the changes in the non-interest income and the size of the effect before, during and after the crisis changes.

Claessens, Coleman, & Donnelly (2018) examined a sample of 3,385 banks between years 2005 and 2013 spanning across 47 countries. They regressed a net interest margin of included banks on a dummy variable indicating whether the country attained a low rate environment, switching at an interest rate of 1.25% using panel fixed effects model. They included further variables controlling for heterogeneity of banks and country-specific macroeconomic variables, as well as the year, fixed effect. Authors' findings are that low interest rates have a marginally larger effect on net interest margin compared to interest rate higher than the selected threshold. Further, they found that the longer the period of low interest rates is effective, the greater is the effect on net interest margin.

Bikker & Vervliet (2018) show risk-taking and bank profitability under low IR - they used system GMM estimator on a sample of more than 5,000 observations of US banking institutions including. Their analysis shows that even though the US banks sustained their level of profits, their net interest margins were impacted, and the banks probably offset the gap by changing loan provisioning. This in turn negatively worsens the ability of banks to react to unexpected credit losses as the authors of the paper claim.

Another study conducted by Lopez, Rose, & Spiegel (2018) inspected panel of size 5,100 of Japan and European banks from the years between 2010 and 2016. On banks' income statements they reveal that negative interest rates have no unexpected effect on the overall income of banks compared to an environment with already low positive interest rates. Nevertheless, the proportions of the types of income might change. However, they are cautious about claiming that the income of the banks in the sample would remain unchanged in the upcoming years if the negative interest rates environment would continue.

Demiralp, Eisenschmidt, & Vlassopoulos (2017) focused solely on banks in the Eurozone and use monthly observations of bank data and match them to ECB's data using a panel fixed-effect regression. Their main research question is to find if the strategy of banks would differ given the current level of interest rates. They find evidence that banks in Eurozone reacted to changes in interest rate. They discover these changes most visible on banks with a business model focused on deposit funding. They further argue that these banks might reorient towards extending their loan exposure to non-financial institutions and changing their overall portfolio to hold non-domestic bonds and decrease the portion of wholesale funding.

Arseneau (2017) contributed to the literature by examining the expectations of US banks of what would happen if the negative environment would be implemented in the US (as the negative interest rate policy has never been implemented in the United States). Thus, instead of actual data, they run their analysis on projections provided by the banks in the sample, with only 22 banks included, given that negative interest environment was introduced as a hypothetical scenario by the US Federal Reserve. In their study, they find out, that the results are most driven by the heterogeneity of the banks. The authors state that approximately one-third of the bank believes that negative interest rates would result in a decline in interest income. The other third would anticipate growth, and the rest does not expect any significant changes. They then conclude that the overall effect of the policy would result in changes depending on the type of institution.

Finally, Nucera, Lucas, Schaumburg, & Schwaab (2017) study the impact of negative interest rates on the riskiness of banks. They use a propensity for a bank to become undercapitalized as a proxy for bank's riskiness and model it with difference-in-difference regression estimation on 111 Eurozone quarterly collected series of banks' data collected from the year 2012 to 2014, omitting the period of the debt crisis in the euro area after 2010. For the analysis, they divide the banks into the six different buckets by their business model. Authors find out that policy cuts below the zero level have different responses in banks' riskiness than the changes by the same absolute value when taking place above the zero bound. They also detect that large banks tend to be riskier than the smaller ones.

2.2 Drivers of the credit risk

Chaibi & Ftiti (2015) examined the determinants of the credit risk proxied by the level of Non-performing loan (NPL). They were using two datasets focused on Germany and France with time period limited to 2005–2011. They proxied the bank inefficiency, leverage, solvency, size, and profitability by bank-specific variables while using inflation, Gross domestic product (GDP) growth, interest rate, unemployment, and exchange rate as macroeconomic variables. Using the system GMM framework, they found out that these variables are useful in explaining the NPL in their examined countries.

Radivojevic *et al.* (2017) performed a cross-country analysis over the sample of 25 emerging countries from the period 2000–2011. They estimated both static (using fixed effects estimator) and dynamic (using GMM methods) model to evaluate the determinants of the NPL ratio. Among other things, they found a significant link between the NPL ratio and GDP, negative effect of profitability variables as well as they confirmed a dynamic persistence of the NPL; hence they preferred the dynamic model approach.

Another recent study focusing on the drivers of the NPL ratio was conducted by Dimitrios *et al.* (2016). Authors analyzed possible effects of various bank-related and macroeconomic variables, such as return on assets, loan to deposits ratio or inflation, tax level, and GDP. Their main area of focus was Eurozone with data available for 138 individual banks for the period between 1990 and 2015. They found the macroeconomic and bank-specific variables to be significant in explaining the dependent variable.

Ahmad & Ariff (2007) studied the determinants of the credit risk proxied by NPL on cross-sectional data obtained from the BankScope database. They examined effects in developing (Malaysia, Korea, Mexico, India, and Thailand) vs. developed countries (Australia, Japan, USA, and France) while using a dataset of 23 thousand observations over a period from 1996 to 2002. They found out that the credit risk in emerging economy banks is higher compared to the developed countries and that the bank-related variables are potentially more useful in explaining risk in emerging countries compared to the developed ones.

Ghosh (2015) focused on banking data in the United States spanning from 1984 until 2013. The author studied the impact of the capitalization, liquidity, profitability or bank size on the non-performing loans using fixed effect and dynamic GMM estimations. Further, the author revealed that the variables do affect the NPL and argued that the state-level economic conditions should be taken into account when designing regulatory policies targeted at the quality of banks' asset portfolio.

Louzis *et al.* (2012) evaluated the determinants of NPL in Greece using a panel sample and dynamic estimation GMM methods. The examined quarterly data between 2003Q1 and 2009Q3 of the nine largest banks in the country. Taking advantage of the detailed data, this allowed them to estimate NPL ratio separately on consumer, business and housing loans. Their results suggest that the NPL in Greece in all their segments of interest can be described by macroeconomic variables (they control for the changes in GDP, unemployment, interest rates, and public debt) and by bank-related proxy for the profitability of the analyzed banks.

In another paper, Gropp & Heider (2010) studied determinants of the banks' capital structure on the data of 200 largest publicly traded bank from the European Union and the United States. Their dataset consisted of total 2,415 observations from 1991 until 2004. They concluded that the time-invariant bank related variables have a significant effect in explaining the capital structure of the bank. They also report that bank in their sample tends to shift from deposit to non-deposit liabilities.

A paper authored by Šútorová & Teplý (2014) assess on the dataset of 594 banks from the European Union over the years 2006–2011 the impact of capital requirements imposed by Basel III. They show their results on models with Risk weighted assets (RWA) density, bank profitability and capital ratios as dependent variables. Through the significance of bank-specific (controlling for such as capital, riskiness of banks, profitability and size of banks) and macroeconomic (for example GDP, inflation) variables they show that a proposal for higher capital requirements can lead to a decrease in banks' profitability and decrease in risk-taking accompanied by decrease of risky assets.

Last but not least, Brewer III *et al.* (2008) examined the determinants of the leverage capital ratio and the Tier 1 capital ratio. In their analysis, they included annual data for 78 large private banks from 12 developed countries over the years 1992 and 2005. They found out that the capital ratios can be explained by the set of macroeconomic (including GDP), bank-related variables (return on assets, a proxy for risk and size) and policy focused parameters. They found several of the variables significant and useful in the explanations of the banks' capital ratios.

Chapter 3

Theoretical background

This chapter covers in following sections theoretical concepts that are important for this thesis. It starts with defining essential topics, focusing on credit risk and defining the term of a zero lower bound and its development discusses different business models of banks and lastly capital structure of banks.

3.1 Credit risk

As an institution, banks face several categories of risk. One of them, which is in particular interest of this thesis, is a threat that its contractual counter-party will not be able to meet agreed obligations; it will either default fully or partially. This risk is referred to as a credit risk. The credit risk falls to the category of financial risks, along with market risk[1] and liquidity risk[2]. The credit risk has the most significant impact on banks' positions, as Mejstřík *et al.* (2015) states, it accounts for over 60% of all risks—it is, therefore, the most important one that banks have to manage.

For a universal bank credit risk represents the central core of its business; hence it follows that banks undertake the credit risk willingly by providing loans to their corporate and residential clients. Their main goal is therefore not to avoid the risk entirely but measure it and control it in a way to maximize the profit and minimize losses. The problem arises due to the information asymmetry when the two counter-parties are not sharing full information with themselves.

[1]Threats to the bank arising from market movements, e.g. from movements of interest rates, stock market fluctuations, foreign exchange rates changes etc.

[2]Liquidity risk can be caused by deficiency of cash supply when facing bank run. (Diamond & Dybvig 1983)

The credit risk encapsulating the process of loan granting can then be decomposed to the adverse selection (before the contract is agreed) and moral hazard (after the contract is agreed). The counter-party is likely to conceal any information that it is not required to provide, and which would inevitably result in a higher risk premium.

The total amount of credit risk is determined by the classification of the soundness of its receivables. The banks divide their credit portfolio into categories, by the probability of default. They usually distribute them to receivables without default (can be further broken down to standard receivables and watch receivables) and receivables with default (these can be fragmented into substandard receivables, doubtful receivables and loss receivables, where the probability of default increases, with the latest, mentioned to be the highest) (Mejstřík *et al.* 2015).

Poor quality of loan portfolios—more accurately the impoverished quality of the sub-prime mortgages—was among the primary triggers of the global financial crisis in the years 2007–2008 (which was the originator for the period of the low interest rates), thus the minimization of non-performing loans is fundamental to the health of the whole economy as Messai & Jouini (2013) point out. More detail on how banks compute their nonperforming loans portfolio is further provided in the Subsection (4.1.1).

The management of the credit risk is thus a necessary process for financial institutions. The Credit rating of a subject typically consists of scoring models, either adopted from established rating agencies (when providing loans to large institutional clients) or by banks' scoring models. These take into account all possible available information reported by the client, such as current income, length of employment, marriage status and importantly previous credit history (Mejstřík *et al.* 2015). More advanced approaches can include models based on econometric analyses or neural networks; more on this topic can be found in West (2000).

Bellotti & Crook (2009) in their work mention the importance of the macroeconomic variables to the credit risk modeling. This thesis in its empirical part tries to find evidence if low interest rates can influence credit rating.

3.2 Zero lower bound

The interest rate setting by central banks plays an essential role as a tool of monetary policy. For example, under the inflation targeting regime, adjustments to the overnight interest rates are expected to influence the current level of inflation. When the central bank aims to decrease inflation, it can increase the level of the interest rate to cool the economy. On the other hand, if the economy tends to underperform, it may choose to lessen the interest rate to stiffen spendings in the economy, incentivize investments and thereby increase the price level.[3]

Nevertheless, this can only be accomplished under the circumstances, where both inflation and interest rates are at "normal" levels, allowing central banks to use conventional monetary policy methods. Therefore, when overnight deposit interest rate stagnates close to zero and inflation is below the monetary target, it becomes apparent that the traditional approach to monetary policy becomes likely inoperative. This scenario, not observed before on this scale[4]as described in the previous sentence, developed after the global financial crisis in the years 2007–2008. Until then, charging a negative interest—or taxing the underlying money—was only theorized (Ilgmann & Menner 2011).

Hence conducting monetary policy under low or negative interest rates is a relatively recent topic in economic literature. (Bernanke & Reinhart 2004, p. 85), before the financial crises, proposed three different strategies of conducting the monetary policy under close to zero interest rates:

> (i) providing assurance to investors that short rates will be kept lower in the future than they currently expect, (ii) changing the relative supplies of securities in the marketplace by altering the composition of the central banks' balance sheet, and (iii) increasing the size of the central banks' balance sheet beyond the level needed to set the short-term policy rate at zero (quantitative easing).

The first strategy—of forming the expectations on the market—argues that if the central bank commits to keeping the interest rate low enough for an even more extended period than it was anticipated earlier. This type of commitment might time constrained (e.g., the central bank would promise to keep the rate low for whole ongoing year) or link the pledge to the future macroeconomic development (for example keep the rates low until the period of low inflation is

[3]Please note that this example is only a simplified view of the monetary policy as a whole, the monetary policy transmission effects are far more complex.

[4]The first notable occurrence of zero—or close to zero—interest rates first appeared in Japan during 1990's, it had only been observed in a single economy accompanied with long-term GDP stagnation. Thus, the circumstances differs from what we are observing in 2010s. See Akram (2016) to examine the historical situation in Japan in more detail.

over). This should then translate into the growth of other asset prices instead of the accumulation of capital in low-earning deposits.

The second approach advises central banks to change the structure of their balance sheet assets by substituting short term securities for those maturing in longer investment horizon. The purchasing power of the large investor could be used to buy a significant volume of such bonds, and by that means to influence the prices on the whole market. Nevertheless, Bernanke & Reinhart (2004) acknowledge that such strategy could be considered speculative and probably would not prove itself useful on its own, therefore in practice it would preferably be conducted in combination with another approach.

Lastly, an effective policy could be attained by expanding the central bank's balance sheet, a policy also known under the name of quantitative easing. The authors (Bernanke & Reinhart 2004, p. 88) describe the possible effects of extensive purchases of in following way:

> ...if money is an imperfect substitute for other financial assets, then large increases in the money supply will lead investors to seek to rebalance their portfolios, raising prices and reducing yields on alternative, non-money assets. In turn, lower yields on long-term assets will stimulate economic activity.

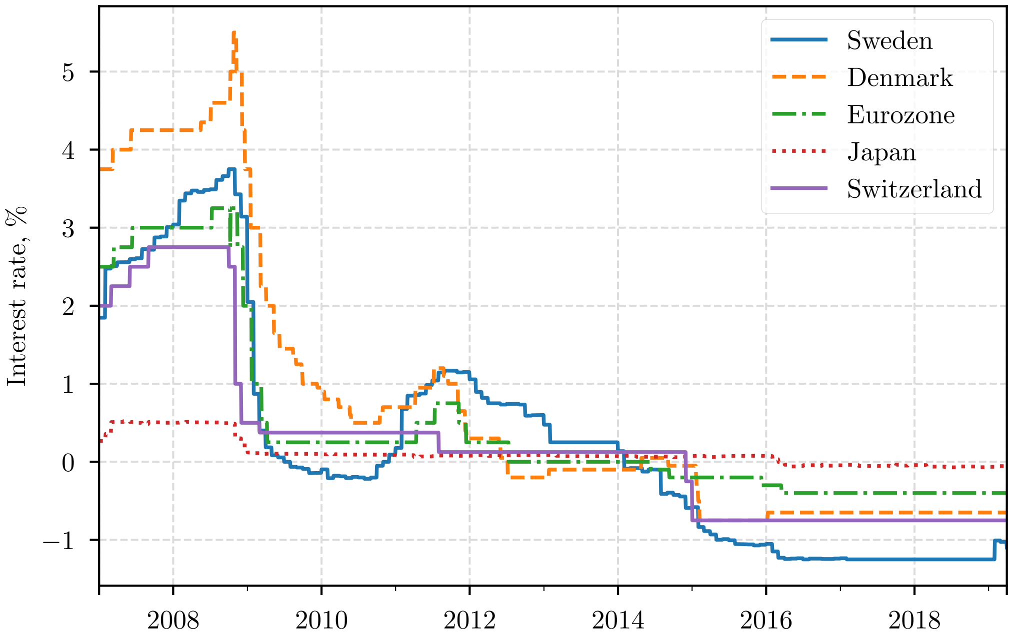
Other favorable outcomes with quantitative easing can be achieved by expectations of proclaimed targets, or if the policy is executed intensively, it also can have an expansionary fiscal effect.

3.3 ZLB after the financial crisis

The development of deposit rates after the global financial crisis of 2007–2008 in selected economies of interest is shown in 3.1. The ECB, SR, and BoJ responded promptly to the crisis by lowering their interest rates close to zero bounds, by the end of 2009 all of the central banks kept the rates below 0.25%. DN reacted to the ECB's first decision with a delay of approximately one year window and then after 2012 keeping relatively on the same level as the ECB rate.

The ECB first broke down the zero barrier in June 2014, when the bank set the deposit facility rate to –0.1%. From this moment onward, the bank kept lowering the rate to have it as low as –0.4% in March 2016. DN outran the move of the ECB in Europe by setting the market deposit rate at –0.2% in 2012. The DN then moved the deposit rate above the zero level, only to lower

Figure 3.1: Monetary policy interest rates for countries with negative interest rates, 2006Q4–2019Q1, a mix of available data granularity



Source: Reporting and data of respective countries' national banks, collected by author

it below zero again in September 2014. The SR went first negative in February 2018, decreasing the repurchasing rate to −0.1%. Unlike the before mentioned national banks, the SNB started to charge −0.25% interest rate only on the part of bank deposits, which exceed the predetermined threshold. In Japan, the BoJ imposed a negative interest rate of −0.1% on deposits in January 2016.[5]

As Williams *et al.* (2016) argue, this state is likely to prevail in the next years. As Kiley & Roberts (2017) point out, while the mean nominal funds rate in the US—from years 1960 until 2007—was equal to approximately 6%, the new steady-state nominal interest since 2007 is probably considerably lower at around 3% rate, and the similar development can also be observed in Japan and Europe.

[5]For further discussion of development see Bech & Malkhozov (2016) describing the situation in Europe and Arteta *et al.* (2016) providing the overview of negative interest rate policies both in Europe and Japan.

3.4 Bank business models

As noted in the previous section, accounting for the bank-specific factors (bank heterogeneity) is an integral part of the correct specification of the models. When analyzing the data-set of banks, these factors are advised to be included to avoid the omitted variable as a potential source of endogeneity. When examining the riskiness of the banks, the size of the banks plays an important role in its assessment. Small banks react differently to stressful situations as opposed to mid-sized and large banks. However, the relationship between bank size and profitability (or risk taking) is inconclusive in literature as Bikker & Vervliet (2018) argue. While larger banks might benefit from economies of scale, they can be at the same time less cost-effective due to the increased costs of the less efficient corporate structure.

