**Charles University**
Faculty of Social Sciences
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DISSERTATION THESIS

# Banks' performance in low and negative interest rate environment

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Prague, July 5, 2022

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# Abstract

This dissertation consists of four empirical papers that focus on the performance of banks in the low or even negative interest rate environment characteristic for the decade after the global financial crisis of 2007-2009. The first paper focuses on the analysis of a relationship between the net interest margin (NIM) of EU banks and market interest rates in a low-interest rate environment while controlling for the impact of market concentration by examining a large sample of annual data on 629 banks from EU countries for the 2011-2016 period. The results show a positive concave relationship between NIM and short-term interest rates, deterioration of NIM for all types of banks and a higher market concentration leading to higher NIM. In the second paper, we examine the determinants of NIM of European and US banks in a zero lower bound (ZLB) situation while controlling for institutional design factors, i.e. difference between capital-based and bank-based financial markets. We analyse a large sample of annual data on 629 European banks and 526 US during the 2011-2016 period confirming that NIM is significantly influenced by the different institutional designs. The third paper deals with prepayment risk and provides empirical evidence from the Czech banking sector. Our analysis quantifies the impact of early repayment of a mortgage on balance sheets and interest margin of three different types of banks, which differ in the structure of their financing. The results of models have shown that these prepayments risks were reflected in the decreasing net interest margin of the Czech banking sector. The fourth paper focuses on the impact of introduction of the liquidity coverage ratio (LCR) as a binding constraint for banks. Using a dataset of 707 banks of EU countries for the period 2012-2018 the impact of gradual phase-in of the LCR starting at 60% in 2015 and ending at 100% in 2018 is considered. The estimation shows positive impact of the LCR requirement on the liquidity situation of the banks while suggesting that the existence of negative interest rate environment has a negative impact.

**JEL Classification** C33, E43, E52, E58, G21
**Keywords** banks, net interest margin, bank heterogeneity, bank profitability, interest rates, non-linearity, low or negative interest rate environment, GMM, prepayment risk, liquidity, LCR, liquid assets, loan-to-deposit ratio

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# Acronyms

**ALM** Asset and liability management (department in a bank)

**ARM** Adjustable-rate mortgages

**bps** Basis point (1/100 of the percentage point)

**CNB** Czech National Bank

**CRD IV** Capital Requirements Directive IV

**CRR** Capital Requirements Regulation

**CZK** Czech crown (currency unit)

**ECB** European Central Bank

**EU** European Union

**EUR** Euro (currency unit)

**(F)GLS** (Feasible) generalized least squares estimator

**FRED** Federal Reserve Economic Data (database of Federal Reserve Bank of St. Louis)

**FRM** Fixed-rate mortgages

**GDP** Gross domestic product

**GMM** Generalized method of moments estimator

**G-SII** Global Systemically Important Institution

**LCR** Liqudity Coverage Ratio

**LIBOR** London interbank offered rate

**LOLR** Lender of last resort

**LSDV** Least squares dummy variables estimator

**MBS** Mortgage-backed securities

**NIM** Net interest margin

**NSFR** Net Stable Funding Ratio

**OECD** Organisation for Economic Co-operation and Development

**OLS** Ordinary least squares estimator

**O-SII** Other Systemically Important Institution

**PRIBOR** Prague interbank offered rate

**ROAA** Return on average assets

**ROAE** Return on average equity

**SME** Small and medium enterprises

**ST** short-term

**UK** United Kingdom of Great Britain and Northern Ireland

**US/U.S.** United States of America

**USD** U.S. dollar (currency unit)

**ZLB** Zero lower bound

**3M** 3-months tenor (of a financial instrument)

**1Y** 1-year tenor (of a financial instrument)

**10Y** 10-year tenor (of a financial instrument)

# Chapter 1

# General Introduction

Nowadays, banks are an important part of the financial system which play a crucial role in the modern economy by enabling the transfer of funds from subjects with an excess of funds to subjects seeking funding for their planned investment or consumption. The role of banks is even more important in countries with so called bank-based financial markets, where most financial intermediation occurs via the banking system, in contrast to the so-called capital-based financial markets, where a substantial part of the intermediation occurs directly through the capital markets where companies issue their debt or shares to obtain the necessary funding.

In the decade following the global financial crisis of 2007-2009 and the sovereign debt crisis in 2010-2012, the banks had to face an unprecedented situation of a very low interest rate environment. This situation is often referred to as the zero lower bound (ZLB) of interest rates. (In past the macroeconomic theories used to describe this situation as the "liquidity trap".) In "normal" times of higher interest rates, the monetary policy conducted by a central bank can help to stabilize the economy via the raising or decreasing of interest rates. However, in that ZLB situation conventional monetary policy could not be used, and the central banks came up with multiple unconventional monetary policy tools.

Many central banks have, in the years since the global financial crisis, adopted some kind of so-called quantitative easing, suggested prior to the crisis by among others Bernanke & Reinhart (2004), which means the large-scale purchases of assets by the central bank and the expansion of its balance sheet with the aim of flattening the yield curve, i.e. decreasing the long-term interest rates. The purchased assets within these quantitative easing programs were mainly government bonds, but they may include also certain commercial papers with a high rating.

Another possible way of escaping ZLB situation was suggested by Svensson (2003) who proposed a strategy called "The Foolproof Way" for escaping from deflation and the liquidity trap. Under this strategy, the central bank should commit to a higher future price level: that is, it should adopt price-level targeting, a clear, strong action that demonstrates the central bank's desire to achieve its goal, and an exit strategy for a return to "normal" monetary policy when the unconventional measures are no longer necessary. As an example of this approach, we may cite the exchange rate commitment of the Czech National Bank (CNB) in 2013-2017 described in Franta *et al.* (2014).

Although it was traditionally believed that monetary policy rates cannot fall below zero, negative rates eventually became another unconventional monetary policy tool. Empirical studies, such as Havránek & Kolcunová (2018), have shown that the effective lower bound for monetary policy interest rates is actually not exactly zero, but a certain value slightly below zero. During the 2010s, the European Central Bank (ECB) and other central banks in Europe adopted negative policy rates as their monetary policy tool, and some of them (including the ECB) have kept them at the negative territory until the present day.

The above mentioned changes in the conduct of monetary policy in the last decade together with the enhanced regulation known as Basel III, which were introduced after the global financial crisis meant a big change in the environment in which European and American banks operate. The topics of the impact of unconventional monetary policy and a low or even negative interest rate environment on banks' profitability have attracted many researchers such as Borio *et al.* (2017), Bikker & Vervliet (2017) and Claessens *et al.* (2018).

This dissertation consists of four papers that deal with the impact of this low and negative interest rate environment on the profitability and liquidity positions of the banks during the last decade.

The paper entitled *"Key Determinants of the Net Interest Margin of EU Banks in the Zero Lower Bound of Interest Rates"* examines the impact of the low and negative interest rate environment on the net interest margin of European banks. This paper builds on previous studies, such as Borio *et al.* (2017), regarding the link between the net interest margin (NIM) of banks and the interest rate structure proxied by the short-term interbank rate and the slope of the yield curve (the difference between 10-year government bond yield and the short-term interbank rate). In addition to the topics of the previous studies, we consider market concentration as another country-specific factor impacting the NIM, as the previous studies on the impact of market concentration did not consider the impact of a ZLB environment.

The empirical analysis is conducted on a panel data sample of 629 banks located in the EU countries with annual data from the period 2011-2016. The composition of the sample allowed for the consideration of certain bank-specific characteristics, such as the type of bank according to specialization (recognizing five types of banks: bank holdings & holding companies, commercial banks, cooperative banks, savings banks, and real estate & mortgage banks) or the size of the bank (based on total assets). The estimation was done using the system GMM as the main estimation method and other standard panel data estimation methods for supplementary analyses and robustness checks.

The results show that the impact of low and negative interest rate environment on NIM is positive concave, but at the same time it shows differences according to the specialization types. Another important finding is the significant positive impact of market concentration, which suggests that banks with greater oligopolistic power are able to maintain better NIM, thus implying that a certain level of market concentration may be desirable from the regulator's point of view in order to support the stability of the banking sector.

The second paper, entitled *"Key Factors of the Net Interest Margin of European and US Banks in a Low Interest Rate Environment"* focuses on the determinants of NIM in a ZLB environment in the United States and EU, while also considering institutional design factors, i.e. the difference between bank-based and capital-based financial markets. This paper uses a methodological approach similar to the previous one, considering the impact of the market interest rate structure and other country-specific factors on NIM while, at the same time, controlling for bank-specific characteristics such as specialization type or bank size. The empirical analysis is done on a sample of 1,155 banks from the EU and United States of America, with annual observations for the years 2011-2016 using the system GMM as the main estimation approach. In this paper we come to three main conclusions: Firstly, that NIM is significantly impacted by the different institutional designs of capital-based (the United Kingdom and the United States) and bank-based financial markets (continental Europe). Secondly, there are differences in NIM caused by bank size, and thirdly, that the differences in NIM are observable according to bank type: savings banks, real estate & mortgage banks and cooperative banks report consistently lower NIMs than the other two types - bank holdings & holding companies and commercial banks. In contrast to other researchers, we find a negative relationship between NIM and the slope of the yield curve.

The third paper, entitled *"Prepayment Risk in Banking: Impact Assessment of the Changing Interest Rate in the Czech Republic"* considers prepayment risk as the risk of an unscheduled early repayment of the principal of the mortgage loan. This paper offers a case study of the mortgage market in the Czech Republic. Prepayment risk becomes an important risk to be considered by banks in a low interest rate environment when a loan features an embedded option allowing the client to refinance the loan with a new loan with a lower interest rate. This risk was to a certain extent strengthened by a new Czech consumer credit law approved in 2016 that allowed the client to prepay up to 25% of the mortgage per year free of charge.

In our theoretical and empirical modeling we have shown how prepayments lead to the deterioration of the NIM when the yield curves are moving down, as was the case during the period 2009-2017. In the case of increasing market interest rates, the bank could theoretically gain on the prepayments, but on the other hand, in such circumstances the incentives for clients to prepay are low and the prepayments occur at the lowest percentage (referred to as "natural prepayment") simply for reasons unrelated to the interest rate environment, e.g. due to sale of a property, marriage, divorce, the client's moving to another city, etc.

The last paper, entitled *"Liquidity Positions of EU banks in the Low Interest Rate Environment under LCR Constraint"* focuses on the impact of the introduction of the liquidity coverage ratio (LCR) designed within the Basel III regulatory framework as a binding constraint for banks in the EU. A unique panel dataset of 707 banks located in EU countries with observations for the period 2012-2018 enables the consideration of the gradual phase-in of the LCR, starting at 60% in 2015 and ending at 100% in 2018. Moreover, it considers the situation of low and negative interest rate environment during that time period. The estimation is done using standard panel data methods (fixed effects and random effects). The results show significant impact on the liquidity ratios of the LCR requirement (positive impact) and the existence of a negative interest rate environment (negative impact). Separate estimations for different specialization types of banks show that the impact of LCR does not significantly differ between those types of banks, while the impact of a negative interest rate environment is stronger in the case of cooperative and savings banks.

The remainder of this dissertation thesis is organized as follows. Chapter 2 consists of the paper entitled *"Key Determinants of the Net Interest Margin of EU Banks in the Zero Lower Bound of Interest Rates"*. Chapter 3 is the paper entitled *"Key Factors of the Net Interest Margin of European and US Banks in a Low Interest Rate Environment"*. In Chapter 4 the paper entitled *"Prepayment Risk in Banking: Impact Assessment of the Changing Interest Rate in the Czech Republic"* is included. Finally, Chapter 5 is the paper entitled *"Liquidity Positions of EU banks in the Low Interest Rate Environment under LCR Constraint"*.

# Chapter 2

# Key Determinants of the Net Interest Margin of EU Banks in the Zero Lower Bound of Interest Rates[1]

## 2.1 Introduction

The last decade was characterized by an unprecedented situation of very low – even negative – interest rates in major economies, which was a new situation not covered in the literature. As a result, this topic has attracted many researchers, such as Borio *et al.* (2017) and Claessens *et al.* (2017), who have tried to estimate an impact of the zero lower bound of interest rates (ZLB) on bank profitability and the effectiveness of monetary policy.

We contribute to the literature by examining key determinants of the net interest margin (NIM) of EU banks in the situation of ZLB. By definition, NIM is closely linked to the overall interest rate environment, which reflects macroeconomic conditions and the monetary policy in a given country. The relevant literature on the determinants of bank profitability, specifically including NIM, was thus mainly concerned with the link between bank profitability and unconventional monetary policy measures, the resulting low or negative rate environment and the problem of ZLB. For instance, Borio *et al.* (2015) found a positive concave relationship between short-term interest rates and bank profitability, i.e., a higher sensitivity in the case of interest rates close to zero.

[1]This chapter has been published as Hanzlík & Teplý (2019).

The objective of this paper is to build on previous studies on the link between NIM and interest rate structure and to consider other factors influencing the NIM. Some previous studies considered the impact of specific market characteristics such as market concentration. However, in contrast to our paper, they have not focussed on the impact of interest rate structure on NIM in a ZLB situation as their main objective.[2] Findings of these studies suggest that banking institutions with higher oligopolistic power may attain higher profitability, which is worthwhile to take into account when considering other determinants.[3] We also aim to include certain bank-specific variables that reflect various business models of individual banks or their size in our analysis because there are likely to be differences in bank profitability based on these characteristics. For this purpose, we use unique annual data on 629 banks located in 24 EU member countries from 2011-2016. This period was characterized by interest rates close to zero and even below zero in 2015 and 2016. The sample thus allows us to examine the impact of market rates on NIM in a situation of ZLB, which makes our research unique.

The remainder of the paper is structured as follows. Section 2.2 provides a review of the literature on the impact of interest rates and monetary policy on bank profitability. Based on this overview, we state three hypotheses. In Section 2.3, we conduct an empirical analysis. We describe the used dataset, introduce selected variables and provide descriptive analysis of the data. Section 2.4 contains the description of our methodology. Results and findings are presented in Section 2.5, where we also discuss further research opportunities.

[2] The impact of market concentration on the NIM was considered by Claeys & Vander Vennet (2008), who studied the interest margin of banks in Central and Eastern Europe. However, their study uses data from the 1994-2001 period, which cannot be considered a ZLB situation, in contrast to the 2011-2016 period covered in this paper. Similarly, Saona (2016) uses an approach similar to our methodology, including concentration as one of the regressors, but his sample includes only Latin American banks. One of the earlier studies considering the impact of market concentration on bank performance is Bourke (1989). Market concentration as one of the determinants of bank profitability is used also in Kok *et al.* (2015) within the EU Financial Stability Report, but they use return on assets (ROA) rather than NIM.

[3] Berger & Hannan (1989) examine the traditional structure-performance hypothesis that assumes that more concentrated market will lead to lower client deposit rates (as a result of collusive behaviour of the banks) in contrast to efficient structure hypothesis that assumes more favourable rates for clients as a result of greater operational efficiency of banks in more concentrated markets. Their empirical results show that indeed the higher concentration leads to lower deposit rates, i.e. confirming the structure-performance hypothesis. Other studies, such as Nabar *et al.* (1993) or Mester & Saunders (1995) discuss also the impact of menu costs on the sluggish adjustment of banks' loan rates. Tripe *et al.* (2005) then analyses the impact of change in the monetary policy regime in New Zeland on the changes in the banks' lending rates finding that the speed of rate adjustment increased.

Finally, Section 2.6 concludes the paper.

## 2.2 Literature Review

The main purpose of this paper is to consider the impact of numerous factors on NIM, which is one of the most common measures of bank profitability.[4] The literature on bank profitability from recent years is concerned mainly with the impact of the very low and in some cases even negative interest rate environment resulting from the unconventional monetary policy major central banks have pursued since the outbreak of the global financial crisis in 2007-2009.

Borio *et al.* (2017) studied the impact of monetary policy on bank profitability. They used annual data for 109 large international banks headquartered in 14 major advanced economies from the Bankscope database covering the period 1995-2012. They used the system GMM method to estimate multiple models, each with a certain income component as the dependent variable. The explanatory variables included the three-month interbank rate and the difference between 10-year government bonds and the three-month interbank rate as a proxy for the slope of the yield curve, both variables serving as monetary policy indicators. To capture assumed nonlinearity in their impact, they also included the quadratic forms of these two variables. The models included other variables controlling for various macroeconomic or bank-specific factors. They found a positive correlation of bank return on assets (ROA) with both the level of interest rate and the steepness of the yield curve. According to their findings, this positive impact of higher short-term rate and steeper yield curve is driven by their positive impact on net interest margin.

Another study of the impact of "low-for-long" interest rates on bank profitability, specifically on NIM, was done by Claessens *et al.* (2017). Their study uses balance sheet and income statement annual data on 3385 banks from 47 countries obtained from Bankscope for 2005-2013. NIM in their model is regressed on the three-month government bond yield, the spread between 10-year and three-month government bond yield, a dummy variable detecting whether the country was in a "low rate environment" (defined as the three-month rate being below 1.25 per cent), and a set of country specific and bank-specific variables. The regression is done for the whole sample and for various subsamples, e.g.,

[4] Other common profitability measures used in the banking industry include return on assets (ROA), return on equity (ROE) and cost-to-income ratio Mejstřík *et al.* (2014), Golin & Delhaise (2013).

for a low-rate environment and a high-rate environment separately, or they decomposed NIM to interest income margin and interest expense margin and used them as dependent variables instead. They discovered that the impact of interest rates on NIM is higher in a situation of low interest rates than in one of high interest rates. Additionally, the impact is stronger on interest income margin than on interest expense margin. On the other hand, they admit that there might be nonlinearities in transmission from interest rate changes to NIM not captured by their methodology; specifically, they mention differences between banking systems.

A similar modelling approach is used by Bikker & Vervliet (2017), who consider the impact of low interest rates on bank profitability and risk taking. Using data on 3582 U.S. banks obtained mainly from the Federal Deposit Insurance Corporation, they considered the impact on NIM using variables capturing the effect of the interest rate environment, other macroeconomic factors, and bank-specific factors. The results are comparable to those of both Borio *et al.* (2015) and Claessens *et al.* (2017), finding a positive and concave impact of short-term interest rates. They also determined that larger banks tend to have somewhat lower margins, which may be explained by an assumption that larger banks' profitability includes a larger portion of non-interest income.

The impact of unconventional monetary policy and a low-interest rate environment on bank profitability was studied by Altavilla *et al.* (2017). The paper focusses solely on the Euro Area, exploiting a cross section of European bank accounting data with quarterly frequency from June 2007 to January 2017. The models used ROA as a profitability measure and individual profitability components, such as net interest income or non-interest income. They found a rather insignificant short-term impact of monetary policy, represented by the short-term rate and slope of the yield curve variables on overall profitability (when treated for its endogeneity) using various settings of models including bank specific and country-specific variables. In the case of the net interest income itself, they found a positive impact of short-term rates but an insignificant impact of the slope of the yield curve. However, they estimated both relationships only as linear.

Other studies on a somewhat similar topic include Arseneau (2017a) and Kerbl & Sigmund (2017). In addition to empirical evidence, Borio *et al.* (2015) provide a theoretical explanation of the impact of decreasing interest rate and flattening yield curve on bank profitability, i.e., the impact of unconventional monetary policy transmission. More recently, Brei & Borio (2019) find that low interest rates induce banks to shift their activities from interest-generating to fee-related and trading activities, what has partially offset the fall in banks' interest margin.

Theoretical papers regarding the problem of zero lower bound on nominal interest rate and providing the reasoning for various unconventional monetary policy tools such as quantitative easing or use of exchange rate include, e.g., Bernanke & Reinhart (2004), Jung *et al.* (2005), Svensson (2003), Svensson (2006), Cúrdia & Woodford (2011), Franta *et al.* (2014) and McCallum (2000).

Based on the previous literature survey, we formulate three hypotheses for our research:

**Hypothesis #1 (erosion of NIM):** The NIM of EU banks eroded in the low or even negative interest rate environment regardless of bank type (bank holdings, commercial, cooperative, savings, or real estate & mortgage banks). We hypothesize that a low-interest rate period (since 2015, including even negative short-term rates in the Euro Area and a few other EU member countries) will have a negative impact on the NIM of all those types of bank.

**Hypothesis #2 (influence of market concentration):** Profitability depends on specific market characteristics. Specifically, higher market concentration in general leads to a lower decrease in NIM. The second hypothesis assumes that the situation differs for each country based on specific market characteristics such as bank ownership structure or market concentration. Previous studies on the link between NIM and interest rate structure in a situation of ZLB did not control for the impact of these factors on bank profitability, which makes our research unique. Because the used dataset does not allow consideration of the ownership structure, the focus is placed on market concentration. The assumption is that a higher market concentration will result in a lower decrease of bank NIM.

**Hypothesis #3 (nonlinearity in the impact of market rate):** Following the results of previous studies, we assume that the impact of a change in interest rate should be significantly greater when the level of interest rate is low. In other words, the closer the market rates are to zero, the more sensitive the NIM should be to changing interest rate.

## 2.3 Empirical Analysis

### 2.3.1 Dataset

Our dataset, which is based on the Orbis Bank Focus database, includes 629 banks from 24 EU member countries. Data were selected for active banks from EU28 countries whose specialization was ranked as bank holdings & holding companies, commercial banks, cooperative banks, real estate & mortgage banks, or savings banks. The data were then filtered by variables assumed for use in the model to achieve a balanced panel for 2011-2016 with no missing observations.

The dataset was then extended by a set of country-specific variables, i.e. GDP growth rate, inflation rate, unemployment rate, 3M interbank rate, 10Y government bond yield, and the Herfindahl index of total assets of credit institutions[5]. GDP growth, inflation rate, and unemployment rate were available in Orbis Bank Focus only for the 2013-2016 period. Short-term interest rate, long-term interest rate and the Herfindahl index variables were not available in Orbis Bank Focus at all. For this reason, country-specific variable data for the whole observed period were obtained from other sources.
The source for the country-specific variables was Eurostat, with the exception of the Herfindahl index data, which were obtained from the Statistical Data Warehouse of the European Central Bank. The 3M interbank rate data for the whole observed period were available only for the Euro Area, Denmark, Sweden, and the United Kingdom; for other countries outside the Euro Area, the last available year was 2014. Therefore, the data for 2015 and 2016 for the Czech Republic were obtained from the Czech National Bank, and for Hungary and Poland, they were obtained from the OECD. Banks from Bulgaria, Croatia and Romania were removed from the sample (35 banks altogether) due to unavailability of a reliable source of data for short-term rates in 2015 and 2016. Long-term rates were proxied by EMU convergence criterion bond yields. Unfortunately, this yield is not available for Estonia because the Es-

[5]Except for the Herfindahl index, market concentration may also be proxied by the Lerner index or by a concentration ratio. The Herfindahl index was chosen mainly due to the best data availability compared to the other measures. The concentration ratio is used by SDW of ECB only in connection with payment services, while the Lerner index is available in the FRED database, but only until 2014. Moreover, as Kraft (2006) shows, the Lerner index, which measures the price mark-up, may be influenced by factors other than market concentration.

Table 2.1: Bank specific variables

| | | |
|---|---|---|
| *Natural logarithm of total assets of the bank* | This variable serves commonly as an approximation of the size of the bank. Transformation by natural logarithm is used in order to smooth out large differences in size of individual banks. | *lta* |
| *Net loans to total assets ratio* | Indicates what portion of total assets is made up of loans. Hence it can be considered a credit risk ratio. Expected sign of the coefficient is ambiguous because a higher value of the ratio may relate to lack of liquidity while low value may lead to a decrease in net interest income. | *nl_ta* |
| *Net loans to deposits and short term funding ratio* | Reflects structure of the balance sheet and especially the liquidity of the bank. | *nl_dstf* |
| *Loan loss reserves to gross loans ratio* | Measures the quality of a bank's assets by evaluating the part of loans put aside for potential charge-off. | *llr_gl* |
| *Cost to income ratio* | Indicator of bank's operational efficiency. Generally, the impact on profitability is supposed to be negative. It should hold for NIM as well since NIM is directly linked to the denominator of the cost to income ratio. | *cir* |
| *Liquid assets to deposits and short term funding ratio* | Liquidity measure capturing the liquid part of the asset side of the bank's balance sheet. | *la_dstf* |
| *Equity to total assets ratio* | Leverage ratio measuring the indebtedness of the bank and its ability to absorb potential losses. The expected sign of the coefficient is unclear since a low ratio may indicate insufficient capital, while a high ratio can be the result of foregone investment opportunities. | *eq_ta* |

*Note:* Source of all variables is Orbis Bank Focus database.

tonian government has issued no such instrument. Hence, the only remaining bank located in Estonia was also removed from the dataset. The final dataset is a balanced panel of 629 cross-sectional units and 6 time units. Other variables, i.e., various dummies or logarithms and squares of certain variables, were computed within this panel.

Table 2.2: Bank specific dummy variables

| | | |
|---|---|---|
| *Bank holdings & holding companies* | Equals 1 for specialisation Bank holdings & holding companies. | *bhhc* |
| *Cooperative banks* | Equals 1 for specialisation Cooperative banks. | *coop* |
| *Real estate & mortgage banks* | Equals 1 for specialisation Real estate & mortgage banks. | *rem* |
| *Savings banks* | Equals 1 for specialisation Savings banks. | *saving* |
| *Large banks* | Equals 1 for banks whose total assets in 2016 were at least USD 30 billion. | *large* |
| *Small banks* | Equals 1 for banks whose total assets in 2016 were below USD 1 billion. | *small* |

*Note:* Variables calculated by authors based on Orbis Bank Focus data.

Table 2.3: Country specific variables

| | | |
|---|---|---|
| *Real annual GDP growth rate* | Annual growth rate of real GDP obtained from Eurostat. The coefficient is likely to be positive. | *gdp* |
| *Inflation rate* | Annual inflation rate obtained from Eurostat. The expected impact on NIM is ambiguous. | $infl$ |
| *Unemployment rate* | Annual unemployment rate obtained from Eurostat. Higher unemployment should have a negative impact on NIM. | *unem* |
| *Short-term interest rate* | For most observations 3M interbank rate is obtained from Eurostat, except for the Czech Republic, Hungary and Poland in years 2015 and 2016 as described in the text. | $st\_ir$ |
| *Square of the short-term interest rate* | Due to assumed non-linearity in the impact of short-term rate, its square is used. | $st\_ir^2$ |
| *Slope of the yield curve* | Approximated by spread between 3M interbank rate and 10Y government bond yield. | *spread* |
| *Square of the slope of the yield curve* | Similarly to short-term rate the square of the yield curve slope is included to capture assumed non-linearity. | $spread^2$ |
| *Herfindahl index* | Measure of market concentration in terms of total assets of credit institutions as defined by EU legislation. Obtained from SDW of ECB. | *hi* |
| *Negative short-term interest rate dummy* | Equals 1 for each country that had a negative short-term interest rate in a given year. | *negrate* |

*Note:* Source of 3M interbank rate data in 2015 and 2016 for Czech Republic is CNB, for Hungary and Poland OECD.

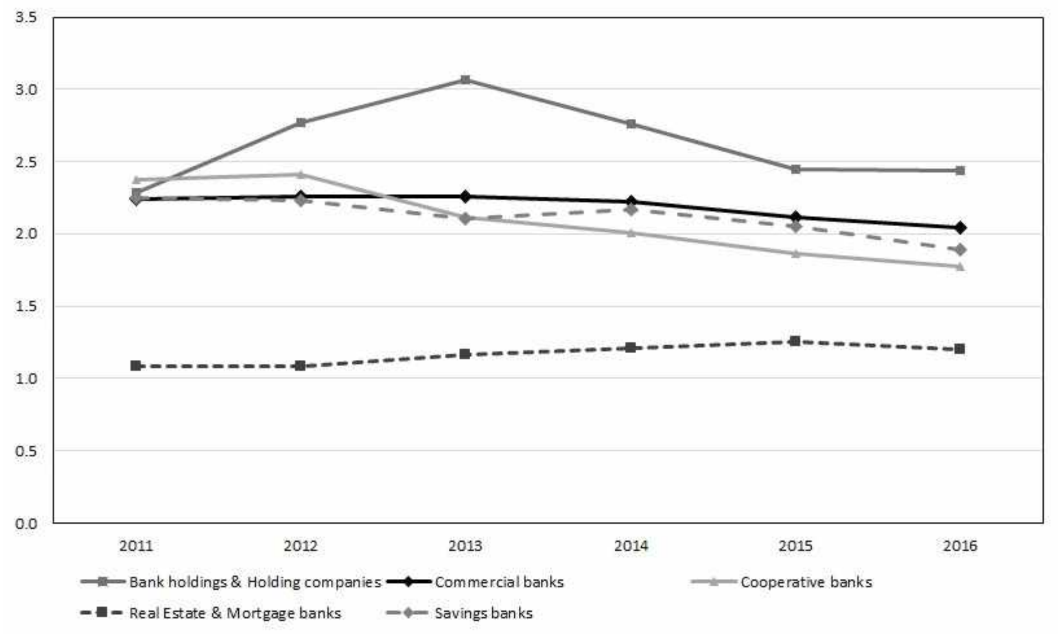
### 2.3.2 Variable selection

We selected variables based on studies on the topic of bank profitability and the impact of interest rate on that profitability, including Arseneau (2017b), Borio *et al.* (2015), Borio *et al.* (2017), Claessens *et al.* (2017), and Fišerová *et al.* (2015). Descriptions of bank-specific variables are provided in Table 2.1, of bank-specific dummy variables in Table 2.2, and of country-specific variables in Table 2.3.

### 2.3.3 Descriptive Analysis

Our dataset includes 132 large banks, 268 medium size banks, and 229 small banks. In terms of bank specialization, it covers 26 bank holdings & holding companies, 235 commercial banks, 272 cooperative banks, 45 real estate & mortgage banks, and 51 savings banks. Numbers of banks from individual countries are provided in Table A.5; summary statistics of all variables are reported in Table A.1 in the Appendix.

Figure 2.1: Average NIM by bank specialisation (%) in EU in 2011-2016

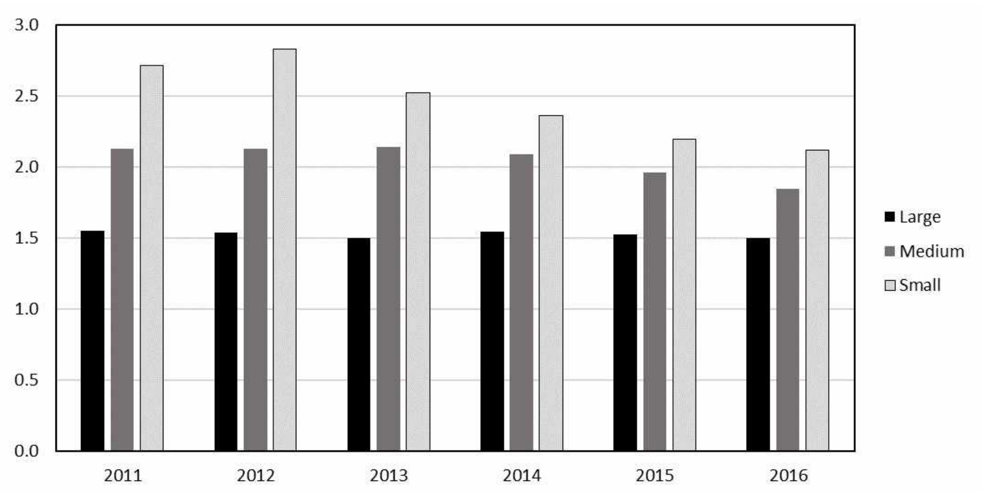



*Source:* Authors based on Orbis Bank Focus.

Figure 2.1 shows the development of average NIM for each of the bank special-

izations. We can see that in the case of bank holdings & holding companies, the time series is relatively unstable. This instability may be caused by the fact that in the dataset restricted only to EU-based banks, there is a very low share of this type of bank. Hence, in such a small sample, an irregularity, caused, e.g., by repricing, may influence the time series' behaviour significantly. Therefore, the figure for bank holdings & holding companies is rather inconclusive.
For the other types of bank, we can distinguish two cases. In the case of cooperative and savings banks, we see a quite sustained and relatively substantial decrease in the period 2011-2016 (approximately 60 basis points for cooperative and approximately 36 basis points for savings banks). On the other hand, in the case of commercial and real estate & mortgage banks, we see a more-stable NIM (20 basis point decrease for commercial banks and 11 basis point increase for real estate & mortgage banks). Overall, these results suggest that Hypothesis #1 be rejected, since we cannot conclude that the protracted period of low and later negative rates in the EU would erode profitability of all types of bank to the same extent.

Figure 2.2: Average NIM by bank size (%) in EU in 2011-2016




*Source:* Authors based on Orbis Bank Focus, Eurostat.

Figure 2.2 displays that the large banks in the EU reported the lowest average NIM, the highest NIM was reported by small banks, while the medium-sized banks came second. Another interesting result is that in the case of the large banks, the average NIM is quite stable during the whole observed period. On the other hand, the small banks' average NIM between 2012 and 2016 dropped by almost 71 basis points, which is another source of evidence that there are

likely to be differences in response to changing interest environment due to bank heterogeneity, in this case heterogeneity by size.
A theoretical explanation for this difference in NIM by size may be that large banks have an advantage in management of their interest spread since they are likely to have diversified more both the loan and the deposit portfolios and have a better position in obtaining funding from the interbank market. The diversification of the loan and deposit portfolios is determined by multiple factors, for example, territorial diversification or client segment diversification. Under territorial diversification, we mean that large banks are more likely to operate in multiple regions with different economic conditions, while small banks usually operate in certain relatively small and economically homogeneous regions. Regarding client segmentation, we assume that large banks are likely to serve all or a majority of client segments, i.e., retail clients, SMEs, private banking clients, or large corporations, while small banks may be focussed on just one or a few of these segments.
Another important feature of the loan and deposit portfolios of small and medium banks, which is likely partially influenced by diversification opportunities, is that they tend to have a higher risk profile compared to the risk profile of the large banks' portfolios. This feature may explain the faster decrease in NIM visible in Figure 2.2. Moreover, the assumption of riskier portfolios is supported by Figure 2.3, which shows a significant increase in the loan loss reserves to gross loans ratio for small and medium banks and relative stability of this ratio for large banks over the observed period.