Size can be approximated by total assets (or its log-transformation), as used by Kashyap & Stein (1995) or Borio *et al.* (2017). In econometric model size can be treated in different ways—bank size can be treated categorically (for example as mentioned above: by dividing banks by sizes into categories of small, medium and big large sized) or continuously by including the (transformed) variable in the model. The advantage of the first method is a more straightforward explanation of the outcome effects.

Another possible source of bank heterogeneity is the difference in the business model of the banks. For example, source of the risk in retail banks varies significantly from the risk faced by investment banks. Literature deals with heterogeneity arising from business model diversity in various ways: Researchers can choose to include proxy variables (such as liquidity ratios or capitalization ratios, see Altunbas *et al.* (2012)) or by dividing the banks into categories according to their subject of business.

Nucera, Lucas, Schaumburg, & Schwaab (2017) propose classification into six business models: (i) large Universal banks, (ii) corporate and wholesale banks, (iii) fee focused banks, (iv) small lending banks, (v) domestic lenders and (vi) saving orientated banks, where each of the business models is characterized with its distinctive features measured using financial ratios. Ayadi, Arbak, & De Groen (2011) estimate that in European banks can be likely distributed in for clusters as (i) wholesale banks, (ii) investment banks, (iii) focused retail banks and (iv) diversified retail banks. Altunbas *et al.* (2012) distinguish three institutional categories: (i) limited companies, (ii) mutual banks and (iii) cooperative banks.

When the characterization is inconclusive (either a bank would fall into more than one category, or none of the criteria would fit), Lucas, Schaumburg, & Schwaab (2018) or Ayadi *et al.* (2011) suggest using clustering methods to identify the outliers.

3.5 Capital structure of banks

In Mejstřík *et al.* (2015) four different types of banks' capital are described as follows:

- accounting capital
- market capitalization
- economic capital
- regulatory capital

The first type of capital follows accounting principles, wherein double-entry bookkeeping the following must hold:

$$Capital = Assets - Liabilities \tag{3.1}$$

Market capitalization is relevant for publicly traded banks. Therefore, given its nature, it is highly volatile and can often change in time as the market responds to the events in the company or external events. The value is equal to the stock price multiplied by a number of issued stocks.

The concept of economic capital is then connected to the treatment of unexpected losses. Whereas the expected losses stemming from the credit risk are covered by loan provisions, the unanticipated losses are covered by economic capital (Mejstřík *et al.* 2015). It is closely related to the accounting capital—when an event of unexpected default would occur, the decline in value of assets will be proportional to the decrease in capital.

Regulatory capital under the Basel Accords[6] is then composed of the following graded components:

- Tier 1 capital: The high-quality capital mostly consisting of shareholder's equity and retained earnings. This type of capital is meant to be able to fully absorb potential losses from the regular operations of the banks (Hannoun 2010).

[6] The term Basel Accords refers to three banking regulations known as Basel I, Basel II and Basel III issued by the Basel Committee on Banking Supervision headquartered within the Bank for the International Settlements. Basel Accords represent a globally applicable regulatory framework, which then can be adopted by governments and central banks.

- Tier 2 capital: Comprises primarily from subordinated debt, revaluation reserves, or hybrid capital instruments. Tier 2 capital is constructed to cover losses on a "gone-concern" basis (Hannoun 2010) in cases of bankruptcy or liquidation.

- Tier 3 capital: This type of capital is not used in the current regulation framework; the Tier 3 capital was mainly targeted at covering market risks (Mejstřík *et al.* 2015).

Modigliani & Miller (1958) theorized that the value of a bank (or any company in general) is indifferent from the proportion of financing—under the assumption of efficient markets, no taxes in the economy and no transaction costs. However, these assumptions are not satisfied in the real economy. Therefore, there should exist an optimal value of capital that maximizes the value of the bank depending on other factors such as deposit insurance, cost of capital vs. the cost of external financing, et cetera. (Mejstřík *et al.* 2015). Thus, banks' shareholders have a motivation to seek for the optimal level of leverage that might be different from the optimal level of leverage perceived by the regulator.

Chapter 4

Methodological background

4.1 Selected credit risk measures

This section covers selected credit risk measures important to this thesis, as their sensitiveness to the deposit interest rate is the main focus of the empirical part of this thesis.

4.1.1 Non-performing loans ratio

As an NPL is generally considered any credit, that is in overdue. However, the time after the loan is considered overdue can vary, typically it is defined to be 90 days (Mejstřík *et al.* 2015). The ratio is then expressed as the total amount of overdue loans to the total amount of gross loans.

$$NPLRatio_t = \frac{Non\text{-}performingLoans_t}{TotalGrossLoans_t} \tag{4.1}$$

where t is a time index representing annual data observations of the given year-end, where years $t = (2011, \ldots, 2017)$. This thesis relies on the data on the NPL as provided by the BankScope database.

Since the amount NPL is a stock variable in accounting, the next year's amount is likely to be driven by the current level. This is also given by the fact that NPL not collected in the current year and not written off are then carried on to the next financial year. Therefore, we expect the NPL ratio in the models to be partially explained by its previous realizations.

4.1.2 Risk weighted assets and risk weighted assets density

The RWA is a term first denoted in Basel I accords in 1988 by the Basel Committee on Banking Supervision. Its purpose is to break down banks' assets and weigh them on their riskiness. The calculation is shown in Equation 4.2 (Mejstřík *et al.* 2015):

$$RWA_t = \sum_{i=1}^{n} w^i Asset_t^i \tag{4.2}$$

where w^i is the corresponding weight for $Asset^i$. Under the current Basel Capital Accords, the banks themselves perform an independent assessment of riskiness of credit instruments. This is, however, a reason, why the RWA may become a target of criticism.

Le Leslé & Avramova (2012) or Dewatripont *et al.* (2010) mentioned numerous reasons why the concept of the RWA might need to be revisited, here we summarize the main points:

- From the regulator's point of view, banks can be incentivized to underestimate their risk to avoid larger capital requirements. Conservative banks can then lose competitive advantage as they face relatively stricter regulation and leave less conservative banks to gain market share.

- RWA rely on external ratings that correspond to the current economic cycle—in time of growth ratings can be too optimistic, and they can react to the crisis when it is too late. Therefore, the RWA may fail to warn ahead of the potential crisis.

- The internal calculation of RWA by individual banks can worsen comparability across banks and undermine the overall credibility as a credit risk measure.

- The calculation can be very complex; for large cross-border this can lead to an overall RWA figure being composed of RWA from its daughter companies in different countries.

Despite the abovementioned potential shortcomings, the RWA remains a key concept in bank regulation under the current effective Basel Accords. Nevertheless, the bank heterogeneity and cross-country effects are possible to be more pronounced than in the case of NPL ratio.

For the purpose of testing of Hypothesis #2, we then adopt a measure of riskiness as a ratio of risk weighted assets to the banks' total assets:

$$RWADensity_t = \frac{RWA_t}{TotalAssets_t} \tag{4.3}$$

At time t, we calculate it as RWA from Equation 4.2 over total assets. This allows us to conveniently compare bank of different sizes among each other and analyze the changes in riskiness over time. Nevertheless, the denomination by assets does not address all comparability concerns as discussed before.

4.1.3 Tier 1 capital ratio

The Tier 1 capital ratio[1] attempts to calculate how large portion of potential losses (measured by RWA) can be covered by the high-quality capital (Tier 1)—the minimum regulatory requirement for the Tier 1 capital ratio proposed by Basel III is 6%[2] (Basel Committee *et al.* 2017). It is calculated as follows:

$$Tier1Ratio_t = \frac{Tier1Capital_t}{RWA_t} \tag{4.4}$$

The relationship to the RWA density is inverse—assuming other things equal, with an increase of a level of the RWA, Tier 1 ratio decreases. Therefore, it also inherits the concerns about comparability across banks and countries. However, given that the RWA are only a part of the formula and Tier 1 ratio as a whole is watched closely by regulators with more attention, the ratio is expected to be more stable over time.

4.2 Model estimation methods

The basic framework to estimate panel data can be formulated as the following regression model:

$$y_{i,t} = \alpha + \boldsymbol{x}_{i,t}\beta + \mu_i + \nu_{i,t} \tag{4.5}$$

where $i = (1, \ldots, N)$ are individual groups, $t = (1, \ldots, T)$ represent time periods $y_{i,t}$ is explained variable, $\boldsymbol{x}_{i,t}$ is a matrix of regressors, μ_i is group-specific

[1] We also refer to Tier 1 capital ratio as Tier 1 ratio in following chapters

[2] Basel III further distinguishes between Tier 1 capital ratio and narrower Common Equity Tier 1 ratio, where capital comprises only of common equity and retained earnings, targeted at 4.5% (Basel Committee *et al.* 2017).

constant term and $\nu_{i,t} \sim i.i.d.N(0, \sigma_\epsilon^2)$ is a variable capturing exogenous shocks to the model.

Depending on the circumstances, Equation 4.5 can be estimated with different approaches. For example, if the $\boldsymbol{x}_{i,t}$ contains only exogenous variables and μ_i represents constant terms, one can use a pooled Ordinary least squares (OLS) regression. If the μ_i is unobserved and correlated with the $\boldsymbol{x}_{i,t}$, then a fixed effects estimator can be employed. However all time-invariant variables are eliminated with fixed effects. Alternatively, if the μ_i is uncorrelated with $\boldsymbol{x}_{i,t}$ and if we assume that these are effects similar to $\nu_{i,t}$ but invariant in time, a random effects approach can be used (Greene 2003).

The advantage of these methods is a simplicity in their formulation and calculation. Nevertheless, the assumptions they require to produce unbiased and efficient estimators are often violated with the financial data. Most importantly, these methods are static—they do not allow to unbiasedly estimate a model of the following form:

$$y_{i,t} = \alpha + \phi y_{i,t-1} + \boldsymbol{x}_{i,t}\beta + \mu_i + \nu_{i,t} \tag{4.6}$$

because now it does not hold that the μ_i is uncorrelated with the lagged $y_{i,t-1}$ term that is now endogenous to the model, which renders the before mentioned methods unusable for estimation of Equation 4.6. These issues were addressed by Arellano & Bond (1991) difference Generalized method of moments (GMM) estimator, which estimates the model using the first differences with lags of the dependent variables used as instruments, which also allows some of the regressors in $\boldsymbol{x}_{i,t}$ to be specified as endogenous.

Nevertheless, as Roodman (2009a) pointed out, the difference GMM method has a weakness in case there missing observations in the dataset, because if we have a particular $y_{i,t}$ missing from the sample, then we subsequently lose observations for $\Delta y_{i,t}$ and $\Delta y_{i,t+1}$ respectively.[3] Arellano & Bover (1995) and Blundell & Bond (1998) proposed another transformation of the data that instead of differencing the preceding observation uses averages of all future observations (not requiring the dataset to be perfectly balanced and using all observations available), this estimator is known as system GMM. This estimator also has other convenient properties over difference GMM—with differencing we might lose a portion of the information as some of our stock bank-specific

[3] Where $\Delta y_{i,t} = y_{i,t} - y_{i,t-1}$

variables can be almost invariant in time (Chaibi & Ftiti 2015), this would also cause problems with variables controlling for the bank heterogeneity.

System GMM as an estimation method is also used for example in Borio *et al.* (2017) or Chaibi & Ftiti (2015). In our empirical analysis, we use an implementation of the system GMM that was developed in Roodman (2018). We estimate the models with a collapsed matrix of instruments, which reduces the number of instruments.[4]

[4]The number of instruments in uncollapsed form is quadratic in T which can result in misleading results of specification tests, while collapsed form is linear in T. More details can be found in Roodman (2009a).

Chapter 5

Data for the empirical analysis

The thesis is using a panel data-set from the Bank Focus database, with a geographical scope limited to Denmark, Eurozone, Japan, Sweden, and Switzerland. The database combines the content from Bureau van Dijk and Moody's Investor and Analytics data. Overall, it covers more than 40 thousand institutions internationally.[1]

5.1 Data on banks

The dataset on banks consists of annually collected data from banks' balance sheets and income statements from a total of 23 countries,[2] with the majority of large Eurozone banks included in the dataset. A total number of 1,610 banks is included in the analysis — these include bank categorized as bank holdings & holding companies, commercial banks, cooperative banks, real estate & mortgage banks, and savings banks. In our dataset, we selected only those banks, that had available results both in 2011 and 2017 (the minimal and maximal year in the analysis respectively) and which had a minimum of 1 million USD in assets in those years (to exclude micro banks from the analysis).

The basic descriptive statistic of the banks' total assets can be found in Table 5.1. The banks per capita ratio differs significantly across countries, for example in Austria, there are 40 times more banks in the sample than in Spain,

[1]Visit www.bvdinfo.com/en-gb/our-products/data/international/bankfocus for a detailed overview of the used data source.

[2]All included countries listed alphabetically: Austria, Belgium, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Portugal, Slovakia, Slovenia, Spain, Sweden, and Switzerland. The list of countries used further in descriptive graphs and tables is also listed under Acronyms in the beginning of this thesis.

therefore even though Austria is a smaller country, it is important to note it will have more considerable weight on the results of the estimation in the analysis. Similar aspect can be observed for the bank size—while the third percentile of the total assets for the whole dataset is smaller than the mean value. Since the analysis in the next chapter is not weighted by assets, the dataset then might be biased towards smaller banks even though they might represent a smaller portion of total assets (the distribution of assets in the sample is also illustrated in Appendix in Figure B.1).

Table 5.1: Dataset description by assets in 2017 (billions USD), summarized by country

	N	Mean	Std.D.	p25	Median	p75	Total
AT	428	2.73	17.66	0.10	0.19	0.41	1,169
BE	17	80.56	124.18	1.22	4.80	182.08	1,369
CH	18	165.14	339.11	3.37	12.46	41.02	2,972
CY	5	7.95	11.80	1.43	1.51	8.21	39
DE	158	34.06	157.01	2.98	6.49	11.11	5,381
DK	33	39.18	107.94	1.03	2.54	12.95	1,293
EE	2	10.01	3.77	8.68	10.01	11.34	20
ES	10	386.16	533.65	64.66	171.06	411.03	3,861
FI	5	55.34	67.48	11.45	16.94	77.29	276
FR	53	283.72	565.74	12.80	28.01	200.94	15,036
GR	7	44.45	39.31	3.69	71.99	75.30	311
IE	5	64.97	58.79	22.14	27.32	108.01	324
IT	294	11.88	82.12	0.28	0.80	2.09	3,491
JP	484	45.48	240.98	1.10	2.88	10.18	22,013
LT	3	5.94	4.87	4.28	8.22	8.74	17
LU	27	11.34	16.74	0.45	3.82	14.73	306
LV	1	5.68	nan	5.68	5.68	5.68	5
MT	4	6.30	6.14	1.61	4.97	9.66	25
NL	23	153.27	321.62	4.91	16.40	36.24	3,525
PT	6	63.73	32.21	41.84	62.25	80.65	382
SE	15	97.46	117.29	11.30	50.78	138.25	1,461
SI	6	5.60	4.67	3.43	4.09	5.53	33
SK	6	6.67	7.77	1.03	3.00	12.31	40
All	1,610	39.35	199.75	0.31	1.41	7.65	63,360

Note: p25—first quartile; p75—third quartile; country codes are listed within Acronyms.

The following bank-related continuous variables are used in the empirical part:

- *NPL*: The ratio of non-performing loans to total gross loans for assessing assets quality, described in Subsection 4.1.1.
- *RWADensity*: Risk weighted assets to total assets ratio, described in Subsection 4.1.2.
- *Tier1Ratio*: Ratio of Tier 1 capital to risk weighted assets, described in Subsection 4.1.3.
- *log(Assets)*: Natural logarithm of total banks' assets, discussed in Section 3.4.
- *EquityToAssets*: Book equity to assets ratio for controlling for different levels of banks' leverage.
- *LoansToDeposits*: Ratio of customer loans to customer deposits as a proxy for the preference of riskiness for banks.
- *ROAE*: Return on average equity to control for the differences in banks' profitability
- *CostToIncome*: A ratio of operating expenses to operating income as a proxy of banks' efficiency.

In Table 5.2, we present descriptive statistic of the bank related variables. The panel dataset is unbalanced with some observations missing. All variables are relative to the size of banks (all variables if not noted otherwise are in percents) except for *log(Assets)*, for the reason that this particular logarithmic transformation of assets attempts to capture the effect of size of the banks in the models.

Table 5.2: Bank specific variables description, year 2017

	N	Mean	Std.D.	p25	p50	p75
NPL	1,104	7.00	7.60	1.95	4.37	9.16
RWADensity	646	49.74	16.79	39.69	50.45	60.50
Tier1Ratio	677	18.66	9.85	13.78	16.06	20.03
log(Assets)	1,610	14.43	2.27	12.65	14.16	15.85
EquityToAssets	1,609	9.50	7.12	5.82	8.28	11.48
LoansToDeposits	1,576	84.43	164.44	53.99	73.95	93.88
ROAE	1,609	3.31	19.20	1.95	3.52	5.85
CostToIncome	1,610	83.89	252.61	65.35	75.11	83.40

Dummy variables included in the empirical analysis are designed to capture the heterogeneity in the dataset. We distinguish between two categories of the bank-specific dummy variables. Firstly, we control for bank business models. The largest business model in the dataset are cooperative banks, accounting for 46.5% followed by savings banks with 25.8% of the total and the third largest category are commercial banks, covering 20.4% of the data. Secondly, we use variables for dummies to observe the effect of the banks' sizes. Table 5.3 summarizes these variables and shows in more detail their representation in the sample.