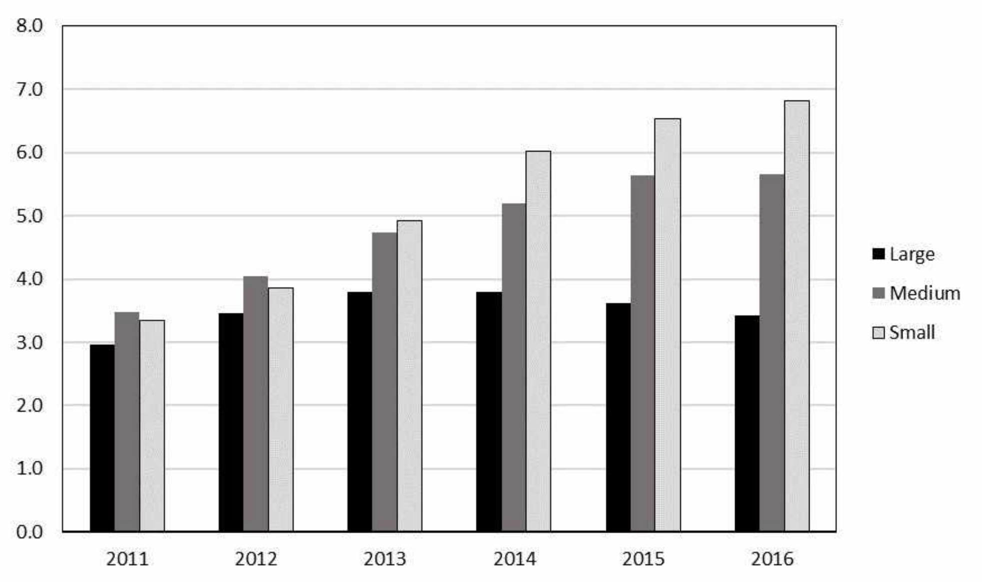
## 2.4 Methodology

We applied a standard methodology used for panel data. For estimation with the panel dataset, we can consider using either static or dynamic panel data methods. Static methods such as pooled OLS, fixed effects (within or LSDV estimator) or random effects (FGLS estimator) allow under certain assumptions the estimation of at least a consistent model of the following form:

$$y_{it} = \alpha + \boldsymbol{x'_{it}}\boldsymbol{\beta} + c_i + \epsilon_{it} \tag{2.1}$$

where $i = 1, \ldots, N$ (cross-sectional units) and $t = 1, \ldots, T$ (time periods), $c_i$ is

Figure 2.3: Average loan loss reserves to gross loans ratio by size (%) in EU in 2011-2016




*Source:* Authors based on Orbis Bank Focus, Eurostat.

the unobservable group-specific fixed or random effect and $\epsilon_{it} \sim i.i.d.\, N(0, \sigma_\epsilon^2)$. To estimate a dynamic panel data model of the form:

$$y_{it} = \alpha + \delta y_{i,t-1} + \boldsymbol{x'_{it}\beta} + c_i + \epsilon_{it} \tag{2.2}$$

where $y_{i,t-1}$ is one-period-lagged dependent variable, we cannot use any of those methods because they would produce biased and inconsistent estimates.

For dynamic panel data, we have available two methods that use instrumental variables within a generalized method of moments (GMM) framework. The difference GMM was developed in Arellano & Bond (1991), and the system GMM was proposed by Arellano & Bover (1995) and Blundell & Bond (1998). A disadvantage of difference GMM is that we can estimate the model only in first differences; using this approach, we would not be able to use the set of group-specific dummy variables. Therefore, we use the other option – system GMM. In this method, the model is estimated in levels and differences jointly and instrumented by both lagged differences and lagged levels of the dependent variable, respectively. Therefore, it allows us to estimate the model including a set of dummy variables.

The basic setup of the estimated model is as follows:

$$nim_{it} = \alpha + \delta nim_{i,t-1} + \theta_1 st\_ir_{it} + \theta_2 st\_ir_{it}^2 + \theta_3 spread_{it} + \\ + \theta_4 spread_{it}^2 + \boldsymbol{x'_{it}\beta} + \boldsymbol{d'_{it}}\gamma + \boldsymbol{z'_{it}\phi} + (c_i + \epsilon_{it}) \quad (2.3)$$

where $\boldsymbol{x'_{it}}$ is a vector of bank specific variables listed in Table 2.1, $\boldsymbol{d'_{it}}$ is a vector of bank specific dummy variables listed in Table 2.2, $\boldsymbol{z'_{it}}$ is a vector of country specific variables listed in Table 2.3 except for short-term interest rate, slope of the yield curve and their squares which are pointed out as the variables of main interest. Finally, the error term consists of a fixed effects component $c_i$ and an exogenous component $\epsilon_{it}$.
System GMM is used as the main estimation methodology in this paper. However, to obtain more-robust evidence of the validity of estimated relationships, we performed the estimation of the dynamic model using static methods and the estimation of a static model (without a lagged dependent variable). The results are presented in the Appendix in Table A.3 and Table A.4.

## 2.5 Results and Findings

As presented in the previous section, our estimates are conducted using the system GMM method. The estimation is performed using second and further lags of the dependent variable as instruments for the differenced equation and using second and further lags of differences of the dependent variable as instruments for the equation in levels. For the estimation, the Stata command *xtabond2* developed in Roodman (2009) is used. More precisely, the command is used with a two-step GMM option and a robust option that requests the Windmeijer (2005) correction. Theoretically, this method should be superior, according to Roodman (2009).
System GMM estimation results of the basic model are reported as column (1) in Table 2.4. The results confirm that the relationship between NIM and short-term interest rate is concave as suggested by previous studies. On the other hand, in the case of the slope of the yield curve, we see a significant (at least on a 10% level), negative coefficient for the linear term but an insignificant coefficient for the quadratic term,[6] suggesting that it might be more accurate

[6]The negative relation to NIM may seem to be counterintuitive and contradictory to the previous empirical results. However, Borio *et al.* (2015) provide a theoretical explanation for

Table 2.4: System GMM estimation results

| | (1) nim | (2) nim | (3) nim | (4) nim |
|---|---|---|---|---|
| L.nim | 0.862*** | 0.859*** | 0.863*** | 0.865*** |
| | (0.0159) | (0.0156) | (0.0149) | (0.0148) |
| st_ir | 0.143*** | 0.147*** | 0.147*** | 0.150*** |
| | (0.0231) | (0.0232) | (0.0231) | (0.0228) |
| st_ir_sq | -0.0268*** | -0.0287*** | -0.0290*** | -0.0292*** |
| | (0.00541) | (0.00561) | (0.00535) | (0.00529) |
| spread | -0.0226* | -0.0374*** | -0.0365*** | -0.0357*** |
| | (0.0128) | (0.00842) | (0.00844) | (0.00824) |
| spread_sq | -0.000912 | - | - | - |
| | (0.000751) | | | |
| gdp | 0.00848** | 0.00769* | 0.00918** | 0.00835* |
| | (0.00418) | (0.00429) | (0.00442) | (0.00443) |
| infl | 0.0547*** | 0.0598*** | 0.0632*** | 0.0635*** |
| | (0.0106) | (0.00963) | (0.00976) | (0.00980) |
| unem | 0.00247 | 0.00410 | 0.00247 | 0.00261 |
| | (0.00301) | (0.00288) | (0.00294) | (0.00297) |
| hi | 0.490** | 0.478** | 0.464** | 0.548** |
| | (0.208) | (0.197) | (0.214) | (0.214) |
| lta | -0.0210** | -0.0221*** | -0.0210*** | -0.0203*** |
| | (0.00819) | (0.00806) | (0.00791) | (0.00756) |
| llr_gl | 0.00746*** | 0.00760*** | 0.00760*** | 0.00704*** |
| | (0.00195) | (0.00187) | (0.00185) | (0.00184) |
| eq_ta | 0.00588** | 0.00619** | 0.00704*** | 0.00742*** |
| | (0.00262) | (0.00255) | (0.00262) | (0.00262) |
| cir | -0.000778** | -0.000790** | -0.000787** | -0.000896*** |
| | (0.000309) | (0.000318) | (0.000311) | (0.000309) |
| nl_ta | 0.00436*** | 0.00431*** | - | - |
| | (0.000819) | (0.000802) | | |
| nl_dstf | -0.000283 | -0.000255 | 0.000704*** | - |
| | (0.000204) | (0.000203) | (0.000174) | |
| la_dstf | -0.000109 | -0.000138 | -0.00175*** | -0.00162*** |
| | (0.000505) | (0.000494) | (0.000434) | (0.000535) |
| bhhc | 0.0274 | 0.0269 | 0.00145 | 0.00309 |
| | (0.0462) | (0.0455) | (0.0467) | (0.0472) |
| coop | -0.0835*** | -0.0824*** | -0.103*** | -0.0906*** |
| | (0.0190) | (0.0189) | (0.0203) | (0.0205) |
| rem | -0.116*** | -0.121*** | -0.122*** | -0.0684** |
| | (0.0373) | (0.0359) | (0.0384) | (0.0349) |
| savings | -0.0486** | -0.0488** | -0.0389* | -0.0306 |
| | (0.0230) | (0.0232) | (0.0237) | (0.0240) |
| large | 0.0603** | 0.0583** | 0.0456 | 0.0508* |
| | (0.0286) | (0.0285) | (0.0287) | (0.0277) |
| small | 0.00796 | 0.00878 | -0.00394 | -0.00589 |
| | (0.0230) | (0.0229) | (0.0242) | (0.0244) |
| Constant | 0.216 | 0.243* | 0.443*** | 0.474*** |
| | (0.148) | (0.145) | (0.150) | (0.144) |
| Number of Observations | 3145 | 3145 | 3145 | 3145 |
| Number of Groups | 629 | 629 | 629 | 629 |
| Number of instruments | 31 | 30 | 29 | 28 |
| Wald statistic | 13576.7*** | 13364.4*** | 13018.6*** | 12936.8*** |
| Arellano-Bond AR(1) | -1.31 | -1.31 | -1.31 | -1.31 |
| Arellano-Bond AR(2) | 0.44 | 0.45 | 0.44 | 0.44 |
| Hansen test | 12.89 | 12.67 | 10.22 | 9.57 |

*Notes:* Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

*Source:* Authors' calculation in Stata 11.2.

Table 2.5: Lagged dependent variable coefficients in S-GMM, FE, and Pooled OLS - robustness check

| | FE | S-GMM | Pooled OLS |
|---|---|---|---|
| | nim | nim | nim |
| L.nim | 0.110 | 0.862*** | 0.928*** |
| | (0.0951) | (0.0159) | (0.0748) |

*Note:* Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

*Source:* Authors' calculation in Stata 11.2.

to specify the relationship as linear. For the other macroeconomic variables, we see a significant positive impact of GDP growth and for inflation. In contrast to other macroeconomic variables, the coefficient of unemployment is insignificant.

The Herfindahl index is the most interesting country-specific variable in our model besides interest rate structure. We have estimated a significantly positive coefficient of this variable. This estimation is consistent with the assumed relation that in general, a higher market concentration should lead to a higher NIM.

Bank-specific variables are mostly significant. The only two exceptions are the variables *net loans to deposits & short-term funding* and *liquid assets to deposits & short-term funding*. In this case, it may be a problem with the correlation with *net loans to total assets*. We see a significantly negative coefficient for *logarithm of total assets*, which probably captures most of the size effects because the dummy variable for small banks is insignificant; while the dummy variable for large banks is significant, it has a positive coefficient contradictory to the patterns in Figure 2.2.

The positive coefficient of *loan loss reserves to gross loans* may signal that banks accepting a higher level of credit risk attain higher NIM. The positive coefficient of *equity to total assets* somewhat surprisingly suggests that lower leverage leads to higher NIM. Unsurprisingly, the coefficient of *cost to income ratio* is still negative. Finally, the positive coefficient of *net loans to total assets* suggests that the more the banks are able to lend to clients, the higher NIM

the possibility of the existence of such a situation: *"Changes in the slope of the yield curve will also have quantity effects, notably influencing the volume of banks' fixed-rate mortgages. Similarly, to what is discussed above, to the extent that, on balance, the demand for mortgages is more responsive (elastic) to changes in the slope than that for medium-term deposits, at some point a higher level of the slope would erode profitability."*

Table 2.6: System GMM estimation results with a dummy of negative short-term rate

| | (5) nim | (6) nim | (7) nim | (8) nim |
|---|---|---|---|---|
| L.nim | 0.862*** | 0.861*** | 0.859*** | 0.859*** |
| | (0.0137) | (0.0133) | (0.0133) | (0.0134) |
| st_ir | 0.149*** | 0.142*** | -0.00184 | - |
| | (0.0315) | (0.0302) | (0.0205) | |
| st_ir_sq | -0.0277*** | -0.0281*** | - | - |
| | (0.00670) | (0.00677) | | |
| spread | -0.0214 | -0.0385*** | -0.0299*** | -0.0301*** |
| | (0.0148) | (0.00925) | (0.00878) | (0.00899) |
| spread_sq | -0.000966 | - | - | - |
| | (0.000827) | | | |
| gdp | 0.00815* | 0.00776* | 0.0101** | 0.00997** |
| | (0.00421) | (0.00431) | (0.00456) | (0.00455) |
| infl | 0.0546*** | 0.0606*** | 0.0639*** | 0.0640*** |
| | (0.0110) | (0.00972) | (0.00962) | (0.0101) |
| unem | 0.00231 | 0.00433 | 0.00181 | 0.00192 |
| | (0.00307) | (0.00286) | (0.00295) | (0.00311) |
| hi | 0.480** | 0.464** | 0.449** | 0.452** |
| | (0.211) | (0.198) | (0.194) | (0.192) |
| lta | -0.0210*** | -0.0220*** | -0.0209*** | -0.0210*** |
| | (0.00790) | (0.00767) | (0.00793) | (0.00795) |
| llr_gl | 0.00742*** | 0.00774*** | 0.00666*** | 0.00667*** |
| | (0.00209) | (0.00190) | (0.00182) | (0.00183) |
| eq_ta | 0.00600** | 0.00625** | 0.00572** | 0.00571** |
| | (0.00270) | (0.00258) | (0.00256) | (0.00254) |
| cir | -0.000788** | -0.000784** | -0.000874*** | -0.000872*** |
| | (0.000307) | (0.000313) | (0.000327) | (0.000326) |
| nl_ta | 0.00439*** | 0.00436*** | 0.00445*** | 0.00446*** |
| | (0.000804) | (0.000790) | (0.000795) | (0.000792) |
| nl_dstf | -0.000290 | -0.000250 | -0.000202 | -0.000206 |
| | (0.000206) | (0.000202) | (0.000200) | (0.000197) |
| la_dstf | -0.0000609 | -0.000101 | -0.000125 | -0.000125 |
| | (0.000498) | (0.000485) | (0.000495) | (0.000493) |
| bhhc | 0.0294 | 0.0293 | 0.0205 | 0.0202 |
| | (0.0458) | (0.0448) | (0.0467) | (0.0466) |
| coop | -0.0842*** | -0.0822*** | -0.0847*** | -0.0849*** |
| | (0.0190) | (0.0186) | (0.0186) | (0.0188) |
| rem | -0.116*** | -0.122*** | -0.139*** | -0.139*** |
| | (0.0366) | (0.0349) | (0.0344) | (0.0344) |
| savings | -0.0489** | -0.0498** | -0.0507** | -0.0510** |
| | (0.0232) | (0.0232) | (0.0226) | (0.0230) |
| large | 0.0590** | 0.0570** | 0.0620** | 0.0620** |
| | (0.0287) | (0.0280) | (0.0277) | (0.0277) |
| small | 0.00648 | 0.00652 | 0.00690 | 0.00691 |
| | (0.0230) | (0.0226) | (0.0224) | (0.0224) |
| negrate | 0.00831 | -0.00305 | -0.0535*** | -0.0526*** |
| | (0.0200) | (0.0182) | (0.0164) | (0.0133) |
| Constant | 0.210 | 0.236* | 0.275* | 0.275* |
| | (0.143) | (0.137) | (0.141) | (0.142) |
| Number of Observations | 3145 | 3145 | 3145 | 3145 |
| Number of Groups | 629 | 629 | 629 | 629 |
| Number of instruments | 32 | 31 | 30 | 29 |
| Wald statistic | 14308.3*** | 14558.9*** | 15398.0*** | 14973.0*** |
| Arellano-Bond AR(1) | -1.31 | -1.31 | -1.31 | -1.31 |
| Arellano-Bond AR(2) | 0.45 | 0.44 | 0.41 | 0.41 |
| Hansen test | 13.16 | 12.88 | 7.23 | 7.23 |

*Notes:* Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

*Source:* Authors' calculation in Stata 11.2.

they attain. Otherwise they would have to invest in government bonds and similar instruments that bore low yields during the observed period. For the specialization bank-specific dummy variables, we observe behaviour consistent with the patterns in Figure 2.1. The coefficient of *bank holdings & holding companies* is positive but insignificant. In contrast, the coefficients of other dummies are significantly negative, suggesting generally lower NIM or a faster decrease in NIM. The bottom lines of Table 2.4 report the estimation diagnostic results. The Wald statistics show the overall significance of the models. Neither the Arellano-Bond AR(1) nor the AR(2) test rejects the null hypothesis. This result suggests that we would not have made a significant mistake had we estimated the model using a static approach. On the other hand, as mentioned previously, system GMM allows us to estimate the model using time-invariant dummy variables. As the results of the estimation in Table A.4 in the Appendix show, in the case of using a static model, we could use only the fixed effects estimation since the estimation by random effects would be inconsistent as confirmed by the result of the Hausman test. Due to this fact, it is still correct to prefer using system GMM.

The results of the Hansen test lead to not rejecting the null hypothesis of exogenous instruments, i.e., to the desired outcome. We must be aware that the Hansen test could be weakened by too many instruments, especially if the number of instruments exceeds the number of groups. However, this effect is not present, since we have only 31 instruments, but the number of groups is 629.

As another robustness check, we compare the estimates of the coefficient on the lagged dependent variable with fixed effects, system GMM, and pooled OLS estimation to verify the condition $\hat{\delta}_{FE} \leq \hat{\delta}_{S-GMM} \leq \hat{\delta}_{OLS}$, which must hold Roodman (2009). The estimated coefficients of lags are presented in Table 2.5, confirming that this condition holds.[7]

Finally, we tried to estimate various modifications of the model when dropping certain variables. Following the estimation results of the basic model, it made sense to consider dropping the square of the slope of the yield curve, as the results suggest a linear rather than a quadratic relationship. Another possibility, due to some correlations among *net loans to total assets*, *net loans to deposits & short-term funding*, and *liquid assets to deposits & short-term funding*, was to consider using fewer than all three of these variables.

The estimation results for the modified models are presented in other columns

[7] All results from this comparison are presented in Table A.3 in the Appendix.

of Table 2.4. All models are again estimated using two-step GMM with the robust option. Model (2) is estimated omitting only *square of the slope of the yield curve*. As the estimation diagnostic shows, the performance is comparable to the original model.

Models (3) and (4) are two model specifications omitting certain variables of the balance sheet structure, i.e., *net loans to total assets*, *net loans to deposits & short-term funding*, and *liquid assets to deposits & short-term funding*. The dropping of *net loans to total assets* generally leads to a decrease in the Hansen test statistic and to an increase of significance of both other variables. On the other hand, dropping any of the variables reduces the Wald statistic. Hence, we are facing a sort of trade-off. However, the results generally suggest using fewer than all three of these variables. We have experimented with other modifications of our original model by omitting some of the variables, but none of experiments have shown significantly better performance than reported versions.[8]

In Table 2.6, we present results for models with a dummy variable for a negative interest rate environment as another robustness check for the assumed nonlinearity in the impact of short-term interest rates on NIM. When we continue including both the linear and quadratic terms for the short-term rate, the negative rate dummy is insignificant, as the results for models (5) and (6) show. On the other hand, when the quadratic term is dropped, the negative rate dummy captures most of the effect, causing the linear term in model (7) to be insignificant. This result clearly supports the hypothesis that the impact on NIM is nonlinear, specifically, positive concave.[9]

### 2.5.1 Summary of Results

This section confronts the estimation results with the three hypotheses tested in this paper to reject or not to reject them. The estimation results are then compared to the results of previous studies.

[8]Estimation results for model specifications denoted (1)-(4) in this paper were also presented in Hanzlík (2018).

[9]The results presented in Table 2.4 and Table 2.6 show that some of the variables are insignificant, especially when they are correlated with other explanatory variables, e.g., logarithm of total assets and large and small dummies. In our estimations, we have tried multiple specifications in which we omitted certain variables with insignificant coefficients, but the results did not change substantially. Therefore, we prefer to present the models with the original set of variables.

**Hypothesis #1 (erosion of NIM) – rejected:** The estimation results do not confirm that the NIM of all bank types would respond similarly to the situation of low and later negative short-term rates, as present during the observed period 2011-2016 in the EU (see also Figure 2.1, which shows differences in both the pace and the direction of the average NIM for each bank type). Similarly, the significance of most of the bank specialization dummies is in favour of differences in NIM.

**Hypothesis #2 (influence of market concentration) – not rejected:** The models estimated in this paper included the Herfindahl index as a measure of market concentration. The estimated coefficient being significantly positive supports the claim that higher market concentration leads to higher NIM. Therefore, this hypothesis cannot be rejected.

**Hypothesis #3 (nonlinearity in the impact of market rate) – not rejected:** The estimated coefficient on short-term rate is significantly positive, and the coefficient on its square is significantly negative. In other words, the estimated relationship of short-term rate and NIM is positively concave and hence nonlinear. As a result, the third hypothesis is therefore not rejected.

Table 2.7 compares our estimation results with other studies, which differ in using datasets of various sizes, geographic location, and bank type variety. Moreover, different estimation approaches are employed in each paper. For this reason, only some of the most commonly included variables are considered in the table. We can find comparable results for certain variables. Our estimation yields comparable results for the coefficients of lagged dependent variable, for short-term rate and its square, GDP growth, and equity to total assets ratio.

In contrast, our results differ, especially for the coefficients of the slope of the yield curve, from those results presented by Borio *et al.* (2017). Some of the authors considered the impact of the size of the bank, at least by including total assets or their logarithm as an explanatory variable. However, our estimation is unique in including the specialization dummies and in including the Herfindahl index as another explanatory variable.

To summarize, the main contribution of the analysis is further exploration of the factors influencing the bank NIM in a situation of ZLB or even negative rates. In this paper, in addition to the impact of interest rate structure, we considered the impact of the market concentration on NIM together with controlling for the differences between various bank specializations and for distinct size categories, and we exploited a unique dataset of EU banks of various sizes and specializations.

### 2.5.2 Further Research Opportunities

In this section, we discuss three opportunities for further research: a further analysis of the impact of the slope of the yield curve, an assessment of other market characteristics besides market concentration, and a larger data sample. The first opportunity is further analysis of the influence of the slope of the yield curve. Our result for the slope of the yield curve suggests the impact to be negative and linear, which seems to be in contradiction with the theoretical assumptions and results in previous studies. On the other hand, this result may be caused by reaching a certain point at which a steeper yield curve may cause decreasing profitability, as predicted in Borio *et al.* (2017).
The second research opportunity would be to collect data for other variables reflecting different specific market characteristics. We have used the Herfindahl index as a measure of market concentration in this paper. However, we were not able to consider other important characteristics such as ownership structure within our dataset. It is not an easy task to find a good proxy for modelling its impact, but doing so would certainly help to better understand the determinants of NIM.
The third opportunity lies in obtaining data from following years. Having more data from a longer time period would be desirable to obtain more-robust results, which will be possible as data from following years become available. While a negative interest rate environment in the Euro Area is still present, it will eventually end. Hence, we could obtain more observations on both the negative rate period and on "normal" times. Moreover, how exactly the banks will cope with the end of a negative interest rate era will be interesting.

## 2.6 Conclusion

This paper focussed on the determinants of NIM of banks in the EU member countries in the situation of a zero lower bound. Moreover, we tested hypotheses that while the NIM is highly influenced by the overall interest rate environment, there exist significant differences between individual banks arising from different business models and from country-specific market characteristics, e.g.,

Table 2.7: Comparison of estimated signs and significance levels for the coefficients of NIM determinants in previous studies

| Author | Data | Methodology | $NIM(1st lag)$ | $Short-term rate$ | $Short-term rate^2$ | $Spread$ | $Spread^2$ | $GDP growth$ | $Inflation$ | $Herfindahl index$ | $Equity/total assets$ | $Specialization$ | $Size^1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Borio *et al.* (2017) | Bankscope (109 large banks, 14 major economies, 1995-2012) | System GMM | + | + | - | + | - | 0 | no | no | + | no | no |
| Claessens *et al.* (2017) | Bankscope (3385 banks, 47 countries, 2005-2013) | Fixed effects | + | + | no | 0 | no | 0/- | no | no | + | no | no |
| Bikker & Vervliet (2017) | Federal Deposit Insurance Corporation (3582 U.S. banks) | System GMM & static methods | + | + | - | $+^2$ | no | + | - | no | $-^3$ | no | yes |
| Altavilla *et al.* (2017) - ECB working paper | ECB datasets (288 banks, Q1 2000 - Q4 2016) | OLS | + | + | no | 0 | no | + | 0 | no | $0^4$ | no | no |
| Arseneau (2017b) | 22 bank holdings (U.S. stress testing scenarios) | GLS | no | no | no | no | no | no | no | no | no | no | yes |
| Kerbl & Sigmund (2017) | OeNB (946 banks, Q1 1998 - Q1 2016) | Fixed effects | no | + | 0 | + | no | + | no | no | no | no | yes |
| This paper | Orbis Bank Focus (629 banks, 2011-2016, EU) | System GMM | + | + | - | - | 0 | + | + | + | + | yes | yes |

*Notes:* $+/-$ - estimated positive/negative coefficient (at least at 10% significance level); 0 - insignificant estimate; no - variable not included in the model; yes - model includes variables/dummy variables for a given effect; [1] Considered both (log of) total assets and size dummies; [2] long-term interest rate used instead of slope of the yield curve; [3] total capital ratio; [4] regulatory capital ratio.

*Source:* Author based on individual papers and own results.

market concentration. For this purpose, we have used a unique dataset of annual data on 629 banks from 24 EU countries from the 2011-2016 period.

The main contribution of this paper may be summarized in three points. First, the composition of the sample allowed us to consider the impact of market rate on NIM in a situation commonly referred to as the zero lower bound, i.e., when interest rates were close to zero or, as in 2015 and 2016 in some countries, even negative. Similarly to Borio *et al.* (2017) and Bikker & Vervliet (2017), we found a positive, concave relation between short-term rates and NIM, confirming the assumed nonlinearity in the impact of market rate on bank profitability. Second, we considered other factors that may influence the NIM in our analysis, most importantly market concentration proxied by the Herfindahl index. Our results confirm that there is a positive relation between NIM and market concentration, which practically means that higher oligopolistic power of a banking institution is connected to higher profitability. This result suggests that a certain level of concentration may be desirable to support the stability of the whole banking sector. On the other hand, as in other industries, higher oligopolistic power is likely to relate to worse and more-expensive services for clients. For the regulators of the banking industry, higher oligopolistic power implies a trade-off that the regulators face within their objectives (ensuring financial stability of the system and simultaneously the protection of consumers). Third, we applied a standard methodology on unique panel data on EU banks, including banks from the Euro Area and from countries with national currencies. Moreover, we were able to distinguish between distinct types of bank, i.e., commercial banks, bank holdings, cooperative banks, savings banks and real estate & mortgage banks, for which we found significant differences in their NIM.

To conclude, we confirmed a positive concave relationship between NIM and short-term interest rates observed in previous studies. On the other hand, we found a negative relationship between NIM and the yield curve slope in contrast to that of other researchers such as Borio *et al.* (2017). We also identified significant differences arising from different bank specializations, and, to some extent, we have observed differences linked to bank size.

# Chapter 3

# Key Factors of the Net Interest Margin of European and US Banks in a Low Interest Rate Environment[1]

## 3.1 Introduction

In this paper, we contribute to the literature examining the determinants of net interest margin (NIM) of US and European banks in a zero lower bound (ZLB) situation while controlling for important institutional design factors – the difference between bank-based and capital-based financial markets. NIM is by definition closely linked to the overall interest rate environment, which reflects macroeconomic conditions and monetary policy in a certain country. During the last decade, we observed in major economies an unprecedented situation of very low – even negative – interest rates. This was a new situation previously not covered by the literature. As a result, this topic has attracted the attention of many researchers, such as Borio *et al.* (2017), Claessens *et al.* (2018) or Albertazzi *et al.* (2020) who tried to estimate the impact of the ZLB of interest rates on bank profitability and the effectiveness of monetary policy. Since interest rates affect both the asset and the liability sides of banks' balance sheet, the effect of negative rates on banks performance remains ambiguous (Riksbank 2016).

The relevant literature on the determinants of bank profitability, specifically

[1]This chapter has been published as Hanzlík & Teplý (2020).

NIM, has mainly been concerned with the link between NIM and a low or negative rate environment resulting from unconventional monetary policy measures and the problem of the ZLB. For instance, Borio *et al.* (2017) found a positive concave relationship of the short-term interest rate with bank profitability, i.e., higher sensitivity in the case of an interest rate close to zero. This paper builds on the previous literature on the link between NIM and interest rate structure and considers other factors influencing NIM. Previous studies on the link between NIM and interest rate structure controlled for the impact of specific market characteristics, e.g., market concentration, which may lead to higher profitability when banking institutions possess higher oligopolistic power.[2] We identify a gap in the literature, because the studies from recent years of low and negative rate environment did not consider the possible differences in bank profitability arising from different institutional designs of the financial market. In regards to these different institutional designs, we investigate whether the financial market is considered to be bank-based (typically continental Europe) or capital-based (typically the United States or the United Kingdom) as defined by Demirgüç-Kunt & Levine (1999).

We also include certain bank-specific variables that reflect various business models of individual banks or their size in our analysis because there are likely to be differences in banks' profitability based on these characteristics. For this purpose, we use unique annual data on 1,155 banks located in the United States and 24 EU member countries from 2011-2016 (thereof 526 banks from the US and 629 banks from the EU). This period was characterized by interest rates close to zero and in 2015 and 2016 even below zero in the case of the majority of European countries. The diversity of the sample thus allows us to examine the impact of market rates on NIM in the negative rate context of many European countries, in contrast to the US and other European countries that opted for different unconventional monetary policy measures in the years following the financial crisis of 2007-2009, which makes our research unique.

Our contribution to the literature is three fold. First, we considered other factors that may influence NIM in our analysis, mainly the institutional design of whether the bank operates within a bank-based or capital-based financial

[2] The impact of market concentration on NIM was considered by Claeys & Vander Vennet (2008), who studied the interest margin of banks in Central and Eastern Europe. However, their study uses data from the 1994-2001 period, which cannot be considered a ZLB situation, contrary to the 2011-2016 period covered in this paper. Other studies considering the impact of market concentration on bank profitability or specifically NIM include Hanzlík & Teplý (2019), Saona (2016), Kok *et al.* (2015), or Bourke (1989).

market. Second, the composition of the sample allowed us to consider the impact of market rate on NIM in the ZLB, what has not been covered by other researchers. Third, we analyse unique panel data of US and European banks, including banks from the euro area and countries with national currencies.

The paper is structured as follows. Section 3.2 provides a review of the existing literature on differences between bank-based and capital-based markets and the impact of interest rates and monetary policy on bank profitability. Based on this overview, we state three hypotheses. In Section 3.3, we conduct the empirical analysis. We describe the dataset used, introduce selected variables and provide a descriptive analysis of the data. Section 3.4 contains the description of our methodology. The results and findings are presented in Section 3.5, where we also discuss further research opportunities. Finally, Section 3.6 concludes the paper and states final remarks.

## 3.2 Literature Review and Hypotheses Testing

### 3.2.1 Literature Review

In this paper, we aim to consider the impact of numerous determinants of net interest margin (NIM), one of the most common measures of bank profitability.[3] The existing literature considering bank profitability from recent years has been concerned mainly with the impact of very low and, in some cases, even negative interest rate environments resulting from the unconventional monetary policy of major central banks pursued since the outbreak of the GFC in 2007-2009. The aim of negative interest rates was to increase the cost to banks of holding excess reserves at the central bank encouraging them to take them back on the balance sheet Cœuré (2016). In the following paragraphs, we provide a literature review divided into four strands. First, we discuss the seminal model by Ho & Saunders (1981), which is the most widely used model to analyze bank interest margins. Second, we focus on the most relevant studies for the subject of our paper: Borio *et al.* (2017), Claessens *et al.* (2018), Bikker & Vervliet (2017). Third, we present other studies of the impact of a low interest rate environment on banks' profitability. Finally, we discuss key studies on bank-based and capital-based financial markets.

[3] Other common profitability measures used in the banking industry include return on average assets (ROAA), return on average equity (ROAE) and cost-to-income ratio Mejstřík *et al.* (2014), Golin & Delhaise (2013).

First, Ho & Saunders (1981) developed a model of bank margins, in which the bank is viewed as a risk-averse dealer. They considered homogenous loans and used data of major US banks in the 1976-1979 period. Later on, this model was extended by other researchers such as Allen (1988), whose model allows for heterogeneous loans, or Angbazo (1997), who included a measure of interest rate risk in his model of net interest margins for banks in the US. Entrop *et al.* (2015) extend the model to capture interest rate risk and expected returns from maturity transformation. To summarize the Ho & Saunders (1981) model and its subsequent extensions show that the interest margin depends on several factors such as market power, interest risk, credit risk, interaction between risks, banks' risk aversion, liquid reserves and operating expenses Cruz-García & Fernandez de Guevara (2020). Second, Borio *et al.* (2017) consider the impact of unconventional monetary policy on bank profitability. Using annual data from the Bankscope database for 109 large international banks headquartered in 14 major advanced economies covering the period 1995-2012, they estimate multiple models using the system GMM method, each with a certain profitability ratio as the dependent variable. As the explanatory variables, they use, e.g., the three-month interbank rate and the difference between the 10-year government bond and three-month interbank rates as a proxy for the slope of the yield curve, both variables serving as monetary policy indicators. Due to the assumed nonlinearity in impact, the authors propose a quadratic estimation that includes the squares of these two variables in the models. In addition, the models include other control variables for various macroeconomic or bank-specific factors. The study finds a positive correlation of bank return on assets with both the level of interest rate and the steepness of the yield curve. According to the findings, the positive impact of a higher short-term rate and steeper yield curve is driven mainly by its positive impact on net interest margin.

Claessens *et al.* (2018) published another study of the impact of "low-for-long" interest rates on banks' profitability, specifically on NIM. This study uses balance sheet and income statement annual data on 3,385 banks from 47 countries for the period 2005-2013 obtained from Bankscope. In their model, NIM is regressed on the three-month government bond yield, the spread between 10-year and three-month government bond yield, a dummy variable detecting whether the country was in a "low rate environment" (defined as three-month rate below 1.25 %), and a set of country-specific and bank-specific variables. The authors perform the regression for the whole sample as well as for various subsamples, e.g., for a low rate environment and high rate environment separately, or they decompose NIM to interest income margin and interest expense margin and use these as dependent variables instead. The findings of this study are that the impact of interest rates on NIM is higher in situations of low interest rates than in high interest rates. Moreover, the impact is stronger on interest income margins than on interest expense margins. However, the authors admit that there might be nonlinearities in transmission from interest rate changes to NIM not captured by their methodology; they specifically mention differences between banking systems.

A similar modelling approach is also used in a study by Bikker & Vervliet (2017), who consider the impact of low interest rates on banks' profitability and risk-taking. This study is based on data on 3,582 US banks obtained mainly from the Federal Deposit Insurance Corporation and considers the impact of variables capturing the effect of the interest rate environment, other macroeconomic factors, and bank-specific factors on NIM. The results are comparable to both Borio *et al.* (2015) and Claessens *et al.* (2018) since the study finds a positive and concave impact of the short-term interest rate. Another finding is that larger banks tend to have somewhat lower margins, which may be explained by an assumption that larger banks' profitability includes a larger portion of noninterest income. More recently, Cruz-García & Fernandez de Guevara (2020) analyse the determinants of net interest margin with a focus on the impact of capital regulation and deposit insurance. When using an unbalanced panel dataset for OECD countries between 2000 and 2014, they found that the most important determinants of the net interest margin are implicit payments, efficiency, average operating costs, the intensity of competition, the deposit insurance premium and capital stringency.