Table 5.3: Bank specific dummy variables description, year 2017

	Count	Share of total
HoldingBank	60	3.73%
CommercialBank	329	20.43%
CooperativeBank	749	46.52%
MortgageBank	57	3.54%
SavingsBank	415	25.78%
SmallBank	704	43.73%
LargeBank	190	11.80%

The following list explains the bank related dummy variables used in the estimation:

- *HoldingBank*: Equals 1 if the bank is classified in the BankScope database as *Bank holding & Holding company.*
- *CommercialBank*: Equals 1 if the bank is classified in the BankScope database as *Commercial banks.*
- *CooperativeBank*: Equals 1 if the bank is classified in the BankScope database as *Cooperative bank.*
- *MortgageBank*: Equals 1 if the bank is classified in the BankScope database as *Real Estate & Mortgage bank.*
- *SavingsBank*: Equals 1 if the bank is classified in the BankScope database as *Savings bank.*
- *SmallBank*: Equals 1 if the bank assets in the financial year 2017 were less than USD 1 billion.
- *LargeBank*: Equals 1 if the bank assets in the financial year 2017 were greater than USD 30 billion.

5.2 Macroeconomic data

Together with the bank-specific data we also use a set of the following macroeconomic variables for explaining our hypothesis:

- *Unemployment*: General unemployment rate for the country where the bank resides in percents. Data from the International Financial Statistics, International Monetary Fund (IFS IMF).
- *GDPGrowth*: Country-specific percentage change of the real gross domestic product in the percents. Data from the IFS IMF.
- *InterestRate3M*: 3M short term interbank rate. Data for Denmark, Japan, Sweden and Switzerland from the IFS IMF, data for Eurozone from Eurostat.
- *Slope*: Slope of the yield curve approximated by the difference between the yield of the 10-year government bond and 3-month interest interbank rate. Data for 10-year government bond for Denmark, Japan, Sweden, and Switzerland were obtained from the IFS IMF, data for Eurozone were acquired from Eurostat.
- *InflationChange*: Percentage change in consumer prices in respecting countries. Data from the IFS IMF.

All macroeconomic data we work within our analysis are in percentages. Descriptive summary of the macroeconomic variables is shown in Table 5.4. Our period, in contrast with the previous studies covered in the literature review, is characterized by low interest, low inflation, the depressed slope of the yield curve—in some cases even negative—and accompanied with a modest level of unemployment.

Table 5.4: Macroeconomic variables description, year 2017

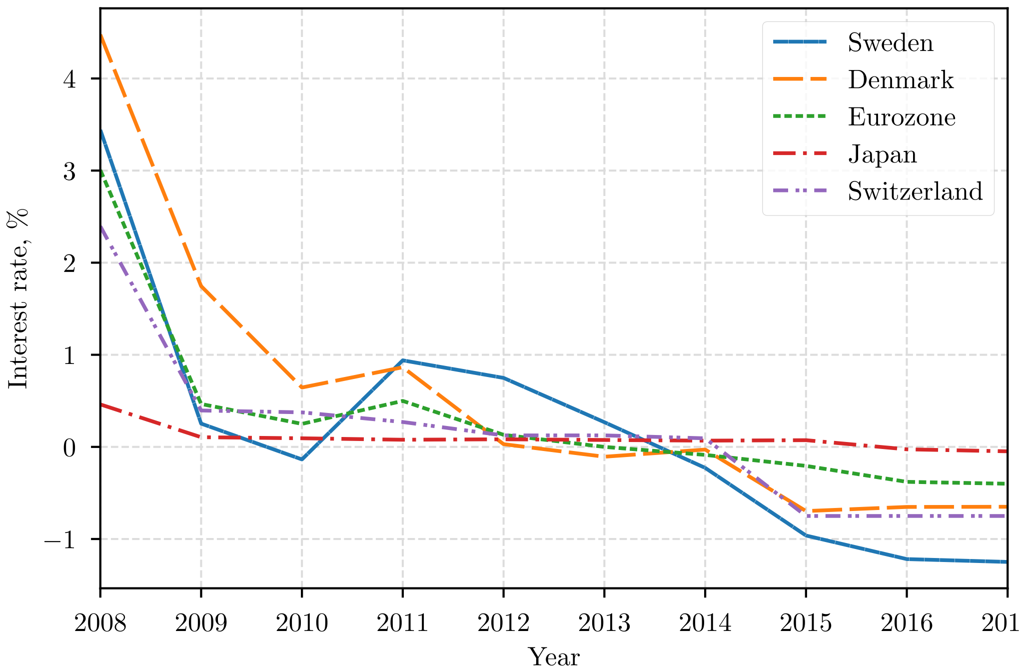
	N	Mean	Std.D.	p25	p50	p75
InterestRate3M	1,610	0.22	0.19	-0.33	-0.33	0.06
InflationChange	1,610	1.27	0.65	0.47	1.23	2.08
Slope	1,610	0.94	0.93	-0.01	0.91	1.14
Unemployment	1,610	5.90	3.33	2.81	5.52	7.10
GDPGrowth	1,610	2.14	0.58	1.93	1.93	2.55

For estimation of the effect of low interest rate environment and testing of our hypotheses, we employ dummy variables indicating whether the given country attained zero lower bound in the given year or the previous period. We constructed the following dummy variables:

- *MonIR.L0*: Equals 1 if the country crossed the zero lower bound in the current period (period $t = 0$, time window 2011–2017)
- *MonIR.L1*: First lag of the variable *MonIR.L0* (period $t = -1$, time window 2010–2016)
- *MonIR.L2*: Second lag of the variable *MonIR.L0* (period $t = -2$, time window 2009–2015)
- *MonIR.L3*: Third lag of the variable *MonIR.L0* (period $t = -3$, time window 2008–2014)

In the following Chapter 6, we refer to these variables with a notation *MonIR.L*λ, where λ is the number of lags this variable looks behind. For example, when $\lambda = 2$, the name of the variable would be *MonIR.L2*, and this would represent the second lag of the monetary interest rate dummy variable.

Figure 5.1: Monetary policy interest rates for countries with negative interest rates, 2008–2017, averaged by year



Source: Reporting and announcements of national banks of the respective countries.

The dummy variables are constructed using the dataset obtained from central banks shown in Figure 3.1 located in the previous chapter. However, for the purpose of the estimation, we use data grouped by the year and averaged as shown in Figure 5.1. We have decided to work with yearly averages as it is a common practice in financial accounting to average the terms that were a source of the year's ending balances. We also decided to suppress the effect of the one year period in 2010 in Sweden, where Swedish interest rate dropped below the zero lower bound after the global financial crisis 2007–2008. In view of the fact that we are mainly interested in the effects of a long term negative interest rate environment.

Chapter 6

Results and discussion

In this chapter, we are presenting results of the estimation and the main findings of the three hypotheses outlined by this thesis followed by a discussion of the outcomes.

6.1 Hypothesis #1: Influence of low interest rates on banks' Non-performing loans ratio

The full formulation of the first hypothesis is as follows:

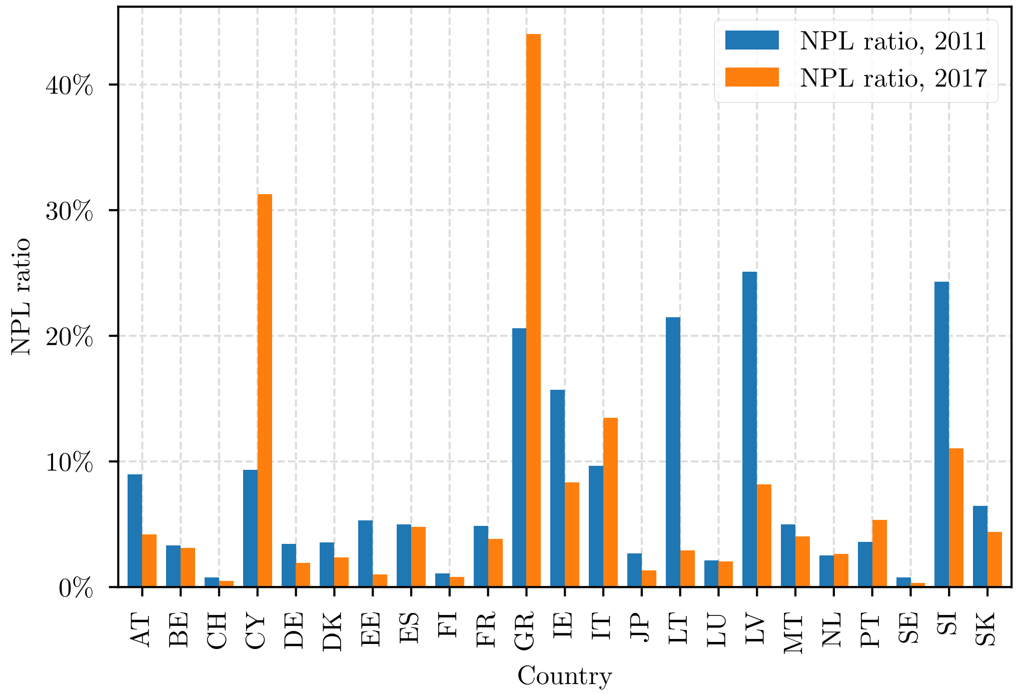
> Low-interest rate environment will influence the banks' Non-performing loans ratio after 1–3 years.

In this section, we are interested whether the monetary policy that might affect the strategy of banks (for example following Borio, Gambacorta, & Hofmann (2017)) can have an observable effect on the portfolio quality of assets. Lopez, Rose, & Spiegel (2018) while examining the determinants of the banks' profitability concluded that there might be observable changes in the interest income proportions, which is closely linked to the loans' portfolio. Therefore, we might expect that when the market conditions change and consequently the generation of the same level of profit as in the preceding years is more challenging, banks might tend to seek more risky positions in lending and the credit risk measures might worsen.

6.1.1 Descriptive analysis of non-performing loans

In Figure 6.1 we can compare the development of the NPL ratio (weighted by assets) from the year 2011 to 2017. The first look on the data suggests that in

Figure 6.1: Non-performing loans ratio, average by country, weighted by assets, 2011 and 2017



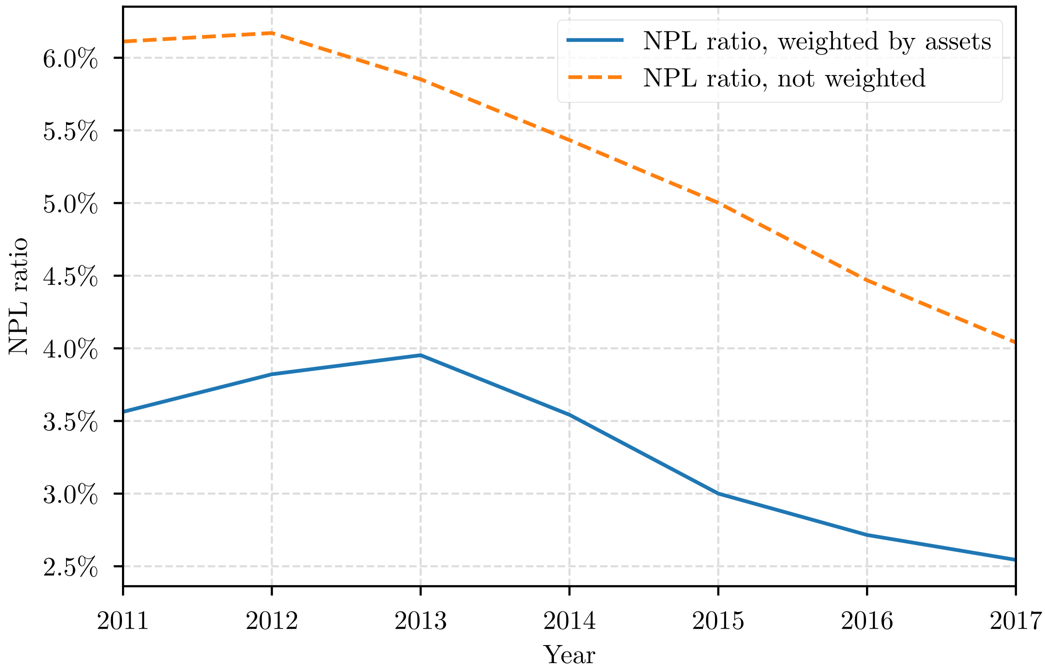
Note: Please refer to Table 6.1 to find the number of observations per country. Given the data availability, this Figure does not necessarily reflect the aggregated level of NPL in the portrayed countries.

Source: Author's computation, data from the BankScope database.

the majority of countries the trend after the global financial crisis was declining or stagnating. Nevertheless, there are few clear outliers such as Cyprus, Greece, Italy and possibly Portugal where the NPL accumulated over time. These countries coincide with those most severely affected by the sovereign debt crisis after 2009 (see for example Acharya *et al.* (2018) and De Marco (2019) for recent information on the topic).[1] Therefore, we further decided to exclude Cyprus, Greece, Italy, and Portugal from the analysis.

[1]The estimated models including all countries can be for completeness found in Appendix in Table A.4, however, the Hansen J test of overidentifying restrictions p-value suggests that the instruments included in the model are not specified correctly; there are also other warning signs, such as the significant sign-switching coefficient for the *InterestRate3M* variable. Furthemore, Appendix Figure B.2 can be directly compared to Figure 6.2; the trend of the NPL in the first is the opposite of the the trend in the latter. Additionally, the levels of NPL in terms of percentage points weighted by assets are more than three times larger than for the rest of the countries. Also, in the CY, GR, IT and PT larger banks show higher level of NPL than smaller banks, which is unusual for the rest of the countries. The highest impact has the exclusion of Italy from the dataset, considering that the Italy accounted for 18.3% of the initial sample.

Figure 6.2: Non-performing loans, average by year, excluding CY, GR, IT and PT, 2011–2017



Source: Author's computation, data from the BankScope database.

Level of the NPL can be observed in Figure 6.2. We present two series: NPL weighted by assets corresponds with the aggregated levels reported in regulatory reports[2] and, in comparison, an unweighted mean of NPL, which is a more accurate visualization for our analysis, as unweighted NPL is in fact estimated. The difference between these two—apart from the different level itself—shows that the smaller banks (represented by the unweighted NPL) on average peaked one year sooner than the weighted sample (illustrating more precisely the trend in the larger banks) and thus the need for controlling for the size and the bank business models in the estimation.

Table 6.1 presents the final distribution of countries in the estimation. Compared to Table 5.1, we have a not trivial portion of NPL observations missing in our data. Therefore, Japanese banks cover more than half of the usable sample, followed by German banks accounting for 17.1% and France, covering 6.2%. These countries will thus have the largest impact on the outcomes.

[2]However, please note that our dataset and correspondingly Figure 6.2 only includes data on NPL which are available on the bank level.

Table 6.1: Non-performing loans, observations in 2015, in percents, summarized by country

	N	of total N	Mean	Median
AT	23	2.8%	7.10	5.41
BE	10	1.2%	3.82	2.65
CH	14	1.7%	1.89	0.69
DE	141	17.1%	2.54	2.12
DK	31	3.8%	13.82	10.89
EE	2	0.2%	1.27	1.27
ES	10	1.2%	8.10	8.63
FI	4	0.5%	1.33	1.25
FR	51	6.2%	3.92	3.16
IE	5	0.6%	15.20	14.17
JP	473	57.5%	5.05	4.46
LT	3	0.4%	8.85	8.48
LU	11	1.3%	2.10	1.17
LV	1	0.1%	14.43	14.43
MT	2	0.2%	4.94	4.94
NL	17	2.1%	7.33	3.23
SE	13	1.6%	0.20	0.12
SI	6	0.7%	17.43	17.09
SK	6	0.7%	7.16	5.86
All	823	100.0%	5.00	3.57

6.1.2 Model estimation results

For testing of the first hypothesis, we estimate the following model:

$$\begin{aligned} NPL_{i,t} = \alpha + \phi NPL_{i,t-1} + \theta MonIR.L\lambda_{i,t} \\ + \rho_1 InterestRate3M_{i,t} + \rho_2 InterestRate3M_{i,t-1} \\ + \boldsymbol{x}_{i,t}\beta + \mu_i + \nu_{i,t} \end{aligned} \tag{6.1}$$

where the $NPL_{i,t}$ is the explained variable and on the right side we include constant α, first lag of NPL as $NPL_{i,t-1}$ and $MonIR.L\lambda_{i,t}$ is a dummy variable indicating whether the given observation attained zero lower bound in that period lagged of λ periods (where we estimate variants for $\lambda = (0, 1, 2, 3)$). Variables $InterestRate3M_{i,t}$ and $InterestRate3M_{i,t-1}$ control for the effect of the interbank interest rate and its lag, $\boldsymbol{x}_{i,t}$ is a matrix of other variables, ϕ, θ, ρ_1, ρ_2 β are coefficients of variables and finally μ_i is an error term of fixed components and $\nu_{i,t}$ error term of exogenous shocks.

The variable selection is based on the literature review, and in our final presented model, we use variables which are believed to have an impact on the explained variable. The impacts of the variables included in the model are summarized in Table 6.2 for bank specific parameters and in Table 6.3 for macroeconomic variables.

Table 6.2: Expected effect of the bank-specific and bank dummy variables explaining non-performing loans

Variable (sign)	Description
EquityToAssets (−)	Highly leveraged banks generally need a higher income to cover costs of debt; thus we expect the relationship to be negative. This variable is treated as endogenous.
LoansToDeposits (+)	We use this variable as a proxy for riskiness—how the banks' are willful to lend (Dimitrios *et al.* 2016). We hypothesize that higher levels of the loans to deposits ratio will lead to higher levels of NPL; treated as endogenous.
log(Assets) (−)	We expect NPL to decrease with the size of the banks as larger banks might be more efficient than smaller banks. This variable is treated as exogenous to the model.
CooperativeBank (−)	In the European context, cooperative banks can be considered to be a stable institution (Kuc & Teplý 2018), we expect this group to have lower NPL compared to other bank types.
MortgageBank (−)	A higher share of collateralized housing loans should also result in a smaller level of NPL.
SmallBank (+)	We predict that the group of smaller banks will have a higher amount of NPL compared to the base group because they cannot utilize the concept of economies of scale.