Third, other studies of the impact of unconventional monetary policy and a low interest rate environment on banks' profitability include Altavilla *et al.* (2018), Arseneau (2017a), Coleman & Stebunovs (2019), López *et al.* (2018), Kerbl & Sigmund (2017). However, these studies generally use different methodologies than our paper. Recently, Albertazzi *et al.* (2020) find mixed results when reviewing empirical papers on the negative interest rate policy and its overall implications for bank profitability. In addition to empirical evidence, Borio *et al.* (2015) provide a theoretical explanation of the impact of decreasing interest rates and a flattening yield curve on banks' profitability, i.e., the impact of unconventional monetary policy transmission. Theoretical papers regarding the problem of the zero lower bound on nominal interest rate and providing rationales for various unconventional monetary policy tools, such as quantitative easing or the use of exchange rates, include Bernanke & Reinhart (2004), Jung *et al.* (2005), Svensson (2003), Franta *et al.* (2014) and McCallum (2000). Fourth, the differences between bank-based and capital-based financial markets (in some studies capital-based markets are referred to as "market-based") were considered, e.g., in a book by Demirgüç-Kunt & Levine (1999) and in a paper by Levine (2002), in which he runs a broad data-based cross-country examination of which type of the financial market performs better in promotion of economic growth. Levine (2002) concludes that there is no support for either the bank-based or market-based view. A more recent study by Bats & Houben (2020) focuses on the implications of bank-based vs. market-based financing for the level of systemic risk.

### 3.2.2 Hypotheses Testing

Based on the previous literature, we formulate the following three hypotheses in this paper:

**Hypothesis #1 (institutional determination of NIM): NIM is lower in bank-based financial markets (Europe) than in capital market-based financial markets (the US and the UK), and it is also more sensitive to changes in the interest rate structure.** The first hypothesis tested in this paper is whether there exists a significant difference in NIM between banks in EU countries and banks in the United States and whether there is a difference in the sensitivity to changes in the interest rate structure. Except for the United Kingdom, most EU countries are usually considered bank-based financial markets. This means that the banking sector plays a substantial role in the intermediation of loanable funds from surplus agents to deficit agents. Banks are thus the main risk carriers. In contrast, the United States and the United Kingdom are usually considered capital-based financial markets. In this setting, the capital market has a much more substantial role in financial intermediation, and the risk is carried to a large extent by investors themselves. Further descriptions of the characteristics of both types can be found in Demirgüç-Kunt & Levine (1999), Levine (2002) and Mejstřík *et al.* (2014). We should highlight that in the real world, there do not exist countries that perfectly fit the definition of either type. However, for the purpose of this paper, we stick to the assumption that capital-based markets are in our sample represented by the United States and the United Kingdom, while the rest of

the EU countries are considered bank-based markets.
We assume that the general level of NIM is lower and that the decrease caused by the lowering short-term rate and flattening yield curve could be larger in bank-based markets than in capital-based markets. This assumption is based on the fact that in bank-based countries, capital markets are rather underdeveloped. Hence, debtors in bank-based countries can more easily enter the capital market to obtain a favourable lending rate while seeking – or at least threaten to do so – while negotiating with possible bank lenders to obtain a lower rate. On the other hand, there are also arguments drawing an opposite conclusion. Banks in a bank-based market may have generally higher monopolistic power over the interest rate they offer to their customers (especially retail customers) on both loans and deposits. Moreover, the decrease in NIM may indeed have been deeper in Europe but for different reasons – namely, the negative rates introduced in Eurozone and some non-Eurozone member countries in 2015. In the United States, in contrast, the rate did not go under zero during the observed period.
**Hypothesis #2 (higher sensitivity of small banks' NIM): NIM eroded most significantly in small banks in both the EU and the US.** The second tested hypothesis is that NIM decreased most significantly in small banks in both the EU and the United States. As Molyneux *et al.* (2019) highlight, banks that rely on wholesale funding (usually large banks) may benefit from negative interest rates in terms of cheaper funding costs compared to those that depend mainly on retail deposits (usually small banks) where rates are 'sticky' downward. Tan (2019), who analysed 189 banks in the Eurozone between 2013 and 2015, finds that high deposit banks are more sensitive to the negative rate environment than low deposit banks. In this paper, banks are divided into three size categories. Large banks are those whose amount of total assets in 2016 was at least USD 30 billion. In contrast, banks are considered small banks when their total assets in 2016 were below USD 1 billion. The rest fall into the category of medium banks. The reason why the NIM of smaller banks is likely to decrease more is that they rely more on funding from retail deposits and hence they cannot lower their interest costs as easily as larger banks that rely on institutional deposits or interbank lending. This may become especially important in the case of negative market rates, which may not be easily transmitted into deposit rates. To support our hypothesis, we also refer to Molyneux *et al.* (2019) who conclude that small banks appear to be more affected by the negative interest rate policy. Moreover, Genay & Podjasek (2014) state that

U.S. banks face decreasing NIMs and returns during periods of low interest rates and the effect is particularly strong for small institutions.

**Hypothesis #3 (savings banks' NIM): Savings banks reported the highest NIM in both types of financial markets.** The third hypothesis predicts that savings banks will have reported the highest NIM. In our dataset, we follow the categorization of banks in the Orbis Bank Focus database, the main source of the data. Five types of banks are considered: bank holdings and holding companies, commercial banks, cooperative banks, real estate and mortgage banks and savings banks. The assumption for savings banks is that they generally tend to have a business model based on collecting longer-maturity retail deposits and lending to retail clients; thus, their profitability and especially net interest income are less sensitive than those of other types of banks to changes in the short-term interest rate. On the other hand, these banks are of rather smaller size, and hence the arguments discussed in the previous paragraph may apply for them.

## 3.3 Empirical Analysis

### 3.3.1 Dataset

In this paper, we use a dataset that includes 526 banks from the United States and 629 banks from 24 EU member countries. The major source of the data was the Orbis Bank Focus database. Data were obtained as two separate datasets. The first includes active banks from EU28 countries whose specialization was listed as bank holdings and holding companies, commercial banks, cooperative banks, real estate and mortgage banks, or savings banks. The second dataset includes active banks from the United States within the same set of five specializations and belonging to the "Classic US coverage" category in the database. Data were then filtered to achieve a balanced panel for the time period 2011-2016 with no missing observations for any of the bank-specific variables used in the model.

The datasets were further extended by a set of country-specific macroeconomic variables, i.e., GDP growth rate, inflation rate, unemployment rate, 3M interbank rate, and 10Y government bond yield. Due to the availability of GDP growth, inflation rate, and unemployment rate data in Orbis Bank Focus only for 2013-2016 and the unavailability of short-term and long-term interest rate variables in this database at all, macroeconomic data for the whole observed time period were obtained from other sources.

For EU countries, the source for all macroeconomic variables was Eurostat. Unfortunately, the 3M interbank rate for the whole observed period was available only for the euro area, Denmark, Sweden, and the United Kingdom. For other countries outside the euro area, the last available year was 2014. For this reason, the data for 2015 and 2016 for the Czech Republic were obtained from the Czech National Bank for Hungary and for Poland from the OECD. Due to the unavailability of reliable sources of data for the relevant short-term rate in 2015 and 2016, banks from Bulgaria, Croatia and Romania were removed from the sample (altogether 35 banks). For the long-term rate EMU convergence criterion, bond yields were used as a proxy. This yield is not available for Estonia because the Estonian government has issued no such instrument. Therefore, the one bank located in Estonia was also removed from the dataset. Macroeconomic data for the United States were obtained from the FRED database of the Federal Reserve Bank of St. Louis, Missouri. Except for the GDP growth rate, inflation rate, and unemployment rate, proxies for short-term and long-term interest rate were obtained. They are the 3M LIBOR for USD-denominated transactions and 10Y Treasury constant maturity rate, respectively. These two datasets were combined and made up a final balanced panel of 1155 cross-sectional units in 6 time periods. Other variables, i.e., various dummies or logarithms and squares of certain variables, were computed within this panel.

### 3.3.2 Variable Selection

We selected variables based on the previous literature on the topics of banks' profitability and the impact of the interest rate on it, including Arseneau (2017b), Borio *et al.* (2015), Borio *et al.* (2017), Claessens *et al.* (2017), Fišerová *et al.* (2015) and Hanzlík & Teplý (2019). The description of bank-specific variables is provided in Table 3.1, the description of bank-specific dummy variables in Table 3.2, the description of country-specific variables in Table 3.3 and the description of country-specific dummy variables in Table 3.4. In total, we analyse 22 variables.

Table 3.1: Bank specific variables

| | | |
|---|---|---|
| *Natural logarithm of total assets of the bank* | Commonly serves as an approximation of the size of the bank. Transformation by natural logarithm is used to smooth out large differences in the size of individual banks. | $lta$ |
| *Net loans to total assets ratio* | Indicates what portion of total assets is made up of loans. Hence it can be considered a credit risk ratio. The expected sign of the coefficient is ambiguous because a higher value of the ratio may relate to a lack of liquidity, while a low value may lead to a decrease in net interest income. | $nl\_ta$ |
| *Net loans to deposits and short term funding ratio* | Reflects structure of the balance sheet and especially the liquidity of the bank. | $nl\_dstf$ |
| *Loan loss reserves to gross loans ratio* | Measures the quality of bank's assets by evaluating the part of loans put aside for potential charge-off. | $llr\_gl$ |
| *Cost to income ratio* | Indicator of bank's operational efficiency. Generally, the impact on profitability is supposed to be negative. Particularly, this should hold for NIM, since NIM is directly linked to the denominator of cost to income ratio. | $cir$ |
| *Liquid assets to deposits and short term funding ratio* | Liquidity measure capturing the liquid part of asset side of the bank's balance sheet. | $la\_dstf$ |
| *Equity to total assets ratio* | Leverage ratio measuring the indebtedness of the bank and its ability to absorb potential losses. The expected sign of the coefficient is unclear, since a low ratio may indicate insufficient capital, while a high ratio can be the result of foregone investment opportunities. | $eq\_ta$ |

*Note:* Source of all variables is Orbis Bank Focus database.

### 3.3.3 Descriptive Analysis

Our dataset consists of 192 large banks, 732 medium-sized banks, and 231 small banks. Regarding bank specialization, the dataset includes 195 bank holdings and holding companies, 570 commercial banks, 272 cooperative banks, 45 real estate and mortgage banks, and 73 savings banks. Numbers of banks from individual countries are provided in Table B.5. Summary statistics of all variables are reported in Table B.1. in the Appendix.

Table 3.2: Bank specific dummy variables

| | | |
|---|---|---|
| *Bank holdings & holding companies* | Equals 1 for specialisation Bank holdings & holding companies. | *bhhc* |
| *Cooperative banks* | Equals 1 for specialisation Cooperative banks. | *coop* |
| *Real estate & mortgage banks* | Equals 1 for specialisation Real estate and mortgage banks. | *rem* |
| *Savings banks* | Equals 1 for specialisation Savings banks. | *saving* |
| *Large banks* | Equals 1 for banks whose total assets in 2016 were at least USD 30 billion. | *large* |
| *Small banks* | Equals 1 for banks whose total assets in 2016 were below USD 1 billion. | *small* |

*Note:* Variables calculated by author based on Orbis Bank Focus data.

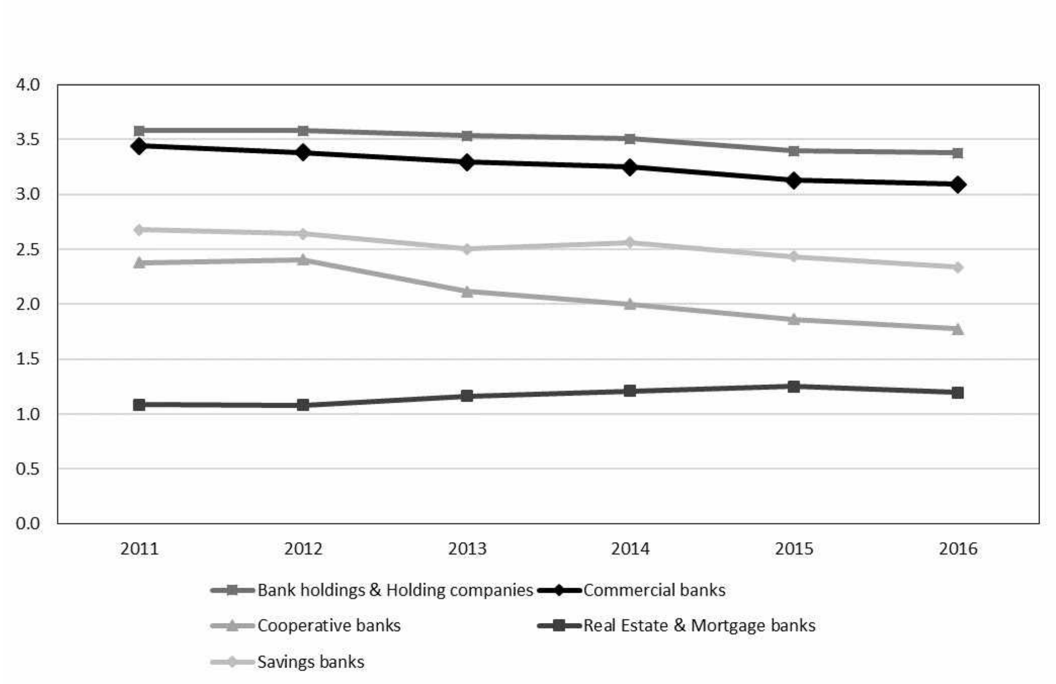
Table 3.3: Country specific variables

| | | |
|---|---|---|
| *Real annual GDP growth rate* | Annual growth rate of real GDP obtained from Eurostat (EU countries) or FRED database (United States). The coefficient is likely to be positive. | *gdp* |
| *Inflation rate* | Annual inflation rate obtained from Eurostat (EU countries) or FRED database (United States). The expected impact on NIM is ambiguous. | $infl$ |
| *Unemployment rate* | Annual unemployment rate obtained either from Eurostat. Higher unemployment should have negative impact on NIM. | *unem* |
| *Short-term interest rate* | For EU countries 3M interbank rate obtained from Eurostat, except for Czech Republic, Hungary and Poland in years 2015 and 2016 as described in the text. For United States 3M LIBOR in USD from FRED. | $st\_ir$ |
| *Square of the short-term interest rate* | Due to assumed nonlinearity in impact of short-term rate its square is used. | $st\_ir^2$ |
| *Slope of the yield curve* | Approximated by spread between 3M interbank rate and 10Y government bond yield. | *spread* |
| *Square of the slope of the yield curve* | As for the short-term rate, the square of the yield curve slope is included to capture assumed nonlinearity. | $spread^2$ |

*Note:* Source of 3M interbank rate data in 2015 and 2016 for Czech Republic is CNB, for Hungary and Poland OECD.

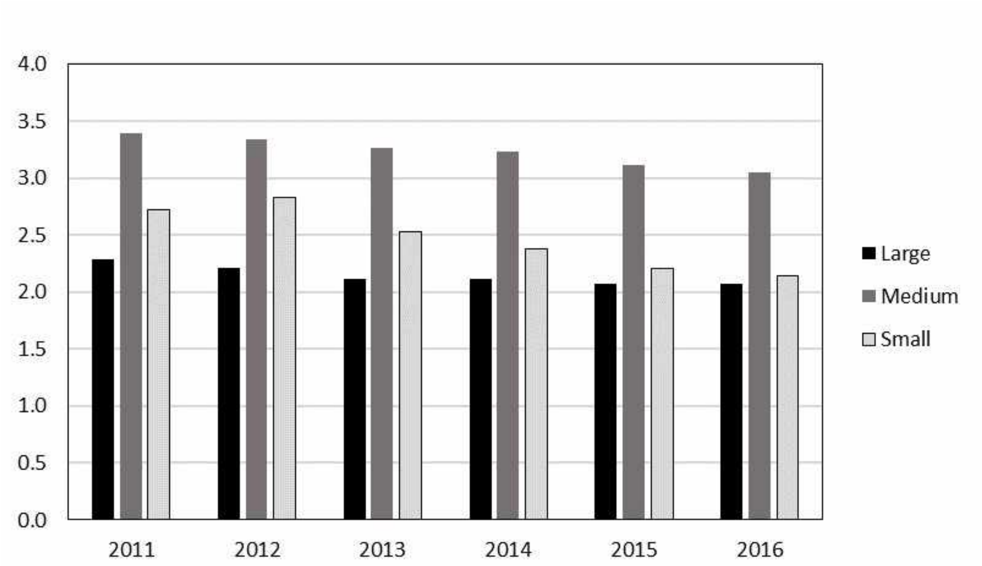
Figure 3.1 shows the development of average NIM by different bank specializa-

Figure 3.1: Average NIM by bank specialisation (%) in 2011-2016




*Source:* Authors based on Orbis Bank Focus.

Figure 3.2: Average NIM by bank size (%) in 2011-2016




*Source:* Authors based on Orbis Bank Focus, Eurostat.

Table 3.4: Country specific dummy variables

| | | |
|---|---|---|
| *Negative short-term interest rate* | Equals 1 for country which had negative short-term interest rate in a given year. | *negrate* |
| *Capital based financial market* | Equals 1 for a country considered to have a capital-based financial market, that is, for the United Kingdom and the United States. (The rest of the countries considered bank-based financial markets.) | *capbas* |

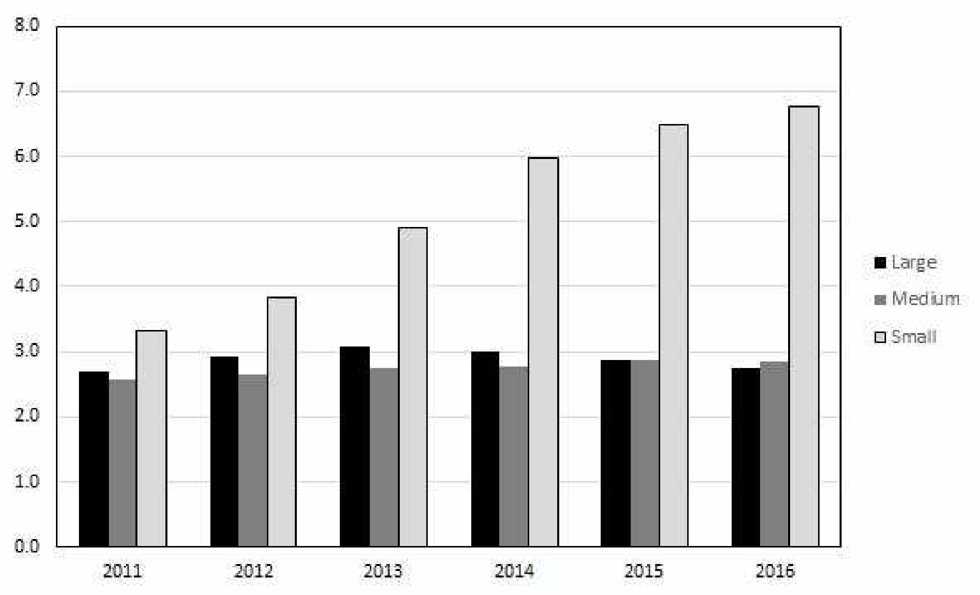
tions. We can see that the highest average NIM throughout the whole observed period reported bank holdings and holding companies, closely followed by commercial banks. In both cases, NIM slightly decreased; in the case of commercial banks, the decrease was more significant, when during the observed period, the average NIM fell from approximately 3.5 % to approximately 3 %. The lowest average NIM, just slightly above 1 %, was observed in real estate and mortgage banks, but on the other hand, these were the only type of banks that saw a slight increase in NIM during the observed period. In contrast, the sharpest decrease can be seen in cooperative banks. Finally, the figure contradicts Hypothesis #3, which states that savings banks reported the highest NIM, as their average NIM appears to be in the middle of the five bank types.