The estimation of Equation 6.1 using the two-step system GMM results is shown in Table 6.4; different columns display different lags of the $MonIR.L\lambda$. Table 6.5 presents the same estimated models with two-step system GMM results with errors robust to heteroskedasticity and autocorrelation. The estimated coefficients of the *EquityToAssets* and *LoansToDeposits* are aligned with our expectations; however, neither coefficient is significant in the robust form of estimation.

We have confirmed, that group of Cooperative banks on average has lower NPL. For the estimated model in the second column, this holds even in the robust specification. Similarly, the coefficient for real estate & mortgage banks

Table 6.3: Expected effect of the macroeconomic variables explaining non-performing loans

Variable (sign)	Description
InterestRate3M (+/−)	The immediate effect of the interbank interest rate can be negative or positive.
Slope (+)	For the slope of the yield curve, we expect a positive relationship with the NPL. Higher differences between the long term and short term yield might indicate a structural problem in the economy.
InflationChange (+/−)	Negative or positive impact — inflation either above or below inflation target can be harmful to the economy. However, the effect of inflation on NPL can be twofold: On the one hand, if the inflation is high and real wages remain unchanged, the value of the outstanding debt would decrease, then a negative effect can be expected; however, on the other hand, if the wages do not sustain the level with inflation, the effect can be positive.
GDPGrowth (−)	Negative effect on the NPL is expected — declining economy might imply worsening of assets quality in the economy. Including GDP in the model allows us to control for the economic cycle.
Unemployment (+)	Higher unemployment could theoretically transform in the deteriorating ability of customers to repay loans. It can have a direct effect on households, which will have a lower cash inflow and generally would consume fewer products. Therefore, it would also affect the firms, because their income would be affected as well.
$MonIR\_L\lambda$ (+)	We hypothesize the effect to be positive — during a low interest rate environment, banks might try to pursue riskier positions.

is significant and of similar size, even though we cannot confirm this in the robust form. We also find that smaller banks have on average lower higher NPL, which is also captured with the continuous logarithm of banks' assets, however, this effect is only marginally significant for some models and only in non-robust estimates.

The immediate effect of the interbank interest rate is negative; the NPL increases when the interest rate decreases. This effect is however corrected with the first lag of the *InterestRate3M* variable, where after the next year the effect is the opposite and smaller in size. Nevertheless, this effect is only significant in the non-robust version. We found a negative connection between

Table 6.4: Non-performing loans estimation results, two-step system GMM, excluding CY, GR, IT and PT

	(1) NPL	(2) NPL	(3) NPL	(4) NPL
L.NPL	0.998***	0.988***	0.994***	0.994***
EquityToAssets	-0.0551	-0.125***	-0.0177	-0.0446
LoansToDeposits	0.0000353	0.0000431	0.0000425	0.0000368
CooperativeBank	-0.0977	-0.158**	-0.0370	-0.0872
MortgageBank	-0.195*	-0.411***	-0.139	-0.185*
SmallBank	0.171*	0.209*	0.136	0.148
log(Assets)	0.00451	-0.0338	0.0225	0.00393
InterestRate3M	-0.583**	-0.718**	-0.562	-0.654*
L.InterestRate3M	0.378**	0.575***	0.418*	0.405**
InflationChange	-0.107***	-0.118***	-0.116***	-0.111***
GDPGrowth	-0.279***	-0.301***	-0.286***	-0.274***
Slope	0.534***	0.718***	0.471***	0.498***
Unemployment	-0.0605***	-0.0894***	-0.0566***	-0.0537***
MonIR.L0	0.0342			
MonIR.L1		0.356***		
MonIR.L2			0.00558	
MonIR.L3				-0.0236
Constant	0.464	1.503*	-0.0464	0.431
Observations	4610	4610	4610	4610
Instruments	32	32	32	32
Number of groups	827	827	827	827
Observations per group	6	6	6	6
Wald statistic p-value	0.0000	0.0000	0.0000	0.0000
A-B AR(1) p-value	0.0049	0.0051	0.0050	0.0051
A-B AR(2) p-value	0.1864	0.1740	0.1988	0.1922
Hansen J p-value	0.0021	0.1073	0.0022	0.0029

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

NPL and inflation. Hence, it is likely that inflation on average might decrease the value of borrowed assets.

The coefficients for the GDP growth and the slope of the yield curve both appear to be significant—*GDPGrowth* has a negative effect as expected, thus with the increase in the output of an economy, the level of NPL decreases, while *Slope* has a positive relationship with NPL. This outcome is in line with our expectations. Nevertheless, we discovered a negative relationship between unemployment with NPL. This is in contrary to our expectations, and the result is significant even in Table 6.5 displaying results with robust statistics.

Table 6.5: Non-performing loans estimation results, two-step system GMM with robust errors, excluding CY, GR, IT and PT

	(1) NPL	(2) NPL	(3) NPL	(4) NPL
L.NPL	0.998***	0.988***	0.994***	0.994***
EquityToAssets	-0.0551	-0.125	-0.0177	-0.0446
LoansToDeposits	0.0000353	0.0000431	0.0000425	0.0000368
CooperativeBank	-0.0977	-0.158	-0.0370	-0.0872
MortgageBank	-0.195	-0.411	-0.139	-0.185
SmallBank	0.171	0.209	0.136	0.148
log(Assets)	0.00451	-0.0338	0.0225	0.00393
InterestRate3M	-0.583	-0.718	-0.562	-0.654
L.InterestRate3M	0.378	0.575	0.418	0.405
InflationChange	-0.107**	-0.118***	-0.116***	-0.111***
GDPGrowth	-0.279***	-0.301***	-0.286***	-0.274***
Slope	0.534**	0.718***	0.471	0.498*
Unemployment	-0.0605*	-0.0894***	-0.0566*	-0.0537*
MonIR.L0	0.0342			
MonIR.L1		0.356**		
MonIR.L2			0.00558	
MonIR.L3				-0.0236
Constant	0.464	1.503	-0.0464	0.431
Observations	4610	4610	4610	4610
Obs. per group	6	6	6	6
Number of groups	827	827	827	827
Instruments	32	32	32	32
Wald statistic p-value	0.0000	0.0000	0.0000	0.0000
A-B AR(1) p-value	0.0055	0.0057	0.0061	0.0061
A-B AR(2) p-value	0.1869	0.1747	0.1995	0.1930
Hansen J p-value	0.0021	0.1073	0.0022	0.0029

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Finally, we found only the model in the second column with the lag of the dummy variable controlling for the negative interest rate environment both in Table 6.4 and Table 6.5 to have a significant coefficient. Consequently, if for any lag we can claim to have a significant effect, it would be the first lag signifying the one-year latency, provided the models are correctly specified.

The p-value for Wald statistic for all models suggests that our overall results are significant. In our models we have a total number of 827 instrumented by 31 variables; thus the effects of instrument proliferation should not cause complications.[3] The Arellano-Bond tests for autocorrelation indicate the significance of the order one autocorrelation and insignificance of the order two. Therefore, we can argue, that the specification of the models including the first lag of the dependent variable is not unsuitable.

However, only for the models in second columns (estimating the possible effects *MonIR.L1*) we can not reject (on 10% level) the null hypothesis of the Hansen J test that the instruments are exogenous. On top of that, even with the p-value of 0.136, we need to be cautious about interpreting the instruments as correctly specified, as Roodman (2009b) notes, p-values around 0.4 are generally agreed to be reliable. We also provide another test if our estimates are close to the true values. Roodman (2009a) argues that an estimate of the lagged dependent variable should lie between the estimate of the pooled OLS estimate (which suffers from the upward bias) and fixed effect estimate (suffering from downward bias). Nevertheless, our result show, that the value of the estimated parameter for the system GMM is likely to be higher or equal to the value of the OLS estimate (details can be found in Appendix in Table A.5).

Last but not least, we try to asses the robustness of the model by estimating modified models that include the *MonIR.L1* variable; non-robust results can be found in Table 6.6. Most notably the variation in column 2 significantly improves the p-value of the Hansen J statistic, however on the expense of decreasing the interpretability of our hypotheses where we estimate the effects on NPL without *InterestRate3M* and its lag. Nevertheless, even two other variations confirm the stability of our results, when the significance and direction of the estimated coefficients do not change. On the other hand, the estimated lagged coefficient of the NPL still shows high persistence, as the estimated value is only marginally lower than 1.

The model in column 4 of Table 6.6 also shows an alternative, where we include all available dummy bank-related variables. The effect of the *ln(Assets)* deteriorates, nonetheless, other bank types are not significant, and *ln(Assets)* most likely captures the size effect more effectively than the inclusion of dummy variable both for small banks and large banks.

Similarly, to other studies, we also estimated a model including the variable for return on average assets. This model can be found in column 5 of Table 6.6. However, in our case, we have found the coefficient only marginally

[3]To the authors' best knowledge there is however no clear rule on how to determine the optimal number of instruments, but generally, the problem arises when the number of instruments is close to the number of groups.

Table 6.6: Non-performing loans estimation, alternative models, two-step system GMM, excluding CY, GR, IT and PT

	(1) NPL	(2) NPL	(3) NPL	(4) NPL	(5) NPL
L.NPL	0.943***	0.983***	0.954***	0.988***	0.892***
EquityToAssets	-0.105***	-0.175***	-0.220***	-0.177***	-0.123**
LoansToDeposits	0.0000311*	0.0000536**	0.0000311*	0.0000427*	0.0000836***
ROAE					-0.0102*
Constant	1.467*	2.872**	3.375***	2.658*	2.899***
HoldingBank				0.203	
CommercialBank				-0.141	
CooperativeBank	-0.200*	-0.279***		-0.373**	-0.168*
MortgageBank	-0.215***	-0.493***		-0.563***	-0.468***
SmallBank	0.129	0.157		0.212*	0.0854
LargeBank				-0.137	
log(Assets)	-0.0523	-0.0885*	-0.128***	-0.0720	-0.0985**
InterestRate3M	-0.323*			-0.759**	-0.0840*
L.InterestRate3M	0.253*			0.614***	0.104
InflationChange	-0.0769***	-0.127***	-0.0898***	-0.107***	-0.119***
GDPGrowth	-0.297***	-0.304***	-0.274***	-0.294***	-0.235***
Slope	0.498***	0.909***	0.755***	0.877***	0.911***
Unemployment		-0.0934***		-0.0793***	-0.0764***
MonIR.L1	0.267***	0.364***	0.355***	0.335***	0.160**
Observations	4610	4610	4610	4610	4610
Instruments	31	30	26	35	39
Number of groups	827	827	827	827	827
Obs. per group	6	6	6	6	6
Wald st. p-value	0.0000	0.0000	0.0000	0.0000	0.0000
A-B AR(1) p-value	0.0053	0.0054	0.0058	0.0054	0.0051
A-B AR(2) p-value	0.1859	0.1823	0.1823	0.1776	0.2034
Hansen J p-value	0.0100	0.5964	0.3725	0.1859	0.0532

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

significant, and it further shifts Hansen J p-value to rejecting the hypothesis of exogeneity of instruments. Hence, we believe, that the specification in Table 6.4 is a possibly superior choice in describing our dataset.

6.1.3 Summary and discussion

In the previous subsection, we have shown a significant relationship between low interest environment delayed by one year, although weakened in terms of model specification. Table 6.7 compares the results of our findings to other studies. Coefficients of the lagged variable on NPL is always positive and also in the range between 0 and 1. However, our estimations are above of those of other authors; hence our outcomes show higher persistence in the data.

The solvency ratio *EquityToAssets* in our estimations has different sign than what Radivojevic *et al.* (2017) found while examining emerging countries and Ghosh (2015) focusing on the United States sample. Nevertheless, we agree with the results of Chaibi & Ftiti (2015) exploring French and German banks and with results of Ahmad & Ariff (2007) in Japan, Mexico, and Thailand.

Table 6.7: Summary of NPL estimation results

Variable	This thesis	Aligned	Against
L.NPL	+ [+]	+ Chaibi & Ftiti (2015) + Radivojevic *et al.* (2017) + Dimitrios *et al.* (2016) + Ghosh (2015)	/
EquityToAssets	− [**0**]	− Chaibi & Ftiti (2015) −/**0** Ahmad & Ariff (2007)	+Radivojevic *et al.* (2017) + Ghosh (2015)
LoansToDeposits	+ [**0**]	+/**0** Ahmad & Ariff (2007) **0** Dimitrios *et al.* (2016)	/
CooperativeBank	− [−]	/	/
MortgageBank	− [**0**]	/	/
InterestRate3M*	− [**0**]	**0** Ghosh (2015)	+ Chaibi & Ftiti (2015)
InflationChange	− [−]	−/**0** Dimitrios *et al.* (2016)	+ Radivojevic + Chaibi & Ftiti (2015) + Ghosh (2015)
log(Assets)	**0** [**0**]	−/**0** Ahmad & Ariff (2007) **0** Ghosh (2015)	+ Chaibi & Ftiti (2015)
GDPGrowth	− [−]	− Chaibi & Ftiti (2015) − Radivojevic *et al.* (2017) −/**0** Dimitrios *et al.* (2016) − Ghosh (2015)	/
Unemployment	− [−]	/	+ Chaibi & Ftiti (2015) + Radivojevic *et al.* (2017) + Dimitrios *et al.* (2016) + Ghosh (2015)
MorIR.L1	+ [+]	/	/

+: significant positive relationship; −: significant negative; **0**: insignificant result;
[ ]: robust result; −/**0** or +/**0**: significant only in some specifications
Note: if the cell is empty, authors did not use this explanatory variable;
* here we omit the lag of this variable, because its effect is smaller.

Chaibi & Ftiti (2015) detected a significant positive relationship with the interest rate variable. They argue that an increase in an interest rate can transform into an increase in a debt burden and thus have a positive effect on the NPL. However, their period of interest (2005–2011) was not that affected by an ultra-low interest rate environment.

We also found an opposite effect of inflation than most of the authors did. Nevertheless, as we argued before, we can expect inflation to have an impact in both directions. All studies tend to agree on the negative effect of the GDP growth on the NPL. On the other hand, our estimates of unemployment are the exact opposite of what other authors estimated, and they are neither aligned with our expectations. This outcome might be possibly related to the situation after the financial crisis—this estimate could be improved by future study when more data is available. Our analysis shows that exclusion of the *Unemployment* variable from the model does not affect the significance of other coefficients.

We do not reject Hypothesis #1: Low-interest rate environment will influence the banks' Non-performing loans ratio after 1–3 years—we discovered that after 1 year of the below zero monetary interest rate, the level of NPL ratio might increase. Additionally, we observed a (non-robust) self-correcting effect of the interbank interest rate, wherein the current year the effect is positive, and the effect of the previous year is negative and with a marginally smaller size compared to the current year.

In our thesis, we estimated a complex dynamic model with a relatively high number of variables. Therefore, we contributed to the research by analyzing the bank heterogeneity controlling for banks' business models, where we found only a dummy variable for mortgage banks to have a marginal effect and rejected a cooperative bank dummy variable as a determinant of the NPL ratio.

To improve the estimates, one could also try to include variables controlling for different policy regimes in different countries as suggested by some authors. However, this is beyond the scope of this thesis. The results could also be improved when more data become available. Specifically, to study the low interest rate environment, it would be interesting to attempt to replicate the results after the interest rates increase.

6.2 Hypothesis #2: Influence of low interest rates on risk weighted assets to total assets ratio

In this section, we investigate the effects of the low interest rates on the RWA denominated to total assets, also known as RWA density.[4] In detail, we are interested in the following hypotheses:

> Hypothesis #2: Low-interest rate environment will influence the banks' Risk-Weighted Assets / Total Assets ratio after 1–3 years.

We follow a similar framework as in the previous section. However, instead of non-performing loans denominated to total loans, we are now interested in a broader ratio covering the whole balance sheet (and including off-balance sheet assets as well) credit risk measure, denominated to total bank's assets. As previously shown in Subsection 4.1.2, from the definition of the RWA density it is evident that the riskier the underlying asset is the higher is the weight of the asset in the calculation. Thus, assuming all other things equal, a bank with riskier assets will have the RWA density higher compared to another bank holding less riskier assets.

6.2.1 Descriptive analysis of risk weighted assets density

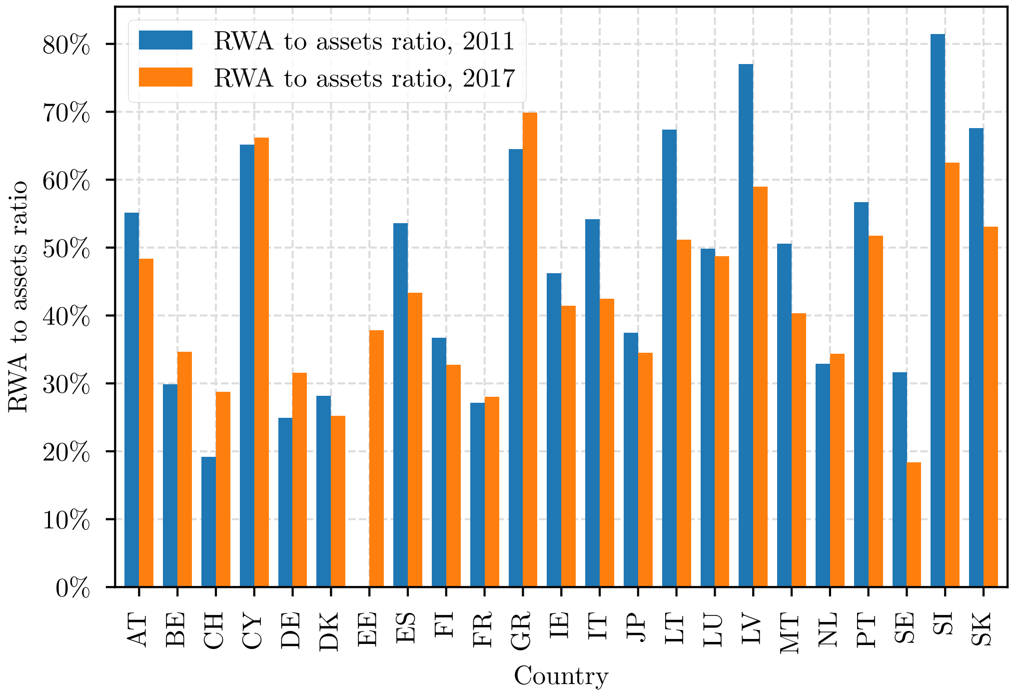
We start this section with Figure 6.3, displaying the different levels of RWA density across countries and its development over time, comparing the years 2011 and 2017. We can again observe the outlying countries identified in the previous section: Greek and Cypriot banks increasing its RWA density over time and relatively high level of asset-weighted RWA density in Italy and Portugal. Therefore, we continue our estimation of RWA density without the beforementioned countries. As we discussed in the previous Section 6.1, these countries were most severely hit by the sovereign debt crisis throughout after the 2009, and the development of the banking sector is closely tied with performance of the sovereigns. The estimated model might thus suffer a bias from the different development in these countries.