Figure 3.2 suggests that the highest average NIM was reported by banks whose size is considered medium. Large banks reported the lowest average NIM. This is quite consistent with the theoretical assumption that large banks rely less on retail deposits, which are relatively cheaper sources of funding in normal times, than on large institutional deposits, which allow the bank to better steer the spread. We can also assume that they may often have a larger portion of their income from other sources, e.g., net fee and commission income or off-balance-sheet activities. The assumption about the relative importance of retail deposit funding depending on size is further supported by the development of NIM by small banks, which at the beginning was higher than in the case of large banks, but throughout the period, it fell to almost the same level. This decrease may have been caused by low or even negative short-term market rates not being fully transmitted into the deposit rates.

A further theoretical explanation for the differences in NIM by size may come from the fact that in addition to the advantage large banks enjoy in management of their interest spread, large banks are likely to have more diversified loan and deposit portfolios as well as a better position in obtaining funding

from the interbank market. Such banks may also have larger territorial and client segment diversification Hanzlík & Teplý (2019).
Moreover, loan and deposit portfolios of smaller banks are likely to have a higher risk profile than the risk profile of the larger banks' portfolios. The assumption of riskier portfolios is supported by Figure 3.3, which shows a significant increase in the average ratio of loan loss reserves to gross loans for small banks, while this ratio remains relatively stable for large and medium banks over the observed period.

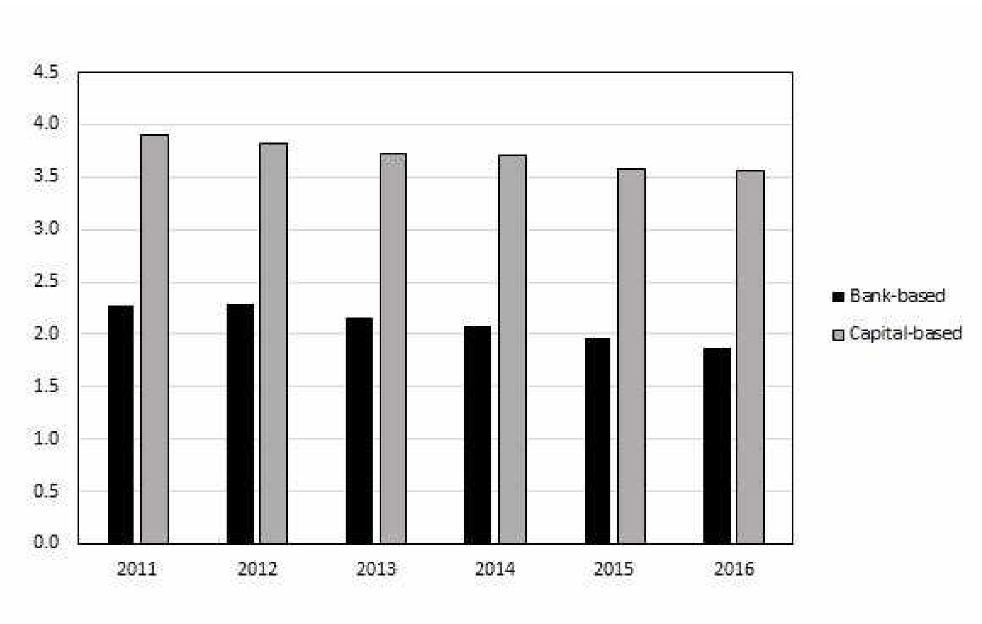
Figure 3.3: Average loan loss reserves to gross loans Ratio by Size (%) in EU in 2011-2016




*Source:* Authors based on Orbis Bank Focus, Eurostat.

The difference in average NIM between bank-based and capital-based financial markets is depicted in Figure 3.4. We can see clearly that during the whole observed period, there is a substantial and relatively stable gap when the NIM of banks operating in capital-based markets is more than 50 % higher than that of banks operating on bank-based markets. Furthermore, we see a slight widening of the gap, but on the other hand, this may be attributed to other factors, such as the negative short-term rate in most of the European countries that appeared during 2015 and 2016.

Figure 3.4: Average NIM in bank-based and capital-based markets in 2011-2016 (%) in 2011-2016




*Source:* Authors based on Orbis Bank Focus, Eurostat.

## 3.4 Methodology

We applied a standard methodology used for panel data. For estimation with a panel dataset, we considered using either static or dynamic panel data methods. Static methods such as pooled OLS, fixed effects (within or LSDV estimator) or random effects (FGLS estimator) allow us, under certain assumptions, to estimate at least consistently a model of the following form:

$$y_{it} = \alpha + \boldsymbol{x'_{it}}\boldsymbol{\beta} + c_i + \epsilon_{it} \tag{3.1}$$

where $i = 1, \ldots, N$ (cross-sectional units) and $t = 1, \ldots, T$ (time periods), $c_i$ is the unobservable group-specific fixed or random effect and $\epsilon_{it} \sim i.i.d.\, N(0, \sigma_\epsilon^2)$. On the other hand, if we need to estimate a dynamic panel data model of the form:

$$y_{it} = \alpha + \delta y_{i,t-1} + \boldsymbol{x'_{it}}\boldsymbol{\beta} + c_i + \epsilon_{it} \tag{3.2}$$

where $y_{i,t-1}$ is the one-period-lagged dependent variable, we cannot use any of those methods because they would produce biased and inconsistent estimates.

For dynamic panel data, we have available two methods using instrumental variables within the generalized method of moments (GMM) framework. The difference GMM was developed in Arellano & Bond (1991), and system GMM was proposed by Arellano & Bover (1995) and Blundell & Bond (1998). Due to the disadvantage of difference GMM that we can estimate the model only in first differences and thus would not be able to use the set of group-specific dummy variables, we use the other option, system GMM. In this method, the model is estimated in levels and differences jointly and instrumented by both lagged differences and lagged levels of the dependent variable, respectively. Therefore, it allows us to estimate a model including a set of dummy variables. The basic setup of the estimated model is as follows:

$$\begin{aligned} nim_{it} = \alpha + \delta nim_{i,t-1} + \theta_1 st\_ir_{it} + \theta_2 st\_ir_{it}^2 + \theta_3 spread_{it} + \\ + \theta_4 spread_{it}^2 + \boldsymbol{x'_{it}\beta} + \boldsymbol{d'_{it}}\gamma + \boldsymbol{z'_{it}\phi} + \boldsymbol{D'_{it}\zeta} + (c_i + \epsilon_{it}) \end{aligned} \tag{3.3}$$

where $\boldsymbol{x'_{it}}$ is a vector of bank-specific variables described in Table 3.1, $\boldsymbol{d'_{it}}$ is a vector of bank-specific dummy variables described in Table 3.2, $\boldsymbol{z'_{it}}$ is a vector of the country-specific variables described in Table 3.3 (except for the short-term interest rate, slope of the yield curve and their squares, which are identified as main variables of interest), and $\boldsymbol{D'_{it}}$ is a vector of the country-specific dummy variables listed in Table 3.4. Finally, the error term consists of a fixed effects component $c_i$ and an exogenous component $\epsilon_{it}$.

System GMM is used as the main estimation methodology in this paper. However, we performed the estimation of the dynamic model using static methods as well as the estimation of a static model (without a lagged dependent variable) to obtain more robust evidence of the validity of the estimated relationships. The results are presented in the Appendix in Table B.3 and Table B.4.

## 3.5 Results and Findings

### 3.5.1 Empirical Results

#### Baseline Results

In this section, we present our estimation results from estimates conducted by the system GMM method. In the estimation, we use second and further lags of the variable *NIM* as instruments for the differenced equation and second and further lags of differences of NIM as instruments for the equation in levels. This is consistent with the fact that the first lag of the dependent variable *NIM* used as an explanatory variable is endogenous by definition; therefore, we follow the treatment of endogeneity recommended in Roodman (2009). For the estimation, we use the Stata command *xtabond2* developed in Roodman (2009). More precisely, the command is used with a two-step GMM option and robust option that requests the Windmeijer (2005) correction. Theoretically, this should be the superior method according to Roodman (2009).

The system GMM estimation results of the basic model are reported in column (1) in Table 3.5. Columns (2)-(4) then present the estimation results for models with certain variables omitted.[4] The results show that the relationship between NIM and short-term interest rate is concave, confirming the results of most previous studies. However, in the case of the slope of the yield curve, we see a negative coefficient in both the linear and quadratic terms, although both are insignificant. Following this result, we tried to re-estimate the model modelling the relation as linear. The results presented in column (2) then show a significant negative linear relationship between NIM and the slope of the yield curve. We follow this estimation approach in the rest of the estimated models. For the other macroeconomic variables, we see a significant positive impact of GDP growth and inflation. The coefficient of unemployment is, in contrast to other macroeconomic variables, insignificant.[5]

The majority of the bank-specific variables are significant. The variable *logarithm of total assets* is insignificant, suggesting that the size effects do not play a large role as a determinant of NIM. The other two insignificant variables are *net loans to deposits and short-term funding* and *liquid assets to deposits and short-term funding*. In this case, the insignificance may be a result of the correlation with *net loans to total assets*. We then omit these two variables in model (4), and the estimation results do not differ substantially, showing that the variable *net loans to total assets* is a sufficient proxy for the balance sheet structure. The positive coefficient of *net loans to total assets* then suggests that the higher the portion of their assets that banks are able to lend to their clients, the higher is the NIM they can achieve.

[4] Estimation results for model specifications denoted (1) and (2) in this paper were also presented in Hanzlík (2018).

[5] For this reason, we have also tried estimation of the models omitting the variable unemployment, but it has not changed the results substantially.

Table 3.5: System GMM estimation results

| | (1) nim | (2) nim | (3) nim | (4) nim |
|---|---|---|---|---|
| L.nim | 0.846*** | 0.846*** | 0.838*** | 0.846*** |
| | (0.0286) | (0.0283) | (0.0290) | (0.0280) |
| st_ir | 0.108*** | 0.0984*** | - | 0.0998*** |
| | (0.0325) | (0.0292) | | (0.0286) |
| st_ir_sq | -0.0223*** | -0.0218*** | - | -0.0220*** |
| | (0.00633) | (0.00620) | | (0.00616) |
| spread | -0.00847 | -0.0204*** | -0.0209*** | -0.0199*** |
| | (0.0131) | (0.00729) | (0.00718) | (0.00729) |
| spread_sq | -0.000895 | - | - | - |
| | (0.000822) | | | |
| gdp | 0.0145*** | 0.0144*** | 0.0135*** | 0.0142*** |
| | (0.00518) | (0.00529) | (0.00496) | (0.00529) |
| infl | 0.0591*** | 0.0607*** | 0.0653*** | 0.0599*** |
| | (0.0112) | (0.0105) | (0.0100) | (0.0103) |
| unem | -0.00322 | -0.00255 | -0.00375 | -0.00181 |
| | (0.00337) | (0.00339) | (0.00347) | (0.00330) |
| lta | -0.0108 | -0.0103 | -0.0128 | -0.00930 |
| | (0.00926) | (0.00932) | (0.00940) | (0.00572) |
| llr_gl | 0.0128*** | 0.0130*** | 0.0122*** | 0.0129*** |
| | (0.00403) | (0.00388) | (0.00399) | (0.00383) |
| eq_ta | 0.0128** | 0.0130** | 0.0122** | 0.0129** |
| | (0.00551) | (0.00536) | (0.00551) | (0.00532) |
| cir | -0.00114** | -0.00116** | -0.00122*** | -0.00116** |
| | (0.000461) | (0.000459) | (0.000469) | (0.000457) |
| nl_ta | 0.00535*** | 0.00530*** | 0.00560*** | 0.00543*** |
| | (0.000920) | (0.000915) | (0.000945) | (0.000846) |
| nl_dstf | -0.0000578 | 0.00000289 | -0.0000810 | - |
| | (0.000301) | (0.000296) | (0.000306) | |
| la_dstf | -0.000244 | -0.000292 | -0.000233 | - |
| | (0.000507) | (0.000502) | (0.000504) | |
| bhhc | 0.0285 | 0.0284 | 0.0252 | 0.0271 |
| | (0.0225) | (0.0225) | (0.0230) | (0.0224) |
| coop | -0.106*** | -0.103*** | -0.111*** | -0.0938*** |
| | (0.0282) | (0.0287) | (0.0291) | (0.0258) |
| rem | -0.177*** | -0.183*** | -0.201*** | -0.183*** |
| | (0.0565) | (0.0553) | (0.0568) | (0.0523) |
| savings | -0.0608*** | -0.0613*** | -0.0646*** | -0.0648*** |
| | (0.0235) | (0.0234) | (0.0240) | (0.0236) |
| large | 0.0261 | 0.0228 | 0.0302 | - |
| | (0.0380) | (0.0385) | (0.0385) | |
| small | 0.0194 | 0.0223 | 0.0270 | - |
| | (0.0315) | (0.0317) | (0.0323) | |
| negrate | -0.00686 | -0.0182 | -0.0515*** | -0.0164 |
| | (0.0227) | (0.0191) | (0.0150) | (0.0187) |
| capbas | 0.0902** | 0.0910** | 0.100*** | 0.0914** |
| | (0.0379) | (0.0377) | (0.0380) | (0.0364) |
| Constant | 0.0216 | 0.0277 | 0.127 | 0.000385 |
| | (0.170) | (0.167) | (0.170) | (0.136) |
| Number of observations | 5775 | 5775 | 5775 | 5775 |
| Number of Groups | 1155 | 1155 | 1155 | 1155 |
| Number of instruments | 32 | 31 | 29 | 27 |
| Wald statistic | 26351.0*** | 26136.3*** | 24678.9*** | 24438.5*** |
| Arellano-Bond AR(1) | -1.83* | -1.83* | -1.83* | -1.83* |
| Arellano-Bond AR(2) | 0.54 | 0.53 | 0.52 | 0.53 |
| Hansen test | 13.26 | 12.77 | 13.35 | 12.81 |

*Notes:* Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

*Source:* Authors' calculation in Stata 11.2.

The positive coefficient of *loan loss reserves to gross loans* suggests that banks assuming higher levels of credit risk tend to have higher NIMs. The positive coefficient of equity to total assets indicates that better capitalized banks generally have higher NIMs. This is in line with the results of some previous studies, including Terraza (2015). The coefficient of *cost to income ratio* is negative, implying that banks with higher operational efficiency are able to attain higher NIMs. For the bank-specialization-specific dummy variables, we see results in line with the patterns in Figure 3.1. The coefficient of *bank holdings and holding companies* is positive but insignificant, suggesting no clear evidence between bank holdings and commercial banks. In contrast, the coefficients of other dummies are significantly negative, suggesting generally lower NIMs or a faster decrease in NIMs.

In this paper, we are most interested in the results for the last two variables – the *negative rate dummy* and *capital-based market dummy*. Regarding the negative rate dummy, we can see that it becomes significantly negative only when the model specification does not include the short-term interest rate variable; otherwise, the assumed nonlinear impact is well captured by the modelled quadratic impact. In the case of the capital-based market dummy, we can see that the variable is significant at the 5 % level in all specifications.

The bottom lines of Table 3.5 report the estimation diagnostic results. The Wald statistics show that the models are significant. Arellano-Bond AR(1) tests are significant at least at the 10% level, while AR(2) tests do not reject the null hypothesis. This result, together with the significance of the lagged dependent variable, suggests that using the dynamic panel estimation method is the correct approach. Moreover, system GMM allows us to estimate the model using the time-invariant dummy variables.

The results of the Hansen test lead to not rejecting the null hypothesis of exogenous instruments, i.e., to the desired outcome. We must be aware of the fact that the Hansen test could be weakened by too many instruments, especially if the number of instruments exceeds the number of groups. However, this is not the case, since we have only 32 instruments at most, but the number of groups is 1155. Some additional tests for robustness were performed.

Table 3.6: Lagged dependent variable coefficients in S-GMM, FE, and Pooled OLS - robustness check

| | FE | S-GMM | Pooled OLS |
|---|---|---|---|
| | nim | nim | nim |
| L.nim | 0.238*** | 0.846*** | 0.941*** |
| | (0.0708) | (0.0286) | (0.0270) |

*Note:* Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

*Source:* Authors' calculation in Stata 11.2.

### Further Robustness Checks

As another robustness check, we compare the estimates of the coefficient of the lagged dependent variable from the fixed effects, system GMM, and pooled OLS estimations to verify the condition $\hat{\delta}_{FE} \leq \hat{\delta}_{S-GMM} \leq \hat{\delta}_{OLS}$, which must hold Roodman (2009). The estimated coefficients of the lags are presented in Table 3.6, confirming that this condition holds.[6]

In Table 3.7, we present estimation results for additional model specifications. Model (5) is a further modification of model (4), also dropping the unemployment variable. We can see that the omission brings no substantial change to the signs and significance of the estimated coefficients. Models (6), (7) and (8) then present the results of the same model specifications as in models (2), (3) and (4), but with a restricted sample dropping all Italian banks. We can see that although there are some differences in the magnitudes of the estimated coefficients, their signs and significance remain comparable, as do the estimation diagnostics.