We can also see relatively high levels in the Central and Eastern European countries[5]. However, this is explained by the Figure B.4 in Appendix: The relationship between RWA density and log-transformed total assets is downward

[4]Please note that we use these terms throughout the work interchangeably.

[5]The Central and Eastern Europe in this thesis considers following Eurozone member countries: Estonia, Lithuania, Latvia, Slovenia and Slovakia

Figure 6.3: Risk weighted assets to total assets, average by country, weighted by assets, 2011 and 2017



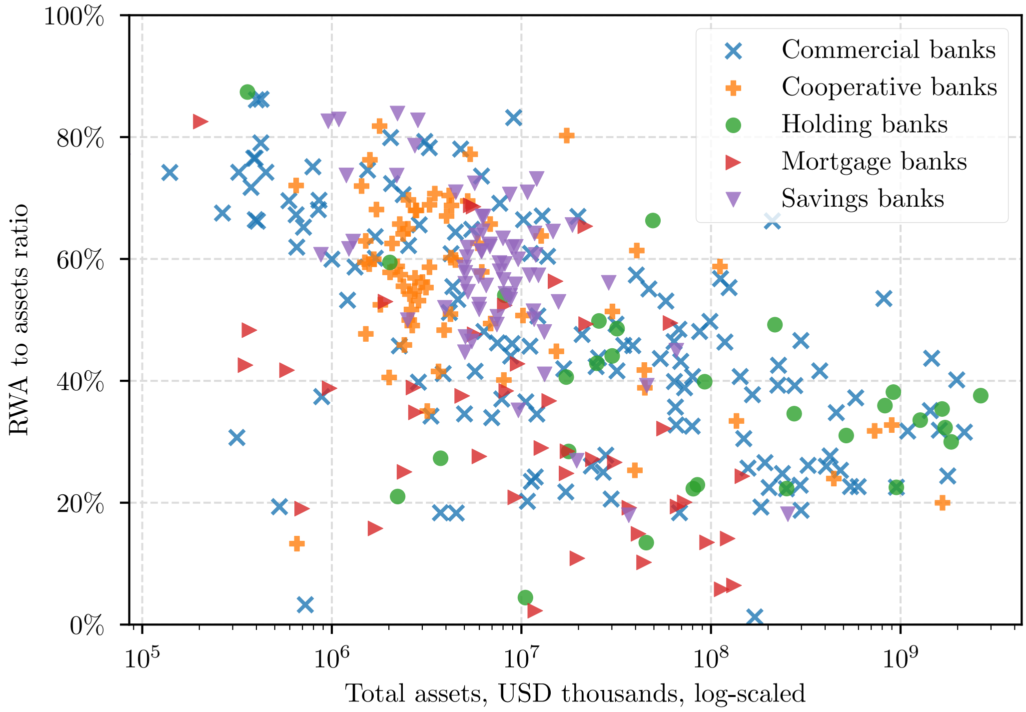
Source: Author's computation, data from the BankScope database.
Note: Please refer to Table 6.8 to find the number of observations per country. Given the data availability, this Figure does not necessarily reflect the aggregated level of NPL in the given country.

sloping, and most banks in these countries included in the dataset are relatively smaller than banks in larger countries (the weighting by assets also makes this more apparent, combined with the small number of observable banks in these countries). Then the smaller countries on average have a higher level of the RWA density compared to the larger countries, assuming that the average size of the banks will be greater in the latter group. Thus, we also expect the *ln(Assets)* parameter to have larger effect than in Section 6.1.

Additionally, the difference between smaller and larger banks is also captured in Appendix in Figure B.3, where the unweighted ratio series is almost twice the size compared to the weighted RWA density series, where the larger bank (in terms of assets) have a higher weight.

Figure 6.4 emphasizes the effect of the bank types on the RWA density. Nevertheless, most of the differences in groups can be explained by the sizes of the banks—commercial banks spread evenly between the small and large banks in the sample, while cooperative banks and savings banks more apparently

Figure 6.4: Risk weighted assets to total assets distribution by assets and bank category, observations in 2015



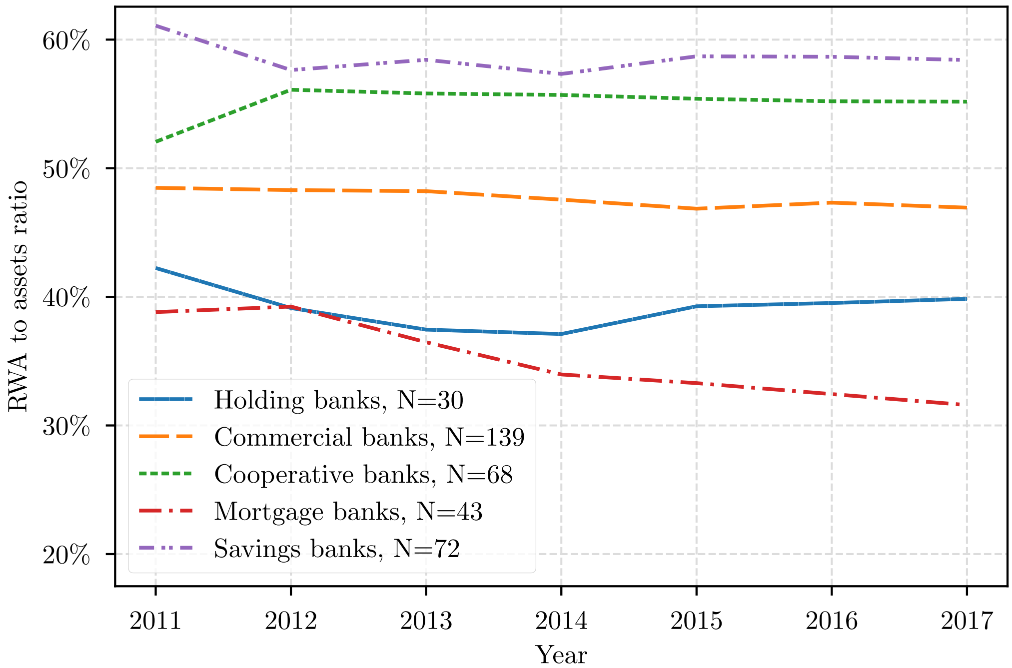
Source: Author's computation, data from the BankScope database.
Note: Excluding Cyprus, Greece, Italy and Portugal.

cluster within the banks with lower assets; on the other hand, holding banks are on average represented by larger institutions.

The only different group where the RWA density is noticeably shifted below the main cluster is the mortgage bank category. Therefore, we expect the mortgage banks to be the most significant banking category in the model—their portfolio is naturally less risky, because of the higher collateralization of the loan assets than for the other categories of banks.

Furthermore, we are also interested in the development of the RWA density over time. This is shown in Figure 6.5. The largest banking category in the sample, commercial banks, declines modestly over time and mortgage banks at slightly higher rates. After the global financial crisis of 2007–2008, regulators motivated the banks to decrease their RWA levels, for example in the European banking industry, the RWA density reduced by approximately 20% between the years 2007-2017 (Schildbach & Schneider 2017). In our time period and dataset, this trend is only marginal. For cooperative banks, holding banks and savings bank, the evolution over time does not exhibit any clear course.

Figure 6.5: Risk weighted assets to total assets, unweighted average by year and bank category, 2011–2017



Source: Author's computation, data from the BankScope database.
Note: Excluding Cyprus, Greece, Italy and Portugal.

The direction of the overall sample is shown in Appendix in Figure B.3, where the unweighted average in the year 2011 is similar to the ending value in 2017, with a modest increase until the year 2013 followed by a slow decrease. Moreover, the series of average RWA density weighted by assets increased by approximately 1 percentage points between the years 2011 and 2017.

The number of usable observations however decreased, the availability of RWA is lower than the availability of NPL in the BankScope database. The breakdown of available data per country is shown in Table 6.8. The largest country in the sample available for testing of the current hypotheses is Germany, with 144 observations for individual banks in 2015, accounting for more than 40% of the dataset, the second largest is Denmark with 33 observations and the third most frequent is Austria, having 31 banks and covering less than 9% of the dataset. Notably, the observations for Japanese banks accounting for the majority of the observations in the case of NPL now represent only 7.1% of the dataset.

Table 6.8: Risk weighted assets density, observations in 2015, in percents, summarized by country

	N	of total N	Mean	Median
AT	31	8.8%	52.27	52.39
BE	11	3.1%	39.61	37.72
CH	15	4.3%	40.97	35.93
DE	144	40.9%	52.53	56.15
DK	33	9.4%	63.54	73.60
EE	2	0.6%	39.06	39.06
ES	9	2.6%	43.46	42.55
FI	5	1.4%	25.24	33.42
FR	16	4.5%	33.83	30.25
IE	4	1.1%	47.11	45.47
JP	25	7.1%	40.47	39.85
LT	3	0.9%	58.21	60.86
LU	8	2.3%	41.33	37.86
LV	1	0.3%	62.20	62.20
MT	3	0.9%	45.31	45.68
NL	18	5.1%	45.39	39.39
SE	15	4.3%	27.26	18.76
SI	6	1.7%	56.45	57.51
SK	3	0.9%	59.44	60.43
All	352	100.0%	48.62	49.89

6.2.2 Model estimation results

For the estimation of the second hypothesis, we estimate the following model and its modifications, similar to Equation 6.1:

$$\begin{aligned} RWAtoAssets_{i,t} = \alpha &+ \phi RWAtoAssets_{i,t-1} + \theta MonIR.L\lambda_{i,t} \\ &+ \rho_1 InterestRate3M_{i,t} + \rho_2 InterestRate3M_{i,t-1} \\ &+ \boldsymbol{x}_{i,t}\beta + \mu_i + \nu_{i,t} \end{aligned} \tag{6.2}$$

where the $RWAtoAssets_{i,t}$ is the explained variable, then we include constant α, first lag of RWA density as $RWAtoAssets_{i,t-1}$ and $MonIR.L\lambda_{i,t}$ represent a dummy variable indicating whether the given observation attained zero lower bound, lagged by λ periods (where we estimate variants for $\lambda = (0, 1, 2, 3)$). Variables $InterestRate3M_{i,t}$ and $InterestRate3M_{i,t-1}$ allow us to observe the effect of the interbank interest rate and its lag, $\boldsymbol{x}_{i,t}$ is a matrix of other variables,

ϕ, θ, β, ρ_1, ρ_2 are coefficients of variables, and eventually μ_i is an error term of fixed components and $\nu_{i,t}$ error term of exogenous shocks.

Table 6.9: Expected effect of the bank-specific and bank dummy variables explaining risk weighted assets density

Variable (sign)	Description
ROAE (+)	Higher returns can be associated with riskier positions in assets. Particularly in the environment of low interest rates, ownership of assets with a higher proportion of conservative investment positions may result in lower profitability of the banks. This variable is treated as endogenous in estimations.
LoansToDeposits (+/−)	We use this variable as a proxy for riskiness—how the banks' are willful to lend (Dimitrios *et al.* 2016). However, RWA is also associated with other balance sheet and off-balance sheets assets so that the effect can be two-fold; treated as endogenous.
log(Assets) (−)	We expect RWA to decrease with the size of the banks as discussed in the descriptive part. This variable is treated as exogenous to the model.
CooperativeBank (−)	Cooperative banks can be considered stable institutions (Kuc & Teplý 2018); we expect this group to have lower RWA density compared to other bank types.
MortgageBank (−)	A higher share of collateralized housing loans should result in a smaller level of RWA density. We assume *MortgageBank* variable to be significant.

Table 6.9 shows expected impact of bank specific variables and Table 6.10 summarizes the expected effect of macroeconomic variables included in the model. Given that NPL ratio and RWA density are positively correlated and due to the fact that the literature estimating directly the determinants of RWA density is limited, we assume that similar variables will affect the RWA density. From available variations of different models, we chose those variables that were not highly correlated and those that helped us to explain the RWA density ratio.

We also addressed concerns and criticism of the RWA raised by Cannata *et al.* (2012) or Le Leslé & Avramova (2012) that due to the fact, that every country (and this possibly applies even on the bank level) can have a different methodology on how to compute the RWA. Therefore, we included in the model dummy variables for Austria, Germany, Denmark, France, Netherlands (the

Table 6.10: Expected effect of the macroeconomic variables explaining risk weighted assets density

Variable (sign)	Description
InterestRate3M (+/−)	The immediate effect of the interbank interest rate can be negative or positive.
GDPGrowth (−)	Negative effect on the RWA is expected—declining economy might imply worsening of assets quality in the economy. Additionally, including GDP in the model allows us to control for the economic cycle.
MonIR.Lλ (+)	We hypothesize the effect to be positive—during a low interest rate environment, banks might try to pursue riskier positions.

most frequent countries in the sample) and for Japan (mainly because ECB does not supervise the Japanese banks, thus the difference can be significant). On the other hand, to avoid overspecification we did not include dummy variables for Sweden and Switzerland as their coefficients were not significant.

The results of the estimation of Equation 6.2 using the two-step system GMM is presented in Table 6.11. Additionally, Table 6.12 shows the corresponding results of the same estimation with errors robust to autocorrelation and heteroskedasticity. We decided not to include the variable *InterestRate3M* in the main models. The reasons are described in the last paragraphs of this Subsection.

The effect of the lagged dependent variable *RWADensity* is significant, suggesting that the previous realization of the variable have important role in explaining the current level of the RWA density. This outcome is anticipated because the RWA is a combination of assets including all items from short-term to long-term positions. Nevertheless, the value of the coefficient close to 1 suggests that as in the previous Section dealing with NPL the effect is highly persistent—the lagged variable itself successfully explains a large portion of the current state.

The coefficient for the bank-specific variable capturing the profitability—*ROAE*—does not reject our expectations described in Table 6.2, the coefficient is significant in all specifications of the model as well as in the non-robust and robust version of the estimations. Moreover, the effect of the *LoansToDeposits* is insignificant. Thus, we do not have enough evidence to accept our assumptions about the variable as a proxy for riskiness.

We have found significant effects of the dummy variables capturing the

Table 6.11: Risk weighted assets density estimation results, two-step system GMM, excluding CY, GR, IT and PT

	(1) RWA D.	(2) RWA D.	(3) RWA D.	(4) RWA D.	(5) RWA D.
L.RWADensity	0.859***	0.863***	0.880***	0.853***	0.829***
ROAE	0.0592***	0.0616***	0.0530***	0.0573***	0.0595***
LoansToDeposits	0.0000264	0.0000128	-0.00000521	0.0000133	0.0000536
HoldingBank	-2.090*	-1.973*	-2.037*	-2.197*	-2.309*
CommercialBank	-0.855	-0.847	-0.738	-0.958*	-1.006*
CooperativeBank	-0.275	-0.272	-0.180	-0.193	-0.182
MortgageBank	-3.093**	-3.175***	-2.972**	-3.426***	-3.700***
log(Assets)	-0.642*	-0.637*	-0.547*	-0.678**	-0.821**
GDPGrowth	-0.111***	-0.0771***	-0.0686***	-0.0598***	-0.0676***
CountryAT	1.623***	1.757***	1.470**	1.417**	1.719***
CountryDE	1.455***	1.628***	1.512***	1.491***	1.596***
CountryDK	1.252	1.269	1.043	1.292	1.580
CountryFR	0.924	1.091*	0.941	0.937	1.086*
CountryJP	2.017***	2.000***	1.793***	1.905***	2.188***
CountryNL	0.661	0.908	0.591	0.442	0.439
MonIR.L0	0.469				
MonIR.L1		0.0544			
MonIR.L2			-0.00546		
MonIR.L3				-0.218	
Constant	16.48*	16.32*	14.13	17.83*	21.28**
Observations	1691	1691	1691	1691	1691
Instruments	34	34	34	34	33
Number of groups	360	360	360	360	360
Observations per group	6	6	6	6	6
Wald st. p-value	0.0000	0.0000	0.0000	0.0000	0.0000
A-B AR(1) p-value	0.0020	0.0015	0.0016	0.0015	0.0017
A-B AR(2) p-value	0.9849	0.9819	0.9958	0.9802	0.9477
Hansen J p-value	0.4441	0.2818	0.2476	0.2080	0.4502

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

bank heterogeneity, most evidently in the model in column 5, although not significant in the robust version. We expected these coefficients to be important in the explanation of the RWA density, as we argued in the previous Subsection. The most significant coefficient is the *MortgageBank* estimate in the model in column 5 in Table 6.11, confirming the expected negative impact on the RWA. Importantly, the coefficient for *log(Assets)* has the correct predicted sign, and it is statistically significant in the non-robust version of estimations.

Furthermore, the results of macroeconomic variables show the significance of the *GDPGrowth* coefficient and confirm the expected negative effect on the RWA density ratio–the non-robust coefficient is significant. Nevertheless, we did not confirm any significance of the coefficients capturing the interest rates: The coefficients in columns 1–4 for *MonIR.L*λ are statistically insignificant. We, therefore, argue that the specification in column 5 in Table 6.11 and similarly in Table 6.12 is likely superior compared to other presented models.