We have also done two other robustness checks (tables not reported in the paper). First, during our estimation we estimated also model specification including time dummy variables, but the results did not differ substantially. Second, we provided the estimation with included country fixed effects and with included country fixed effects and dropped macroeconomic variables. The results showed that with inclusion of the country dummies the macroeconomic variables remain significant. In case they were dropped, the Hansen test rejected a null hypothesis and thus suggested for misspecification of the model.

[6] All results from this comparison are presented in Table B.3 in the Appendix.

Table 3.7: System GMM estimation results

| | (5) nim | (6) nim | (7) nim | (8) nim |
|---|---|---|---|---|
| L.nim | 0.845*** | 0.850*** | 0.848*** | 0.850*** |
| | (0.0282) | (0.0304) | (0.0306) | (0.0296) |
| st_ir | 0.100*** | 0.0528* | - | 0.0532* |
| | (0.0288) | (0.0318) | | (0.0316) |
| st_ir_sq | -0.0221*** | -0.0144** | - | -0.0145** |
| | (0.00615) | (0.00636) | | (0.00638) |
| spread | -0.0214*** | -0.0277*** | -0.0284*** | -0.0277*** |
| | (0.00654) | (0.00932) | (0.00873) | (0.00941) |
| gdp | 0.0144*** | 0.00880* | 0.00823* | 0.00863* |
| | (0.00525) | (0.00507) | (0.00485) | (0.00507) |
| infl | 0.0608*** | 0.0393*** | 0.0378*** | 0.0389*** |
| | (0.0101) | (0.0125) | (0.0130) | (0.0124) |
| unem | - | 0.000913 | 0.000860 | 0.00109 |
| | | (0.00395) | (0.00399) | (0.00385) |
| lta | -0.00965* | -0.00306 | -0.00479 | -0.00659 |
| | (0.00571) | (0.0115) | (0.0114) | (0.00662) |
| llr_gl | 0.0125*** | 0.0196*** | 0.0188*** | 0.0194*** |
| | (0.00349) | (0.00642) | (0.00657) | (0.00623) |
| eq_ta | 0.0130** | 0.0134* | 0.0129* | 0.0132* |
| | (0.00537) | (0.00723) | (0.00736) | (0.00724) |
| cir | -0.00114** | -0.00111** | -0.00113** | -0.00112** |
| | (0.000447) | (0.000510) | (0.000520) | (0.000510) |
| nl_ta | 0.00545*** | 0.00487*** | 0.00497*** | 0.00557*** |
| | (0.000855) | (0.00107) | (0.00109) | (0.00110) |
| bhhc | 0.0272 | 0.0306 | 0.0309 | 0.0299 |
| | (0.0225) | (0.0224) | (0.0227) | (0.0223) |
| coop | -0.0963*** | -0.0656* | -0.0679* | -0.0739* |
| | (0.0260) | (0.0371) | (0.0374) | (0.0391) |
| rem | -0.182*** | -0.169*** | -0.171*** | -0.158*** |
| | (0.0523) | (0.0645) | (0.0655) | (0.0576) |
| savings | -0.0650*** | -0.0330 | -0.0320 | -0.0373 |
| | (0.0234) | (0.0266) | (0.0270) | (0.0269) |
| negrate | -0.0168 | -0.0408 | -0.0614*** | -0.0405 |
| | (0.0187) | (0.0260) | (0.0207) | (0.0260) |
| capbas | 0.0951** | 0.129*** | 0.134*** | 0.121*** |
| | (0.0376) | (0.0443) | (0.0445) | (0.0401) |
| nl_dstf | - | 0.000300 | 0.000201 | - |
| | | (0.000378) | (0.000387) | |
| la_dstf | - | -0.000562 | -0.000486 | - |
| | | (0.000639) | (0.000636) | |
| large | - | -0.00316 | 0.00255 | - |
| | | (0.0474) | (0.0471) | |
| small | - | 0.0736 | 0.0815 | - |
| | | (0.0791) | (0.0793) | |
| Constant | -0.00741 | -0.0952 | -0.0364 | -0.0594 |
| | (0.137) | (0.189) | (0.189) | (0.149) |
| Number of observations | 5775 | 4275 | 4275 | 4275 |
| Number of Groups | 1155 | 855 | 855 | 855 |
| Number of instruments | 26 | 31 | 29 | 27 |
| Wald statistic | 24415.4*** | 19323.0*** | 18518.1*** | 19293.9*** |
| Arellano-Bond AR(1) | -1.83* | -1.74* | -1.74* | -1.74* |
| Arellano-Bond AR(2) | 0.53 | 0.52 | 0.52 | 0.52 |
| Hansen test | 12.79 | 12.38 | 13.34 | 12.61 |

*Notes:* Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

*Source:* Authors' calculation in Stata 11.2.

### 3.5.2 Summary of Results

In this section, we analyse the estimation results to reject or not reject the three hypotheses tested in this paper. We also compare the estimation results to the results of previous studies.

**Hypothesis #1 (institutional determination of NIM) – not rejected:** Inclusion of the capital-based market dummy allowed us to consider the possible difference in the level of NIM between banks located in the United States and United Kingdom as capital-based markets compared to banks located in other European countries as bank-based markets. The estimated significant positive coefficient of this dummy, together with the pattern visible in Figure 4, shows evidence of the impact of institutional design on the level of NIM. Hence, the decision on this hypothesis is not to reject it.

**Hypothesis #2 (higher sensitivity of small banks' NIMs) – not rejected:** The estimation results provide mixed evidence on the second hypothesis. On one hand, we can see in Figure 2 that there are clear differences in NIMs according to size and, moreover, that the NIM of small banks decreases over the observed period while the NIM of large banks remains relatively stable and the NIM of medium banks decreases only modestly. Our findings are in line with Molyneux *et al.* (2019), Genay & Podjasek (2014) and Tan (2019). On the other hand, the estimation results show significance neither of the logarithm of total assets nor of the large and small dummy variables. Hence, the conclusion on the hypothesis is not to reject it, but this decision is mainly due to the mixed evidence.

**Hypothesis #3 (savings banks' NIMs) – rejected:** We predicted that savings banks would report the highest NIMs. However, Figure 3.1 indicates that an average NIM of this type of bank is steadily lower than for bank holdings and commercial banks. This is also supported by the negative coefficient of the savings banks dummy, which is significant for all specifications with the full dataset. The insignificance of the coefficient in the case of the sample with excluded Italian banks is caused by a lower estimated magnitude but is still negative, while the standard error of the estimated coefficient remains relatively stable. Overall, this gives us relatively clear evidence for the decision to reject this hypothesis.

In Table 3.8, we compare our estimation results with those of other studies, which differ in using datasets of various sizes, geographic location, and variety of bank types. Moreover, different estimation approaches are employed in each of the papers. For this reason, only some of the most commonly included variables are considered in the table. We find comparable results for certain variables. Our estimation brings comparable results for the coefficients of the lagged dependent variable, the short-term rate and its square, GDP growth, and the ratio of equity to total assets.

Our results differ, especially in terms of the coefficients of the slope of the yield curve, from those presented by Borio *et al.* (2017). Some authors considered the impact of the size of the bank, at least by including total assets or their logarithm as an explanatory variable. However, our estimation is unique in including the specialization dummies as well as the capital-based market dummy. Moreover, we have used a unique dataset combining data for US and European banks from the very recent period 2011-2016. In summary, the main contribution of the analysis is further exploration of the factors influencing banks' NIMs in ZLB or even negative rate situations. In this paper, we considered, in addition to the impact of the interest rate structure, the impact of the institutional design of the market on NIM while controlling for differences between various bank specializations and for distinct size categories.

### 3.5.3 Further Research Opportunities

In this section, we discuss opportunities for further research: a further analysis of the impact of the slope of the yield curve; a more sophisticated approach to size effects, especially regarding the impact of the yield curve; a larger data sample; and more variables.

The first opportunity is further analysis of the influence of the slope of the yield curve. Our result for the slope of the yield curve suggests the impact to be negative and linear. This seems to be in contradiction with the theoretical assumptions and results in previous studies. However, this result may be caused by reaching a certain point at which a steeper yield curve may cause decreasing profitability, as predicted in Borio *et al.* (2015). Another possible explanation can be attributed to the different time periods we are using compared to Borio *et al.* (2017), who use data from 1995-2012, while we use data from 2011-2016. The development of the yield curve shape was quite different in the years after the Great Recession, which may be one of the causes of the different estimated impacts.

The second opportunity is related to the yield curve as well. We can suppose

that another cause for the different impact of the yield curve in our results may be related to the size effects. Borio *et al.* (2017) use data on 109 large international banks. In contrast, we use a much larger sample of 1155 banks of various sizes. It is likely that smaller banks, which rely more on retail deposit financing, may respond differently to changes in the yield curve than large international banks, which are likely to rely more on wholesale funding.
The third opportunity lies in obtaining data from the years that follow. Having more data from a longer time period would be desirable to obtain more robust results. This will be possible as data from later years become available. While a negative interest rate environment in the euro area is still present, it may eventually end. Hence, we could obtain more observations on both the negative rate period and "normal" times. Moreover, it would be interesting to observe how exactly banks cope with the end of a negative interest rate era.
Finally, an assessment of other bank-specific (e.g. capital requirements, deposit requirements, interest rate risk, market power) and country-specific variables (e.g. creditor rights protection, restrictions on non-traditional bank activities, taxation, depth of credit information) affecting bank NIM might reveal interesting facts and relationships.

## 3.6 Conclusion

This paper focused on the determinants of the net interest margin of banks in the United States and European countries in a zero lower bound situation. Moreover, we tested hypotheses stating that while NIM is highly influenced by the overall interest rate environment, there exist significant differences between individual banks arising from their different business models as well as country-specific market characteristics, specifically, the institutional design feature of whether the financial market is bank-based or capital-based. For this purpose, we have used a large dataset of annual data on 1155 banks from the United States and 24 EU countries from the 2011-2016 period.
The main contribution of this paper may be summarized in three points. First, we considered other factors that may influence NIM in our analysis, mainly the institutional design of whether the bank operates within a bank-based or capital-based financial market. Our results confirm that banks operating in capital-based markets attain higher NIMs. This suggests that underdeveloped capital markets are harming the ability of banks to optimize their NIMs.

Second, the composition of the sample allowed us to consider the impact of market rate on NIM in a situation commonly referred to as the zero lower bound. Similar to Borio *et al.* (2017) and Bikker & Vervliet (2017), we found a positive concave relation between the short-term rate and NIM, confirming the assumed nonlinearity in the impact of market rate on bank profitability. On the other hand, we found a negative linear impact of the slope of the yield curve on NIM, contrary to Borio *et al.* (2017), who found a positive concave impact. This result opens a space for more detailed research on the impact of the varying shape of the yield curve on NIM, which is beyond the scope of this paper.

Third, we applied a standard methodology on unique panel data of US and European banks, including banks from the euro area and countries with national currencies. Moreover, we were able to distinguish between distinct types of banks, i.e., commercial banks, bank holdings, cooperative banks, savings banks and real estate and mortgage banks, for which we found significant differences in NIMs.

In summary, we confirmed a positive concave relationship of NIM with the short-term interest rate observed in previous studies, but we found a negative relationship of NIM with the yield curve slope, contrary to other researchers. We also found significant differences arising from different bank specializations, and we found a significant impact of institutional factors on bank profitability.

Table 3.8: Comparison of Estimated Signs and Significance Levels for the Coefficients of NIM Determinants in Previous Studies

| Authors | Data | Methodology | NIM (first lag) | Short-term rate | Short-term rate squared | Spread | Spread squared | GDP growht | Inflation | Equity/total assets | Specialization | Size[1] | Low/negative rate | Capital-/Bank-based |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Borio *et al.* (2017) | Bankscope (109 large banks, 14 advanced economies, 1995-2012) | System GMM | + | + | − | + | − | 0 | no | + | no | no | no | no |
| Claessens *et al.* (2017) | Bankscope (3385 banks, 47 countries, 2005-2013) | Fixed effects | + | + | no | 0 | no | 0/− | no | + | no | no | yes[2] | no |
| Bikker & Vervliet (2017) | Federal Deposit Insurance Corporation (3582 U.S. banks) | System GMM & static methods | + | + | − | +[3] | no | + | − | −[4] | no | yes | no | no |
| Altavilla *et al.* (2017) | ECB datasets (288 banks, Q1 2000 - Q4 2016) | OLS | + | + | no | 0 | no | + | 0 | 0[5] | no | no | no | no |
| Arseneau (2017b) | 22 bank holdings (U.S. stress testing scenarios) | GLS | no | no | no | no | no | no | no | no | no | yes | yes[6] | no |
| Kerbl & Sigmund (2017) | OeNB (946 banks, Q1 1998 - Q1 2016) | Fixed effects | no | + | 0 | + | no | + | no | no | no | yes | yes[7] | no |
| Cruz-García & Fernandez de Guevara (2020) | Bankscope (31 OECD countries, 2000-2014) | System GMM | + | + | no | no | no | 0 | no | 0 | no | + | no | no |
| This paper - Hanzlík & Teplý (2020) | Orbis Bank Focus (1155 banks, 2011-2016, EU & US) | System GMM | + | + | − | − | 0 | + | + | + | yes | yes | yes | yes |

*Notes:* +/− - estimated positive/negative coefficient (at least at 10% significance level); 0 - insignificant estimate; no - variable not included in the model; yes - model includes variables/dummy variables for a given effect; [1] considered both (log of) total assets and size dummies; [2] low interest rate environment dummy; [3] long-term interest rate used instead of slope of the yield curve; [4] total capital ratio; [5] regulatory capital ratio; [6] negative interest rate environment dummy; [7] impact of negative rate considered as forecast in separate ARIMA model.

*Source:* Author based on individual papers and own results.

# Chapter 4

# Prepayment Risk in Banking: Impact Assessment of the Changing Interest Rate in the Czech Republic[1]

## 4.1 Introduction

Prepayment risk is an important type of risk to be considered by every bank. Choudhry (2018, p. 107) defines it as *"the risk associated with the early unscheduled return of principal on an instrument. ... This risk also extends to typical retail lending products (for instance unsecured loans, mortgages, and vehicle finance)."* Therefore, it has to be considered especially by those banks whose assets consist to large extent from long-term retail loans, particularly mortgages. The prepayment risk may result in decrease of banks' profitability in times of decreasing market interest rates. In such circumstances the bank clients have incentives to refinance their existing loans with higher interest rates by new loans with lower interest rates. In times of increasing rates, the prepayment risk may tend to decrease as in such case clients would prefer to stick to previously contracted lower rates. However, the banks may experience higher default rates when the mortgages are repriced at the end of fixation period to higher rate. Such increase in mortgage defaults caused by combination of increasing interest rates and house price bubble occurred in the United States in 2007 and 2008 and contributed to the start of the Global Financial Crisis

[1] This chapter will be published as Hanzlík & Teplý (2022).

Mayer *et al.* (2009). The prepayment risk may be to some extent limited by contractual terms or legal provisions which specify the circumstances at which the loan can be prepaid. On the other hand, the legislation may be also designed in favor of the clients and thus contribute to the prepayment risk.

Our paper provides a case study of the mortgage market in the Czech Republic. The legislation in the Czech Republic effective since 1st December 2016 (Act No. 257/2016 Coll. on Consumer Loan which transposed the European directive 2014/17/EU to the Czech law) allowed for an interpretation by the Czech National Bank that the bank can charge the client only very limited scope of the costs related to the prepayment of a loan. This interpretation leads to higher probability of prepayment risk materialization in the Czech banking sector by lowering the costs of the prepayment option for the client.

Our analysis thus focuses on the impact of prepayment risk, defined as the risk of a fully repaid mortgage balance (but foregone interest) prior to the scheduled or contracted maturity, on the issuing Czech banks. The remainder of the paper is organised as follows: in Section 4.2 we discuss key basic terms (embedded options of a bond and of a bank loan) needed for our research. Section 4.3 presents the methodology applied (case study on interest rate risk of a bank and the net present value concept of a banks' total loss). In Section 4.4, we undertake an empirical analysis and compute the impact of early repayment of the mortgage on the balance sheets of three different types of banks. The last section concludes the paper.

## 4.2 Theoretical Part

### 4.2.1 Embedded Options of a Bond

In this section we provide theoretical context, which will serve as the basis for our empirical research. In the financial markets, the problem of an early repayment of a mortgage is similar to the problem of valuing callable bonds. Fabozzi (2015) defines *"a callable bond as a bond in which the bondholder has sold the issuer a call option that allows the issuer to repurchase the contractual cash flows of the bond from the time the bond is first callable until the maturity date."* The call feature is a special feature of a bond or other financial instrument that give creditors and/or debtors the right to take action in the future against their counterparty. The embedded option is an integral part of

a financial instrument and is generally not separately tradable. One financial instrument may include more embedded options. The value of a callable bond is then expressed as the difference between the value of a non-callable bond and the value of the call option.
The call option protects the borrower or lender from unexpected changes in market interest rates (i.e. against the price loss that may arise from the decrease/ increase of the interest rate between the issue date and the maturity date). Fabozzi (2004) lists a call option as the most typical embedded option, which gives the right to the debtor to repay his debt before an agreed maturity at a pre-agreed upon price (serving as a defacto ceiling on the price of the bond). This fact favours the borrower in the event of a fall in market interest rates, because it gives him the opportunity to refinance debt under more favourable conditions. On a related note, Fabozzi (2004) introduces a put option on the market as a typical option to protect the lender, when interest rates go up. In the remainder of our paper we will focus primary on the impact of the call option, which favours the borrower during decreasing market interest rates and it also results in the lender's (bank) loss. Recently, two embedded options have been examined in the Czech financial market: construction savings by Horváth & Teplý (2013) and savings accounts by Džmuráňová & Teplý (2016).