Table 6.12: Risk weighted assets density estimation results, two-step system GMM with robust errors, excluding CY, GR, IT and PT

	(1) RWA D.	(2) RWA D.	(3) RWA D.	(4) RWA D.	(5) RWA D.
L.RWADensity	0.859***	0.863***	0.880***	0.853***	0.829***
ROAE	0.0592**	0.0616***	0.0530*	0.0573**	0.0595**
LoansToDeposits	0.0000264	0.0000128	-0.00000521	0.0000133	0.0000536
HoldingBank	-2.090	-1.973	-2.037	-2.197	-2.309
CommercialBank	-0.855	-0.847	-0.738	-0.958	-1.006
CooperativeBank	-0.275	-0.272	-0.180	-0.193	-0.182
MortgageBank	-3.093	-3.175	-2.972	-3.426	-3.700
log(Assets)	-0.642	-0.637	-0.547	-0.678	-0.821
GDPGrowth	-0.111	-0.0771	-0.0686	-0.0598	-0.0676
CountryAT	1.623*	1.757*	1.470*	1.417	1.719**
CountryDE	1.455**	1.628**	1.512**	1.491**	1.596**
CountryDK	1.252	1.269	1.043	1.292	1.580
CountryFR	0.924	1.091	0.941	0.937	1.086
CountryJP	2.017*	2.000*	1.793	1.905*	2.188*
CountryNL	0.661	0.908	0.591	0.442	0.439
MonIR.L0	0.469				
MonIR.L1		0.0544			
MonIR.L2			-0.00546		
MonIR.L3				-0.218	
Constant	16.48	16.32	14.13	17.83	21.28
Observations	1691	1691	1691	1691	1691
Obs. per group	6	6	6	6	6
Number of groups	360	360	360	360	360
Instruments	34	34	34	34	33
Wald st. p-value	0.0000	0.0000	0.0000	0.0000	0.0000
A-B AR(1) p-value	0.0063	0.0046	0.0067	0.0053	0.0044
A-B AR(2) p-value	0.9850	0.9819	0.9958	0.9803	0.9478
Hansen J p-value	0.4441	0.2818	0.2476	0.2080	0.4502

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Additionally, we identified a significant effect of the dummy variables controlling for the effects of individual countries. The results show that for the model in column 5, the coefficients controlling for Denmark, Germany and Japan individual effects are statistically significant. Thus, the level of RWA density might be country dependent.

Arelando-Bond test for the autocorrelation of order 1 is statistically significant at the 1% level. Nevertheless, we try to control for the order 1 autocorrelation with the lagged variable *RWADensity*, and we reject the autocorrelation of order two. We do not reject the null hypothesis of the Hansen J test that the instruments are exogenous, suggesting that we did not specify the instruments in the model incorrectly. The value of the Hansen J p-value close to the 0.4 for the model in column 5 in Table 6.12 is optimal according to what Roodman (2009b) suggests in his analysis. The ratio of instruments to the number of groups is around 10%. Therefore, we have enough degrees of freedom for the estimation of the system GMM model to avoid the negative effects of the instruments' proliferation.

Table 6.13: Alternative risk weighted assets density estimation result, two-step system GMM, excluding CY, GR, IT and PT

	(1) RWADensity	(2) RWADensity	(3) RWADensity
L.RWADensity	0.914***	0.923***	0.892***
ROAE	0.0465***	0.0602***	0.0592***
LoansToDeposits	-0.0000228	-0.0000415	-0.00000727
HoldingBank	-1.801	-1.556	-1.721
CommercialBank	-0.372	-0.423	-0.600
CooperativeBank	-0.0615	-0.129	-0.194
MortgageBank	-2.306*	-2.125*	-2.565*
InterestRate3M	-0.0857	-0.595	
L.InterestRate3M	-0.330		-0.401
log(Assets)	-0.405	-0.348	-0.499
GDPGrowth	-0.0952***	-0.118***	-0.115***
CountryAT	1.493**	1.424**	1.558**
CountryDE	1.550***	1.544***	1.531***
CountryDK	0.751	0.667	0.974
CountryFR	1.105*	1.051	1.045*
CountryJP	1.598**	1.570**	1.652**
CountryNL	0.787	0.898	0.827
Constant	10.01	8.576	12.80
Observations	1691	1691	1691
Instruments	35	34	34
Number of groups	360	360	360
Observations per group	6	6	6
Wald statistic p-value	0.0000	0.0000	0.0000
A-B AR(1) p-value	0.0018	0.0016	0.0017
A-B AR(2) p-value	0.9594	0.9511	0.9929
Hansen J p-value	0.2946	0.3646	0.4810

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In Appendix in Table A.6 we compare the robustness of the model in column 5 in Table 6.12 by estimating the same model specification using pooled OLS and fixed effect panel estimation. It does hold that the estimated coefficient of the system GMM model for the lagged variable of the *RWADensity* falls between the estimate of the pooled OLS estimate and fixed effect estimate.

Finally, we include the estimation of the alternative models with variable *InterestRate3M* and its lag included; the results are presented in Table 6.13. We can observe, that no combination shown in columns 1, 2 or 3 helps us to explain the *RWADensity* better than the specification in Table 6.12 in column 5. Moreover, the coefficient for the *log(Assets)* becomes insignificant, and the significance of other variables also decreases. Last but not least, the coefficient for lagged *RWADensity* variable is higher compared to the coefficient in the preferred model—this may also suggest decreasing explanatory power of other variables with specifications shown in the Table 6.13.

6.2.3 Summary and discussion

We did not find any evidence to support that the low interest rate environment will influence the banks' risk-weighted assets to total assets ratio after 1–3 years. Hence, we reject Hypothesis #2. In this section, we dealt with relatively strong effects of regulation in individual countries. Nevertheless, we identified potential determinants of the RWA density, notably, return on average equity and identified heterogeneity in our sample of the bank's categories. Robustness of the estimation is a possible problem that could be improved in future studies, either by enhancing the dataset with additional explanatory variables or try to enlarge the time window of the dataset.

The results of our estimation our aligned with the outcomes of Šútorová & Teplý (2014)—they also discovered dynamics in significant persistence of the RWA density and estimated a significant positive effect of the bank profitability on their dataset covering the period from 2006–2011. Therefore, the results of this thesis contribute to the limited literature (compared to the literature examining NPL) focusing on finding possible explanatory variables of the RWA density. Moreover, our dataset covers the most recent period after the global financial crisis 2007–2008 and tries to explain the effects of the current environment characterized by low interest rates, modest GDP growth and increasing regulatory burden (see Basel Committee *et al.* 2019).

6.3 Hypothesis #3: Influence of low interest rates on banks' capital structure

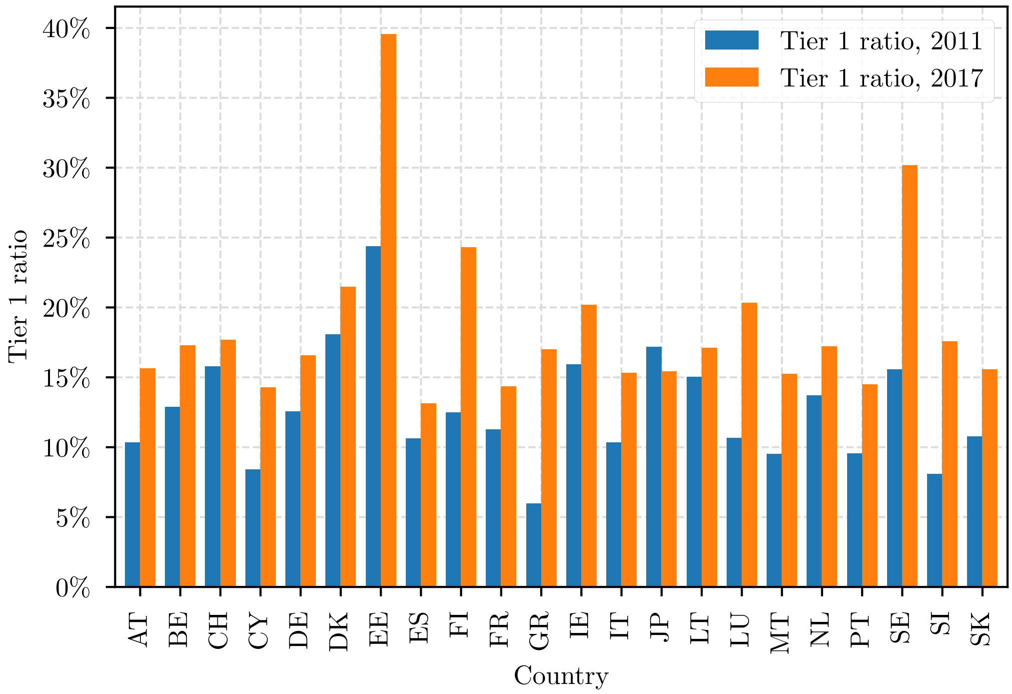
In the last section of this chapter, we are interested in the effects of the low interest rates on the Tier 1 capital ratio.[6] We try to estimate the determinants of this ratio to test for the following hypotheses:

> Hypothesis #3: Low-interest rate environment will result in a change of banks' capital structure.

To estimate the effects on the banks' capital structure proxied by the Tier 1 capital ratio, we use an approach similar to the previous sections of this empirical chapter.

6.3.1 Descriptive analysis of Tier 1 ratio

Figure 6.6: Tier 1 ratio, average by country, weighted by assets, 2011 and 2017

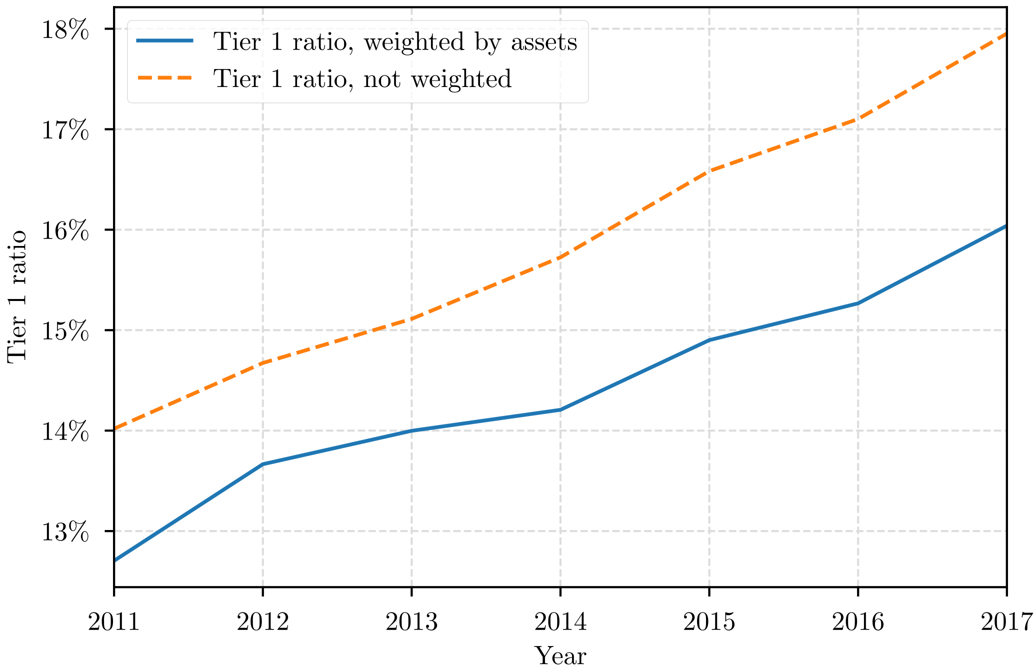


Source: Author's computation, data from the BankScope database.
Note: Please refer to Table 6.14 to find the number of observations per country, resulting levels are computed only from available observations.

[6] Please note that we use the name Tier 1 ratio and Tier 1 capital ratio interchangeably.

Figure 6.6 displays the average Tier 1 ratio grouped by country and its development in our dataset starting from the year 2011 to 2017. It shows the growth of Tier 1 ratio in all countries, except for Japan. As IMF (2017) mentions, this is a possible result of the low interest rate margins and increased credit risk in the country. Nevertheless, the 2017 value for Japan is not different from the overall 2017 average value for the whole dataset, as shown in Figure 6.7. The value for Tier 1 ratio for Estonia coincides with above the average value for Sweden, as the majority of banks in Estonia are Scandinavian based.

Figure 6.7: Tier 1 ratio, average by year, weighted and unweighted by assets, 2011–2017



Source: Author's computation, data from the BankScope database.
Note: Excluding Cyprus, Greece, Italy and Portugal.

Analogically to previous sections, we continue our estimation without Cypriot, Greek, Italian and Portuguese banks. The development of the average Tier 1 ratio is shown in Figure 6.7. After the global financial crisis 2007–2008, the average capital in the banks is steadily increasing, while the RWA density as shown in Appendix in Figure B.3 remained approximately at the same level, this resulted in an almost linear increase in the Tier 1 ratio.

The distribution of Tier 1 ratio is more homogeneous across bank categories than RWA density; as shown in Figure B.5 in Appendix, therefore, we do not expect bank categories to be as significant factor in explaining of the Tier 1 ratio determinants as in the previous estimations.

Table 6.14: Tier 1 ratio observations in 2015, in percents, summarized by country

	N	of total N	Mean	Median
AT	32	8.7%	15.02	13.29
BE	10	2.7%	17.61	15.90
CH	17	4.6%	22.52	18.51
DE	150	40.7%	14.58	13.46
DK	33	8.9%	16.90	15.50
EE	2	0.5%	39.99	39.99
ES	10	2.7%	12.83	12.73
FI	5	1.4%	41.52	19.90
FR	24	6.5%	13.35	13.50
IE	4	1.1%	17.25	17.40
JP	22	6.0%	13.82	13.00
LT	1	0.3%	17.84	17.84
LU	11	3.0%	20.87	19.42
LV	0	0.0%	/	/
MT	3	0.8%	12.80	12.30
NL	21	5.7%	18.57	16.70
SE	15	4.1%	26.38	23.70
SI	6	1.6%	18.89	18.22
SK	3	0.8%	13.80	14.07
All	369	100.0%	16.58	14.50

Finally, in Table 6.14 we show the countries included in the analysis of the Tier 1 ratio. The number of available observations in the dataset is comparable to the previous Section 6.2. The German banks are again the largest group in the available sample accounting for more than 40%, followed by Denmark and Austrian banks.

6.3.2 Model estimation results

Next, to test the third hypotheses, we estimate the following equation and its modifications:

$$
\begin{aligned}
\mathit{Tier1Ratio}_{i,t} = \alpha + \phi\,\mathit{Tier1Ratio}_{i,t-1} + \theta\,\mathit{MonIR.L}\lambda_{i,t} \\
+ \rho_1 \mathit{InterestRate3M}_{i,t} + \rho_2 \mathit{InterestRate3M}_{i,t-1} \\
+ \boldsymbol{x}_{i,t}\beta + \mu_i + \nu_{i,t} \qquad (6.3)
\end{aligned}
$$

where the $\mathit{Tier1Ratio}_{i,t}$ is the dependent variable and on the right of the equation we include α as a constant term, first lag of $\mathit{Tier1Ratio}_{i,t-1}$ as a dynamic part, $\mathit{MonIR.L}\lambda_{i,t}$ as a dummy variable indicating controlling for the under-zero monetary interest rates, lagged by λ periods (where $\lambda = (0, 1, 2, 3)$). Variables $\mathit{InterestRate3M}_{i,t}$ and $\mathit{InterestRate3M}_{i,t-1}$ control for a possible effect of the interbank interest rate and its lag, $\boldsymbol{x}_{i,t}$ is a matrix of other variables, ϕ, θ, β, ρ_1, ρ_2 are coefficients of variables and finally μ_i is an error term of fixed components and $\nu_{i,t}$ error term capturing exogenous shocks. We summarize the expected effects of dependent variables on the Tier 1 ratio in Table 6.15 that describes bank-related variables and Table 6.16 explaining macroeconomic variables.

Table 6.15: Expected effect of the bank-specific and bank dummy variables explaining Tier 1 capital ratio

Variable (sign)	Description
ROAE (+/−)	Higher returns can be associated with riskier positions in assets, particularly in the environment of low interest rates, this can drive up the RWA denominator. However, bigger profitability can be linked to increasing value of retained earnings that could increase the numerator of the Tier 1 ratio. This variable is treated as endogenous in estimations.
EquityToAssets (+)	This variable can control for the changes in book values of the numerator and denominator part. We treat this variable as endogenous.
CostToIncome (+/−)	Costs larger than income can signify either an inefficiency of the bank or possibly a higher share of investments that can contribute to the overall health of the company. The variable is treated endogenously.
log(Assets) (+)	We expect Tier 1 ratio to increase with the size of the banks—bigger banks can take advantage of the returns to scale. This variable is treated as exogenous to the model.
MortgageBank (+)	A higher share of collateralized housing loans should result in a higher level of the Tier 1 ratio.

Table 6.16: Expected effect of the macroeconomic variables explaining Tier 1 capital ratio

Variable (sign)	Description
InterestRate3M (+/−)	The immediate effect of the interbank interest rate can be negative or positive.
GDPGrowth (+)	Positive effect on the Tier 1 ratio is expected—increasing economy might imply improving of assets quality in the economy. Additionally, including GDP in the model allows us to control for the economic cycle.
Unemployment (−)	Higher employment can translate to an increased health of banks reflected in the Tier 1 ratio.
MonIR.Lλ (−)	We hypothesize the effect to be negative—during a low interest rate environment, banks might try to pursue riskier positions.

We present the results of the model in Table 6.17 in the variation with non-robust errors and Table 6.18 displaying the results for the robust version of the system GMM estimation. The columns 1–4 in both Tables try to capture if there is any effect of the below-zero interest rate period. The results suggest that lagged coefficient for the dependent variable is significant and between 0 and 1, suggesting that the current realization of the *Tier1Ratio* is partially affected by its lagged value. We do not find any evidence, that the Tier 1 ratio can be satisfactorily explained by the return on equity ratio.

Further, we detect that the *EquityToAssets* can help us explain the Tier 1 ratio, the effect is significant and positive, although not in the robust version. It is the same case as with the coefficient for the *log(Assets)* parameter, where we also fail to find it significant in the robust version, the larger the bank. Thus, the group of the mortgage banks has on average higher Tier 1 capital ratio than the base group, although even this estimate is only significant with non-robust error terms in Table 6.17.

We, however, do find that the explained *Tier1Ratio* is positively affected by the *CostToIncome* and we find this effect significant in all presented alternatives in the non-robust version. We do not find any significant effect of the macroeconomic variables controlling for the level of GDP growth. Nevertheless, we observe unemployment might have a negative effect on the Tier 1 ratio—when the unemployment in the economy decreases, the level of Tier 1 capital on average increases.

More importantly, we do not discover any relationship between the inter-

Table 6.17: Tier 1 ratio estimation results, two-step system GMM, excluding CY, GR, IT and PT

	(1) Tier1Ratio	(2) Tier1Ratio	(3) Tier1Ratio	(4) Tier1Ratio	(5) Tier1Ratio
L.Tier1Ratio	0.537***	0.545***	0.538***	0.547***	0.536***
ROAE	0.0140	0.0167	0.0151	0.0186	0.0136
EquityToAssets	0.450***	0.458***	0.491***	0.424***	0.477***
CostToIncome	0.00059***	0.00065***	0.00058***	0.00065***	0.00059***
MortgageBank	2.599***	2.660***	2.827***	2.638***	2.701***
log(Assets)	0.467***	0.495***	0.534***	0.479***	0.518***
InterestRate3M	-0.363	-0.353	-0.0653	-0.398	-0.367
L.InterestRate3M	0.205	0.301	0.0782	0.200	0.116
GDPGrowth	-0.0120	-0.0222	-0.0201	-0.000496	-0.00130
CountryAT	-2.607***	-2.705***	-2.835***	-2.860***	-2.659***
CountryDE	-2.269***	-2.195***	-2.165***	-2.215***	-2.124***
CountryDK	-1.407**	-1.407**	-1.405**	-1.321**	-1.300**
CountryFR	-1.756***	-1.806***	-1.813***	-1.868***	-1.768***
CountryJP	-3.244***	-3.194***	-3.294***	-3.294***	-3.302***
CountryNL	-0.756	-0.872	-0.824	-0.849	-0.773
Unemployment	-0.219***	-0.213***	-0.212***	-0.208***	-0.207***
MonIR.L0	0.227				
MonIR.L1		0.293			
MonIR.L2			0.223		
MonIR.L3				0.113	
Constant	-1.454	-2.203	-2.910	-1.570	-2.480
Observations	1945	1945	1945	1945	1945
Instruments	41	41	41	41	40
Number of groups	381	381	381	381	381
Obs. per group	6	6	6	6	6
Wald st. p-value	0.0000	0.0000	0.0000	0.0000	0.0000
A-B AR(1) p-value	0.1271	0.1259	0.1253	0.1264	0.1267
A-B AR(2) p-value	0.1766	0.1763	0.1744	0.1764	0.1761
Hansen J p-value	0.1815	0.2829	0.2374	0.2051	0.2301

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

bank interest rate and the Tier 1 capital ratio. We also do not find any effect of neither of the *MonIR.Lλ*. Thus, we do not observe any significant effect of the negative interest rate period on the Tier 1 capital ratio in our estimations or any significant effect of the interbank interest rate.

Dummy variables controlling for the country-specific effects are significant, even mostly in the robust version of the estimation. Therefore, the role of regulators in the motivation of the banks to keep their Tier 1 ratio sound is likely important.

Additionally, we check the estimated models for robustness. Firstly, the Hansen J p-value suggests that we cannot reject the null hypothesis that the instruments are exogenous, however, our estimated p-value is again different

Table 6.18: Tier 1 ratio estimation results, two-step system GMM with robust errors, excluding CY, GR, IT and PT

	(1) Tier1Ratio	(2) Tier1Ratio	(3) Tier1Ratio	(4) Tier1Ratio	(5) Tier1Ratio
L.Tier1Ratio	0.537***	0.545***	0.538***	0.547***	0.536***
ROAE	0.0140	0.0167	0.0151	0.0186	0.0136
EquityToAssets	0.450	0.458	0.491	0.424	0.477
CostToIncome	0.000587	0.000647	0.000584	0.000654	0.000591
MortgageBank	2.599	2.660	2.827	2.638	2.701
log(Assets)	0.467	0.495	0.534	0.479	0.518
InterestRate3M	-0.363	-0.353	-0.0653	-0.398	-0.367
L.InterestRate3M	0.205	0.301	0.0782	0.200	0.116
GDPGrowth	-0.0120	-0.0222	-0.0201	-0.000496	-0.00130
CountryAT	-2.607*	-2.705*	-2.835	-2.860	-2.659
CountryDE	-2.269	-2.195	-2.165	-2.215	-2.124
CountryDK	-1.407*	-1.407*	-1.405*	-1.321*	-1.300*
CountryFR	-1.756	-1.806	-1.813	-1.868	-1.768
CountryJP	-3.244**	-3.194**	-3.294**	-3.294**	-3.302**
CountryNL	-0.756	-0.872	-0.824	-0.849	-0.773
Unemployment	-0.219***	-0.213***	-0.212**	-0.208**	-0.207**
MonIR.L0	0.227				
MonIR.L1		0.293			
MonIR.L2			0.223		
MonIR.L3				0.113	
Constant	-1.454	-2.203	-2.910	-1.570	-2.480
Observations	1945	1945	1945	1945	1945
Obs. per group	6	6	6	6	6
Number of groups	381	381	381	381	381
Instruments	41	41	41	41	40
Wald st. p-value	0.0000	0.0000	0.0000	0.0000	0.0000
A-B AR(1) p-value	0.1406	0.1363	0.1320	0.1353	0.1385
A-B AR(2) p-value	0.1952	0.1936	0.1944	0.1957	0.1965
Hansen J p-value	0.1815	0.2829	0.2374	0.2051	0.2301

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

from the relatively safer value of 0.4 for the Hansen J p-value as Roodman (2009b) propose. Secondly, we do not reject both Arellano-Bond tests for autocorrelation of order 1 and order 2 with the null hypothesis of present autocorrelation in the respective lags of *Tier1Ratio*. Thirdly, in Appendix in Table A.7 we compare coefficient for the lagged *Tier1Ratio* of the model in column 5 in Table 6.18 using pooled OLS estimator and fixed effect estimator. For the reason that the value of the coefficient for the system GMM model is lower than for the fixed effects model, we can not reject that the value of *Tier1Ratio* is not biased.

In Table 6.19 we present two alternative models. The first model is specified without dummy variables for specific effects of individual countries, and in the second model, we exclude macroeconomic variables for GDP growth and unemployment. The analysis shows that the effects of the variables are unchanged from the previous specification of models. Nevertheless, the significance of coefficients might change. Lastly, the Hansen J p-value decreases for the alternative specifications, therefore we argue that our conclusion about the effects of the low interest rates derived earlier in this chapter are sufficiently robust.

Table 6.19: Alternative Tier 1 ratio estimation results, two-step system GMM, excluding CY, GR, IT and PT

	(1) Tier1Ratio	(2) Tier1Ratio
L.Tier1Ratio	0.552^{***}	0.541^{***}
ROAE	0.0121	0.0140
EquityToAssets	0.460^{***}	0.490^{***}
CostToIncome	0.000867^{***}	0.000632^{***}
MortgageBank	2.253^{***}	2.664^{***}
log(Assets)	0.460^{***}	0.483^{***}
InterestRate3M	-1.191^{*}	-0.777
L.InterestRate3M	0.569	0.157
GDPGrowth	0.0860	
Unemployment	-0.0550	
CountryAT		-1.899^{**}
CountryDE		-1.191^{**}
CountryDK		-0.836
CountryFR		-1.830^{***}
CountryJP		-1.922^{***}
CountryNL		-0.349
Constant	-4.471^{*}	-3.973
Observations	1945	1945
Instruments	34	38
Number of groups	381	381
Observations per group	6	6
Wald statistic p-value	0.0000	0.0000
A-B AR(1) p-value	0.1197	0.1247
A-B AR(2) p-value	0.1755	0.1752
Hansen J p-value	0.0644	0.1120

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

6.3.3 Summary and discussion

In this section, we have not discovered interest rates as significant determinants of the Tier 1 capital ratio. We did not confirm short term interbank interest rate to have any effect, neither the dummy variables controlling for the negative interest rate environment. Therefore, we reject Hypothesis #3—we do not find that the low-interest rate environment will result in a change of banks' capital structure.

Both Brewer III *et al.* (2008) (dataset spanning over 1992–2005) and Gropp & Heider (2010) (dataset for years 1991–2004) found in their studies significant and positive effect of the size on the Tier 1 ratio, the opposite of what our thesis suggests. However, in their models they work with datasets dated before the global financial crisis 2007–2008, and this decreases the comparability of our studies.

Our dataset proved to be difficult to be analyzed, as we raised concerns about the robustness of our results on the studied sample. We suspect the system GMM estimator on our dataset to be potentially biased due to the nature of the data and available variables. This could be possibly addressed either by incorporation of additional explanatory variables, for example by dummy variables capturing the regulatory environment or by extending the dataset when more data become available.

Chapter 7

Conclusion

The effects of the low—or below the zero—interest rates have been studied in relation to the profitability of banks; this topic was a subject of recent studies for example by Borio *et al.* (2017) or Claessens *et al.* (2018). Authors however mostly focused on profitability, predominantly on the effects on the net interest margin.

This thesis, on the other hand, aspires to analyze effects of the low interest rate environment on the credit risk indicators: The Non-performing loan (NPL) ratio, Risk weighted assets (RWA) density and changes in the regulatory Tier 1 capital ratio. Moreover, the available literature on the determinants of the two latter indicators is limited, and the information is non-existent on the effect of the low interest rate environment on these credit risk indicators.

We examined a sample of 827 banks limited to the countries within Eurozone, Denmark, Japan, Sweden, and Switzerland for years spanning from 2011 until 2017. Using dynamic panel estimation methods (models were estimated by the system Generalized method of moments (GMM) framework), we found a significant one-year delayed effect on the NPL ratio of the indicative variable controlling for the below-zero monetary interest rates, under which the NPL increases. Therefore, we did not reject Hypothesis #1.

As an additional support for Hypothesis #1, we also discovered a marginally significant self-correcting effect of the interbank 3-month interest rate. The NPL ratio changes in the same direction as the interbank interest rate in the current year, but the lag of this interbank interest rate with an effect of a lower size corrects the movement in the opposite direction.

Moreover, we compared our results employing the recent data to other studies that estimated the drivers of the NPL, e.g. Chaibi & Ftiti (2015), Dimitrios *et al.* (2016) or Radivojevic *et al.* (2017). Within this comparison, we found our results to be mostly consistent with the previous research and the majority of differences can be explained by the changes in the economic environment.

However, we rejected Hypothesis #2 that the interest rates have an effect on the RWA to total assets ratio because we did not find any supporting results. Furthermore, we also rejected Hypothesis #3 as we did not find any evidence of the effect on the Tier 1 capital ratio.

Furthemore, this thesis contributes to the research in the following ways: Firstly, with the dataset covering the recent period, we were able in the case of NPL ratio to confirm the significance of some determinants of the credit risk other authors found to be significant in their studies focused on earlier periods and different geographical scope. On the other hand, we identified other determinants to be insignificant or having an opposite impact. These outcomes can be a subject of further research.

Secondly, using a system GMM, we were able to observe the effects of bank heterogeneity, where we controlled for different business bank models and found significant (in non-robust specifications) impact of the heterogeneity. For the category of mortgage banks, we found a significant effect on all three credit risk indicators used in this work.

Finally, we contributed to the limited literature on the determinants of the RWA density and Tier 1 capital ratio. Nevertheless, on our collected data sample the results are significant mostly in the non-robust version of estimations. Hence, this could become a focus of consequent studies on other geographies or a more recent dataset.

Therefore, we believe that outcomes of this work can be useful for consideration of potential impacts of monetary policies. Commercial banks can also benefit from this study, where it can help understand the relations between credit risk measures and macroeconomic or bank-related parameters. Last but not least, this thesis can serve as a beneficial support for future academic research.

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Appendix A

Supplementary tables

Table A.1: Dataset description by assets in 2017 (billions USD), summarized by bank category

	N	Mean	Std.D.	p25	Median	p75	Total
Holding banks	60	298.86	601.22	7.41	35.98	203.57	17,931
Commercial banks	329	102.14	302.18	2.18	12.87	53.83	33,603
Cooperative banks	749	11.63	91.98	0.47	1.25	3.45	8,712
Real Estate & Mortgage banks	57	28.90	38.75	2.69	16.60	34.00	1,647
Savings banks	415	3.53	15.43	0.12	0.25	0.94	1,464
All	1,610	39.35	199.75	0.31	1.41	7.65	63,360

Table A.2: Pair-wise correlations between variables, all countries

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(1)	NPL	1.000																	
(2)	RWADensity	0.248	1.000																
		(0.000)																	
(3)	Tier1Ratio	−0.028	−0.243	1.000															
		(0.068)	(0.000)																
(4)	LoansToDeposits	0.009	−0.002	−0.013	1.000														
		(0.429)	(0.904)	(0.390)															
(5)	EquityToAssets	0.116	0.498	0.463	−0.008	1.000													
		(0.000)	(0.000)	(0.000)	(0.395)														
(6)	ROAE	−0.165	−0.065	0.049	−0.041	0.039	1.000												
		(0.000)	(0.000)	(0.001)	(0.000)	(0.000)													
(7)	CostToIncome	0.031	−0.016	−0.006	−0.004	0.001	−0.045	1.000											
		(0.007)	(0.291)	(0.673)	(0.661)	(0.901)	(0.000)												
(8)	InterestRate3M	−0.048	0.186	−0.098	0.024	−0.032	−0.018	−0.024	1.000										
		(0.000)	(0.000)	(0.000)	(0.011)	(0.001)	(0.054)	(0.011)											
(9)	L.InterestRate3M	0.014	0.136	−0.092	0.013	−0.009	−0.035	−0.026	0.879	1.000									
		(0.265)	(0.000)	(0.000)	(0.212)	(0.381)	(0.001)	(0.011)	(0.000)										
(10)	InflationChange	−0.056	0.179	−0.070	0.012	0.107	0.014	0.005	0.543	0.461	1.000								
		(0.000)	(0.000)	(0.000)	(0.209)	(0.000)	(0.141)	(0.635)	(0.000)	(0.000)									
(11)	Slope	0.397	0.255	0.007	0.050	0.134	−0.059	−0.021	0.338	0.405	0.352	1.000							
		(0.000)	(0.000)	(0.645)	(0.000)	(0.000)	(0.000)	(0.027)	(0.000)	(0.000)	(0.000)								
(12)	Unemployment	0.494	0.108	0.052	0.030	0.121	−0.063	−0.030	−0.021	0.090	−0.029	0.733	1.000						
		(0.000)	(0.000)	(0.001)	(0.002)	(0.000)	(0.000)	(0.002)	(0.026)	(0.000)	(0.002)	(0.000)							
(13)	GDPGrowth	−0.163	−0.182	0.012	0.024	0.005	0.056	0.013	−0.085	−0.545	−0.103	−0.496	−0.306	1.000					
		(0.000)	(0.000)	(0.428)	(0.013)	(0.604)	(0.000)	(0.158)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)						
(14)	MonIR_L0	0.144	−0.105	0.078	−0.009	0.132	0.019	0.007	−0.663	−0.551	−0.347	−0.069	0.247	0.123	1.000				
		(0.000)	(0.000)	(0.000)	(0.331)	(0.000)	(0.043)	(0.446)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)					
(15)	MonIR_L1	0.161	−0.116	0.089	−0.007	0.134	0.026	0.011	−0.618	−0.619	−0.298	−0.132	0.233	0.337	0.750	1.000			
		(0.000)	(0.000)	(0.000)	(0.472)	(0.000)	(0.006)	(0.238)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)				
(16)	MonIR_L2	0.186	−0.088	0.086	−0.005	0.143	0.030	0.023	−0.617	−0.542	−0.199	−0.101	0.239	0.328	0.550	0.733	1.000		
		(0.000)	(0.000)	(0.000)	(0.604)	(0.000)	(0.002)	(0.016)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)			
(17)	MonIR_L3	0.133	−0.068	0.069	−0.004	0.110	0.020	0.032	−0.560	−0.542	−0.063	−0.066	0.165	0.310	0.418	0.558	0.761	1.000	
		(0.000)	(0.000)	(0.000)	(0.663)	(0.000)	(0.033)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
(18)	MonIR_L4	0.076	−0.044	0.049	−0.003	0.078	0.004	0.046	−0.394	−0.447	0.133	−0.001	0.084	0.250	0.278	0.371	0.506	0.665	1.000
		(0.000)	(0.004)	(0.001)	(0.762)	(0.000)	(0.697)	(0.000)	(0.000)	(0.000)	(0.000)	(0.909)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	

Note: p-values reported in parenthesis.

Table A.3: Pair-wise correlations between variables, excluding CY, GR, IT and PT

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(1)	NPL	1.000																	
(2)	RWADensity	0.404	1.000																
		(0.000)																	
(3)	Tier1Ratio	−0.070	−0.248	1.000															
		(0.002)	(0.000)																
(4)	LoansToDeposits	0.019	0.002	−0.013	1.000														
		(0.153)	(0.937)	(0.532)															
(5)	EquityToAssets	−0.013	0.588	0.343	−0.008	1.000													
		(0.339)	(0.000)	(0.000)	(0.440)														
(6)	ROAE	−0.184	−0.039	0.085	−0.049	0.061	1.000												
		(0.000)	(0.074)	(0.000)	(0.000)	(0.000)													
(7)	CostToIncome	0.005	0.001	−0.019	−0.007	0.000	−0.043	1.000											
		(0.714)	(0.978)	(0.367)	(0.516)	(0.999)	(0.000)												
(8)	InterestRate3M	0.103	0.031	−0.108	0.028	−0.047	−0.039	−0.027	1.000										
		(0.000)	(0.150)	(0.000)	(0.010)	(0.000)	(0.000)	(0.010)											
(9)	L.InterestRate3M	0.109	0.031	−0.096	0.006	−0.017	−0.047	−0.022	0.867	1.000									
		(0.000)	(0.177)	(0.000)	(0.594)	(0.128)	(0.000)	(0.054)	(0.000)										
(10)	InflationChange	−0.007	0.080	−0.056	0.013	0.131	−0.004	0.002	0.478	0.369	1.000								
		(0.607)	(0.000)	(0.007)	(0.216)	(0.000)	(0.712)	(0.833)	(0.000)	(0.000)									
(11)	Slope	0.192	0.008	−0.032	0.111	0.144	−0.082	−0.022	0.470	0.498	0.553	1.000							
		(0.000)	(0.702)	(0.115)	(0.000)	(0.000)	(0.000)	(0.034)	(0.000)	(0.000)	(0.000)								
(12)	Unemployment	0.154	−0.063	−0.033	0.053	0.073	−0.048	−0.035	0.058	0.133	0.111	0.616	1.000						
		(0.000)	(0.003)	(0.107)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)							
(13)	GDPGrowth	0.001	0.006	0.051	0.031	0.064	0.080	−0.005	0.030	−0.437	0.032	−0.012	0.049	1.000					
		(0.914)	(0.775)	(0.013)	(0.004)	(0.000)	(0.000)	(0.609)	(0.005)	(0.000)	(0.003)	(0.269)	(0.000)						
(14)	MonIR_L0	−0.102	0.059	0.068	−0.009	0.140	0.042	0.013	−0.632	−0.507	−0.215	−0.090	0.171	0.120	1.000				
		(0.000)	(0.006)	(0.001)	(0.382)	(0.000)	(0.000)	(0.235)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)					
(15)	MonIR_L1	−0.093	0.045	0.074	−0.007	0.145	0.047	0.014	−0.592	−0.581	−0.159	−0.155	0.181	0.343	0.750	1.000			
		(0.000)	(0.037)	(0.000)	(0.528)	(0.000)	(0.000)	(0.175)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)				
(16)	MonIR_L2	−0.071	0.044	0.072	−0.005	0.159	0.053	0.022	−0.594	−0.509	−0.083	−0.120	0.223	0.336	0.542	0.723	1.000		
		(0.000)	(0.040)	(0.000)	(0.662)	(0.000)	(0.000)	(0.035)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)			
(17)	MonIR_L3	−0.072	0.039	0.060	−0.004	0.125	0.040	0.029	−0.541	−0.516	0.023	−0.093	0.151	0.329	0.415	0.554	0.767	1.000	
		(0.000)	(0.073)	(0.003)	(0.710)	(0.000)	(0.000)	(0.005)	(0.000)	(0.000)	(0.030)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
(18)	MonIR_L4	−0.060	0.030	0.045	−0.003	0.089	0.010	0.040	−0.383	−0.428	0.176	−0.002	0.062	0.266	0.278	0.371	0.513	0.669	1.000
		(0.000)	(0.158)	(0.030)	(0.795)	(0.000)	(0.327)	(0.000)	(0.000)	(0.000)	(0.000)	(0.837)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	

Note: p-values reported in parenthesis.

Table A.4: Non-performing loans estimation results, two-step system GMM, including CY, GR, IT and PT

	(1) NPL	(2) NPL	(3) NPL	(4) NPL
L.NPL	1.092***	1.089***	1.080***	1.099***
EquityToAssets	-0.0559*	-0.0839***	-0.0714**	-0.115***
LoansToDeposits	0.000053***	0.000088***	0.000067***	0.000029**
CooperativeBank	-0.245***	-0.294***	-0.296***	-0.398***
MortgageBank	0.138	0.0673	0.150	0.143
SmallBank	-0.0350	0.00903	-0.0403	0.0122
InterestRate3M	0.789***	0.797***	0.293	-0.493**
InflationChange	-0.0542*	-0.105***	-0.108***	-0.0438
log(Assets)	0.0157	0.00687	-0.00486	-0.0227
GDPGrowth	-0.427***	-0.498***	-0.448***	-0.403***
Slope	0.0562	0.0928	0.0730	0.125*
Unemployment	-0.00439	-0.0159	0.0149	0.0188
MonIR_L0	0.333***			
MonIR_L1		0.532***		
MonIR_L2			-0.00150	
MonIR_L3				-0.719***
Constant	-0.177	0.327	0.547	1.111*
Observations	6400	6400	6400	6400
Instruments	31	31	31	31
Wald st. p-value	0.0000	0.0000	0.0000	0.0000
A-B AR(1) p-value	0.0000	0.0000	0.0000	0.0000
A-B AR(2) p-value	0.3304	0.3095	0.3823	0.3678
Hansen J p-value	0.0000	0.0000	0.0000	0.0000

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.5: NPL estimation results, comparison of fixed effects, pooled OLS and system GMM, excluding CY, GR, IT and PT

	(1) Fixed effects	(2) Pooled OLS	(3) two step system GMM
L.NPL	0.502^{***}	0.902^{***}	0.988^{***}
	(38.19)	(169.10)	(16.19)
Observations	4610	4610	4610
Wald statistic			19744.0
F statistic	319.3	1960.7	

Note: Output of other explanatory variables is omitted. The same estimation specification as for the model in the second column of Table 6.5 is used

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.6: RWA density estimation results, comparison of fixed effects, pooled OLS and system GMM, excluding CY, GR, IT and PT

	(1) Fixed effects	(2) Pooled OLS	(3) two step system GMM
L.RWADensity	0.536^{***}	0.932^{***}	0.829^{***}
	(23.05)	(92.51)	(7.17)
Observations	1691	1691	1691
Wald statistic			11647.0
F statistic	206.8	843.6	

Note: Output of other explanatory variables is omitted. The same estimation specification as for the model in the fifth column of Table 6.12 is used

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.7: Tier 1 capital ratio estimation results, comparison of fixed effects, pooled OLS and system GMM, excluding CY, GR, IT and PT

	(1) Fixed effects	(2) Pooled OLS	(3) two step system GMM
L.Tier1Ratio	0.630***	0.727***	0.535***
	(44.96)	(71.73)	(7.68)
Observations	1945	1945	1945
Wald statistic			618.7
F statistic	324.9	344.4	

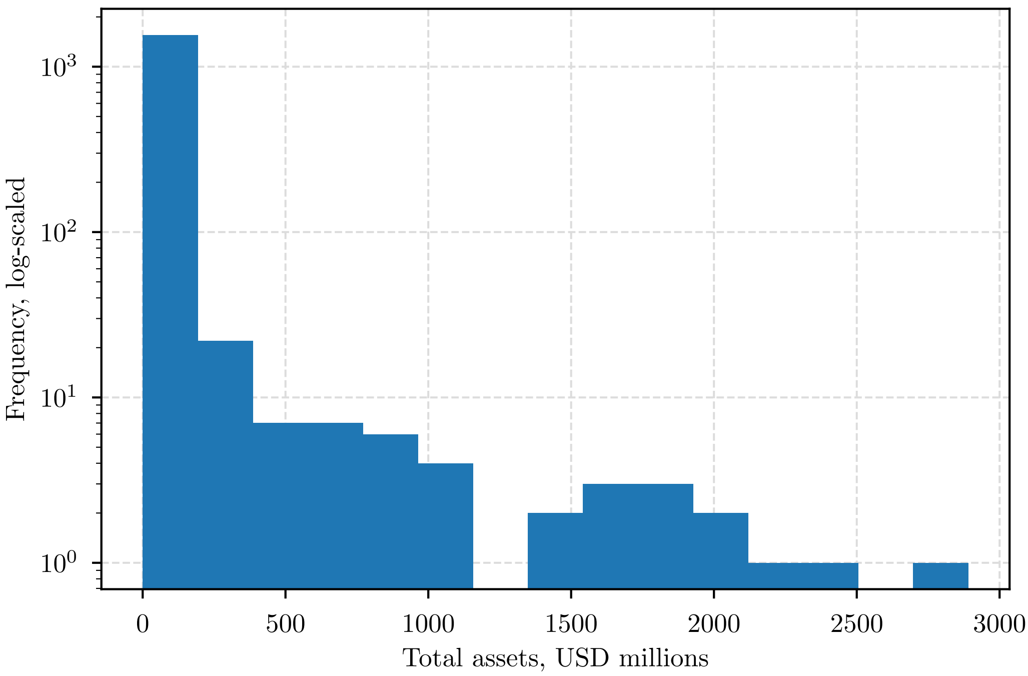
Note: Output of other explanatory variables is omitted. The same estimation specification as for the model in the fifth column of Table 6.18 is used

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix B

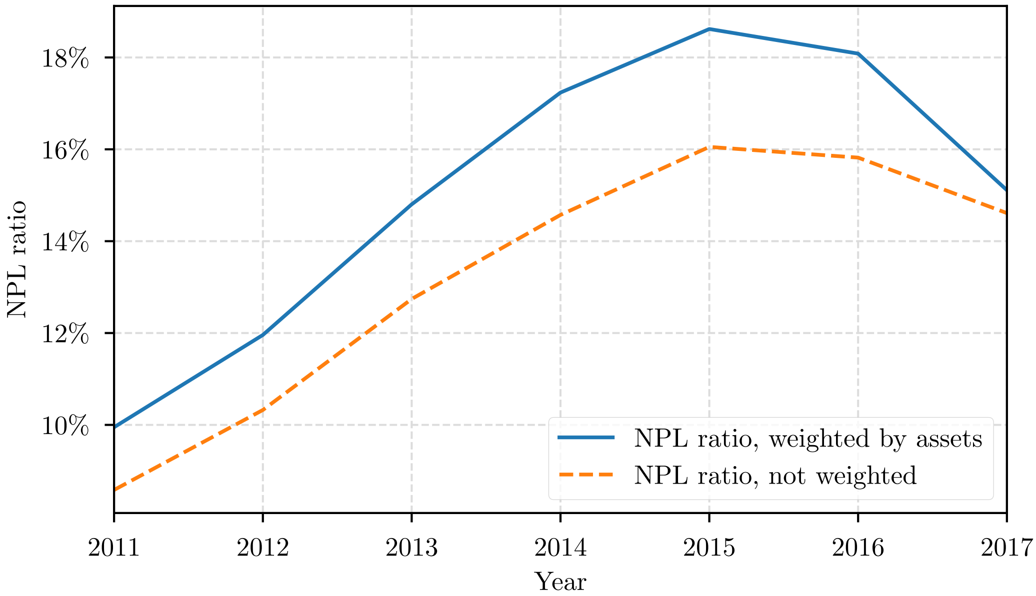
Supplementary figures

Figure B.1: Distribution of the banks in the dataset by assets, observations in 2017



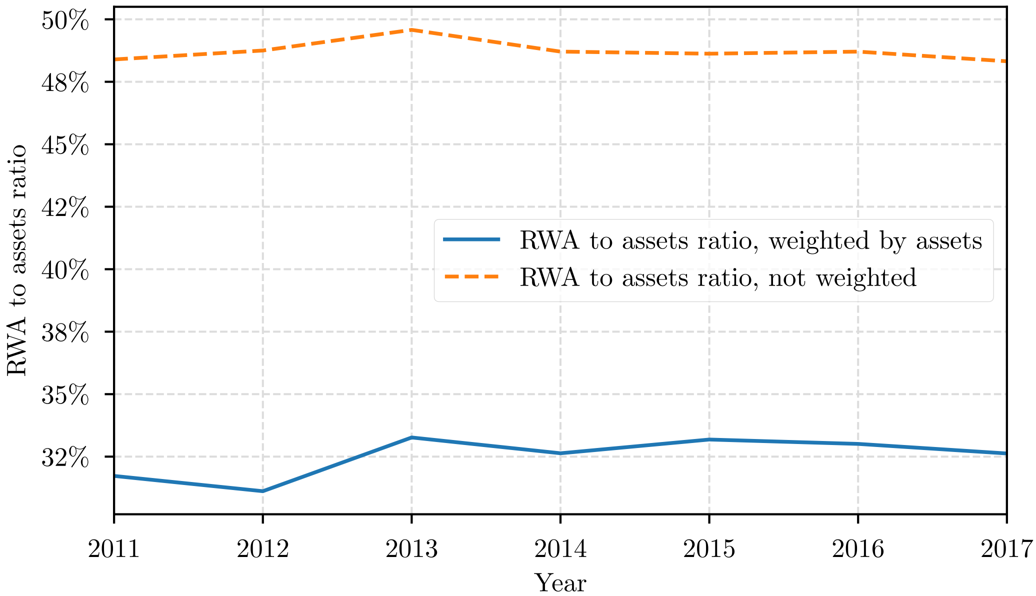
Source: Author's computation, data from the BankScope database.

Figure B.2: Non-performing loans mean for Cyprus, Greece, Italy and Portugal, weighted and unweighted by assets, 2011–2017



Source: Author's computation, data from the BankScope database.

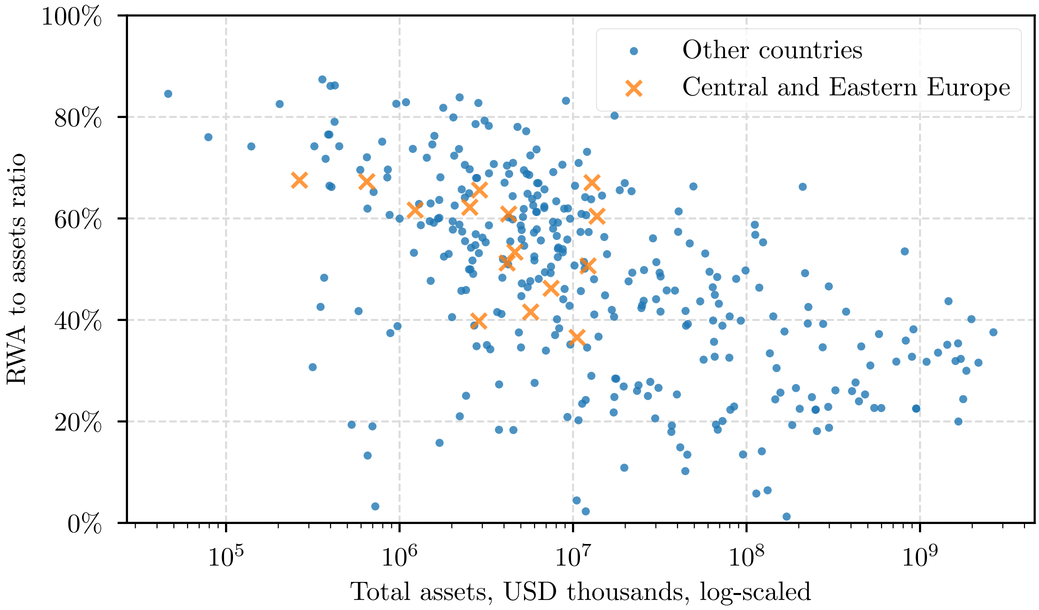
Figure B.3: Risk weighted assets to total assets mean, weighted and unweighted by assets, 2011–2017



Source: Author's computation, data from the BankScope database.

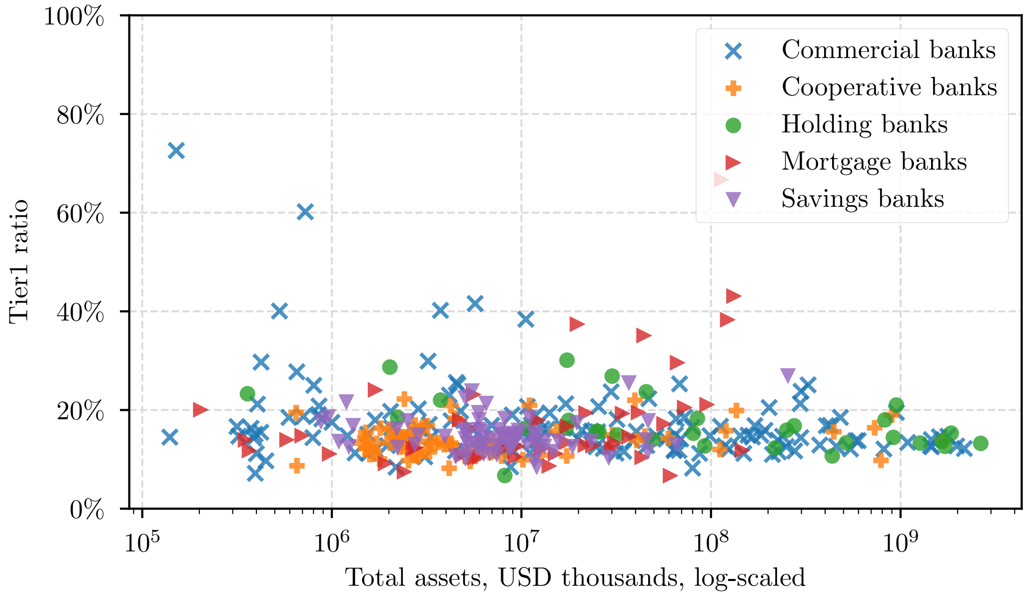
Note: Excluding Cyprus, Greece, Italy and Portugal.

Figure B.4: Risk weighted assets to total assets distribution by assets, observations in 2015



Source: Author's computation, data from the BankScope database.
Note: Excluding Cyprus, Greece, Italy and Portugal.

Figure B.5: Risk weighted assets to total assets distribution by assets and bank categories, observations in 2015



Source: Author's computation, data from the BankScope database.
Note: Excluding Cyprus, Greece, Italy and Portugal.