### 4.2.2 Embedded Options of a Bank Loan

The prepayment risk of a loan represents an embedded option for a client to refinance his bank loan (e.g. a mortgage) for a lower interest rate. When the client exercises his early repayment option, he can repay the remaining balance of the loan (and forego future interest payments) before its maturity, which is better for him because this represents a lower implied interest rate. Obviously, this client's profit means a loss (of foregone interest payments less the risk of a default of an outstanding loan) to the bank as a mortgage provider. Moreover, the early mortgage repayment will have an impact on interest rate position of the bank as discussed later.
Hayre & Young (2004) highlight five main causes of premature repayment of a mortgage: replacement of housing (prepayment rate depends on the replacement of existing homes), refinancing (full early repayment for a new loan for better conditions), default (full repayment of the house as a seized collateral), partial prepayment (the client prepays part of the loan and shortens the orig-

inal maturity) and full payment (e.g. in case of destruction of the house by a natural disaster). However, it is necessary to distinguish the different sensitivity of the client's willingness to prepay a mortgage. While interest rates are decreasing, the sensitivity is high. In contrary, the sensitivity can be quite minimal in case of solving the life situation such as divorce or settlement of inheritance.

### 4.2.3 Prepayment Risk

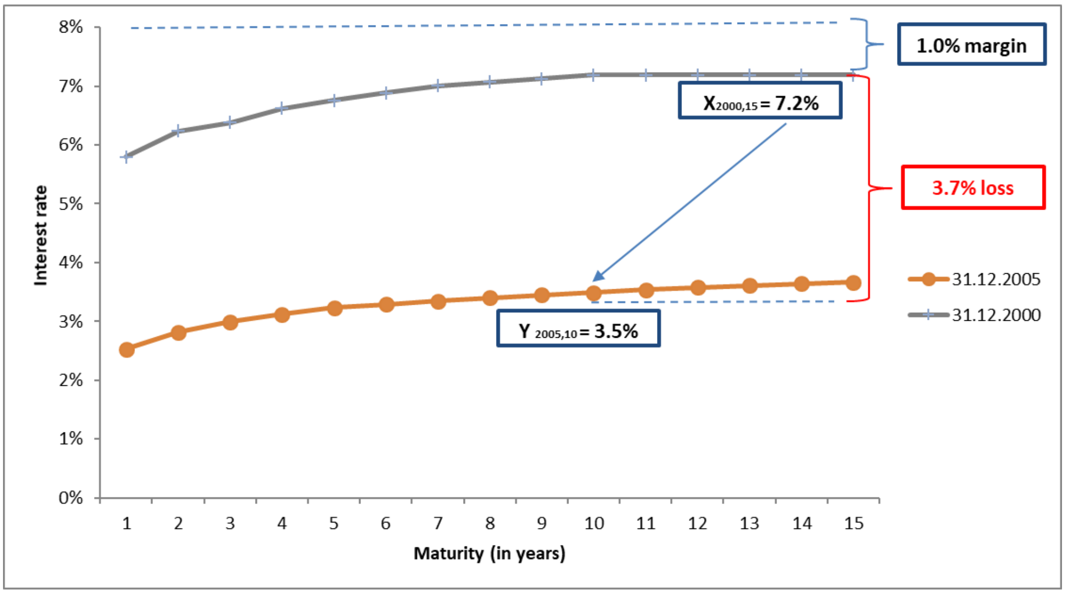
*"Prepayment or Early Redemption Risk: applies on fixed-rate loans and deposits, where customers have the right (or an option) to repay loans or redeem deposits ahead of the scheduled maturity date, on payment of an early repayment or redemption charge."* (Choudhry 2018, p. 1015) Banks in different countries handle the prepayment risk on mortgages differently. In countries such as United States or the United Kingdom the risk is transferred via process known as securitisation to the investors who buy mortgage-backed securities (MBS) issued by special purpose entity to which the mortgages are sold by the originating bank. On the other hand, in many European countries including Germany or the Czech Republic the prepayment risk remains on the banks' balance sheets and the mortgages are funded either by issuance of covered bonds or by retail deposits.

The existing literature on prepayment risk focuses mainly on the prepayment risk securitised through the MBS in the United States Becketti *et al.* (1989) or option-adjusted valuation of MBS related to the prepayment risk Levin & Davidson (2005). Kau *et al.* (1992) provide a generalized valuation model for fixed-rate mortgages (FRM). Paper by Ambrose & LaCour-Little (2001) deal with prepayment risk in adjustable-rate mortgages (ARM) and its securitisation through MBS and provides the evidence that prepayment risk is much less important for ARM than for FRM. Chernov *et al.* (2018) developed a reduced-form modelling framework to observe the implied prepayment function in which the prepayment rates are beside interest rates influenced by other macroeconomic factors.

## 4.3 Methodology

Our paper uses two methodological approaches. First, we present a case study on the interest rate risk of a bank through the bank's ALM. Second, we apply a net present value concept for the calculation of the bank's losses that resulted from lower interest income.

Figure 4.1: Interest rate risk of the Bank as of 31 December 2005



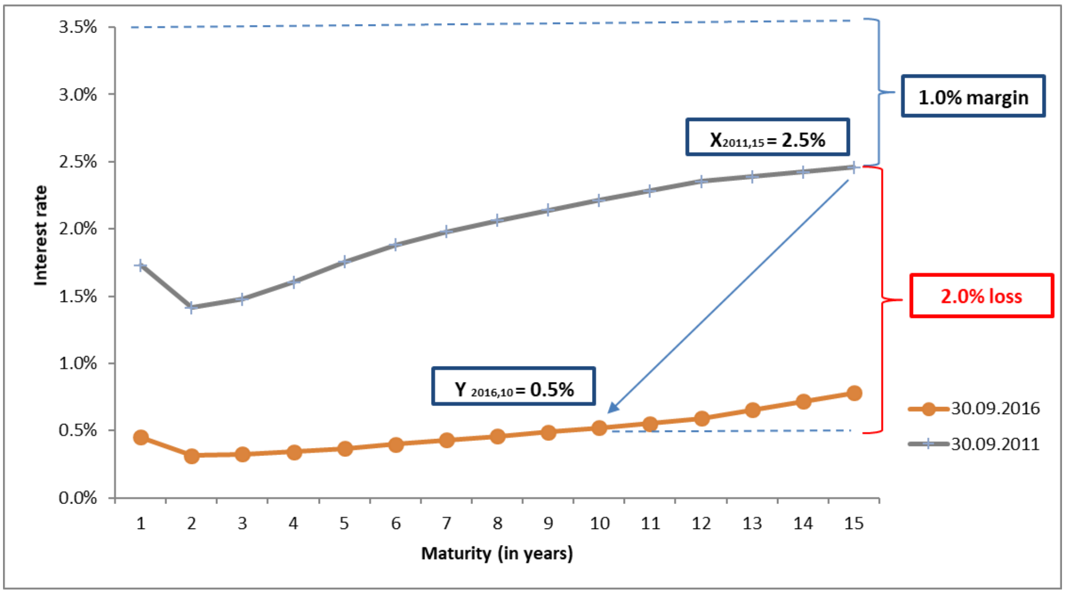

*Source:* Authors

*Note:* Loss from funding $= X_{(2000,15)} - Y_{(2005,10)} = 7.2\% - 3.5\% = 3.7\%$, where $X_{(2000,15)}$ is a 15-year interest rate in 2000 and $Y_{(2005,10)}$ is a 10-year interest rate in 2005.

### 4.3.1 Case Study on Interest Rate Risk of a Bank

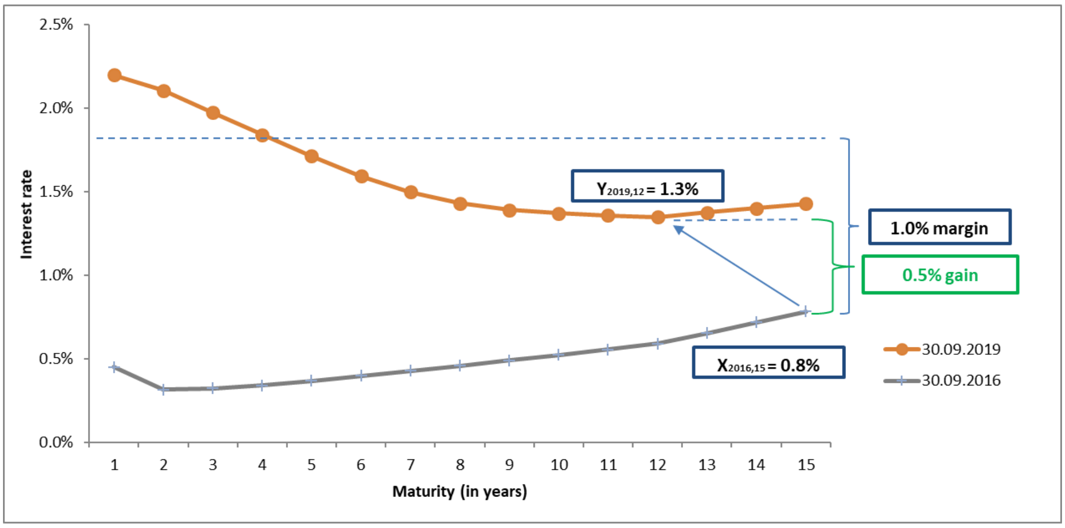
The impact of early repayment of the mortgage can be illustrated by the bank's asset-liability-department (ALM) problem. For example, for a mortgage with a 5-year fixed term, the bank would need to offset its risk by finding adequate resources, such as an interest rate swap with the same maturity (a 5-year bank's liability). If a mortgage is terminated before its contractual maturity, the bank's ALM should ensure that such a situation is balanced in the bank's balance sheet by means of a substitute transaction (e.g. by replacing the original source of mortgage funding with a new instrument with a shorter maturity). This problem becomes significant at a low-interest rate environment. For simplicity, let's assume that a bank has two parts of its portfolio: the first part

Figure 4.2: Interest rate risk of the Bank as of 30 September 2011




*Source:* Authors
*Note:* Loss from funding = $X_{(2011,15)} - Y_{(2016,10)} = 2.5\% - 0.5\% = 2.0\%$, where $X_{(2011,15)}$ is a 15-year interest rate in 2011 and $Y_{(2016,10)}$ is a 10-year interest rate in 2016.

Figure 4.3: Interest rate risk of the Bank as of 30 September 2016




*Source:* Authors
*Note:* Gain from funding = $Y_{(2019,12)} - X_{(2016,15)} = 1.3\% - 0.8\% = 0.5\%$, where $X_{(2016,15)}$ is a 15-year interest rate in 2016 and $Y_{(2019,12)}$ is a 12-year interest rate in 2019.

is funded at recent low interest rates and the second one is funded at past high interest rates. Figure 4.1 and Figure 4.2 below illustrate this interest rate risk based on the development of real yield curves in the Czech Republic valid between 31 December 2000 and 31 December 2005 and between 30 September 2011 and 30 September 2016. Let's suppose a bank (denoted as "the Bank") entered a 15-year fixed rate payer swap on 31 December 2000 with a fixed rate of 7.2%[2] to finance a mortgage on that day with a 1% margin[3] (i.e. a total rate of 8.2%). However, five years later in 2005, the mortgage was prepaid and the Bank put the money raised from the mortgage prepayment on the market through a 3.5% fix rate receiver swap for the remaining 10 years, implying a loss of 3.7%[4] for the period 2006-2015 as displayed in the Figure 4.1. Similar situation is illustrated in the Figure 4.2 where the bank entered a 15-year fixed rate payer swap on 30 September 2011 with a fixed rate of 2.5% to finance a mortgage on that day with a 1% margin (i.e. a total rate of 3.5%). However, five years later in 2016, the mortgage was prepaid in a market environment in which the Bank was able to place the money raised from the prepayment on the market through a 0.5% fix rate receiver swap for the remaining 10 years.
In contrast to a situation of decreasing market rates depicted in Figure 4.1 and Figure 4.2, we identified an opposite situation of a period of increasing market rates in Figure 4.3 between 30 September 2016 and 30 September 2019. In this case the prepayment is rather desirable for the Bank since it can put the money from prepayment into the fix rate receiver swap for higher rate (1.3%) than at the time of the loan origination (0.8%). However, in such case the Bank still loses the 1% margin in case the money is placed on the market instead of being used for provision of new mortgage with the same margin.

[2]It means that Bank was receiving a variable rate, based on 1-month Prague Interbank Offered Rate (PRIBOR) for instance. In practice the banks are hedging their fixed-rate assets such as mortgages by entering the fixed rate payer swaps while the actual funding of the balance sheet comes either from deposits or issued (covered) bonds.

[3]The nominal value of the mortgage is not important for our illustrative calculation. Also, for simplification, we neglect the amount of the fee paid by the client for this prepayment on December 31, 2015 (i.e. the bank's compensation costs payable by the client – the option adjusted spread (OAS) spread rate – is equal to zero).

[4]3.7% = 7.2% - 3.5% (loss on funding = funding costs – a new swap interest rate). In fact, the total loss for the bank is 4.7% = 3.7% + 1% (loss on funding + margin).

### 4.3.2 The Net Present Value of Bank's Total Loss

If we want to calculate the total loss for the whole 2006-2015 period, it is possible to use a standard formula for discounted cash flows:

$$PV = \sum_{t=1}^{T} \frac{CF_t}{(1 + r_t)^t}$$

where $PV$ is a present value of a loss, $CF$ is a cash flow in a given year, $r_t$ is an interest rate in a given year, $t$ is a given year and $T$ is the end of the period. Let us assume that the Bank will provide a mortgage of CZK 1,000,000, then an annual loss of CZK 37,000 (3.7% loss from funding) was generated over the entire period, with the interest rate corresponding to the yield curve as of 31 December 2005 (see also Figure 4.1):

$$Loss = \frac{CF_1}{(1 + r_1)^1} + \frac{CF_2}{(1 + r_2)^2} + ... + \frac{CF_{10}}{(1 + r_{10})^{10}} =$$

$$= \frac{37,000}{(1 + 2.5\%)^1} + \frac{37,000}{(1 + 2.8\%)^2} + ... + \frac{37,000}{(1 + 3.5\%)^{10}} = 310,900$$

The loss can be understood as a bank's cost that a counterparty (such as a corporate client or other bank) would terminate a swap contract. As a result, the Bank would have to conclude a new contract as of December 31, 2005, but at a lower rate (3.5% instead of the original 7.2% as of December 31, 2000). The total loss for the bank discounted as of 31 December 2015 arising from the swap contract termination amounted to CZK 310,900 over the 10-year period, which corresponds to a high volume since it is 31.09% of the nominal value of the loan.

## 4.4 Empirical Part

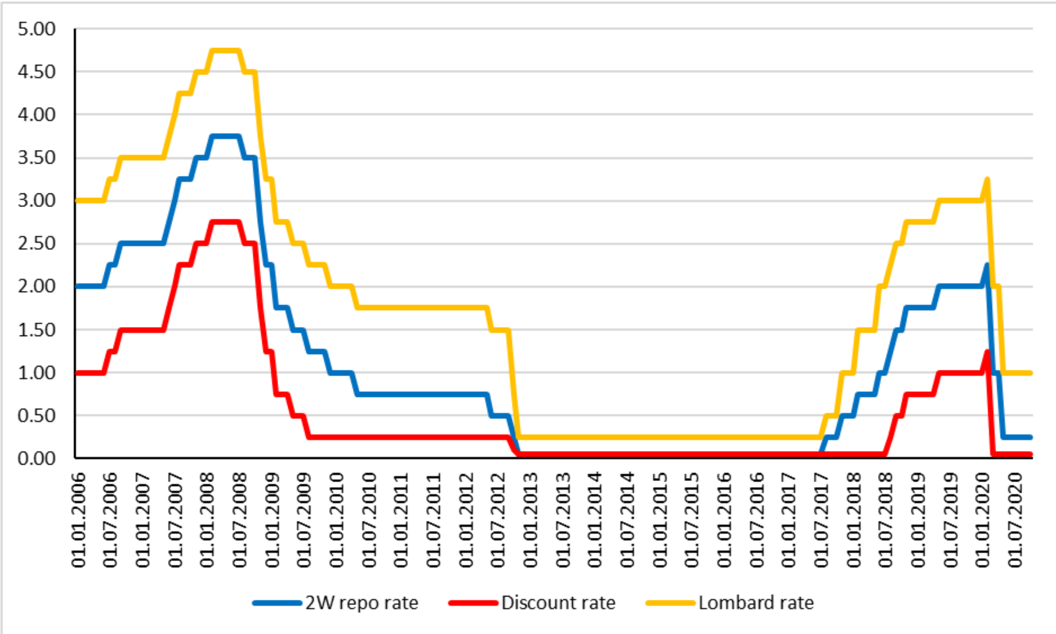
In this section we provide the quantification of the impact of early repayment of a mortgage on three types of banks with different costs of funding. First, we provide a model of banks' portfolios without mortgage prepayment and then a model with mortgage prepayment. We distinguish three different periods of decreasing interest rates (2006-2011), low interest rates (2012-2017) and increasing interest rates (2017-2020).

### 4.4.1 Modelling Periods

#### Decreasing Interest Rates (2006-2011)

The period 2006-2011 is in our paper considered as a period of decreasing interest rate, although during the years 2006-2008 the rates were in fact increasing as shown in Figure 4.5. However, in 2008 they started to drop quickly due to the Global Recession.

Figure 4.4: CNB policy rates 2006-2020




*Source:* Authors based on CNB data

#### Low Interest Rates (2012-2017)

The Czech banking sector is stable, well-capitalized and reports a liquidity surplus (CNB 2017). In the 2012-2017 the Czech National Bank (CNB) was keeping key interest rates technically at the zero level. The risk of early repayment of mortgages can be therefore significant yet this risk is somewhat offset by long-term fixed mortgages granted before 2012, i.e. in periods of relatively higher interest rates. Moreover, this phenomenon can fully materialize in the next economic cycle.

(CNB 2015) presented in its Financial Stability Report an analysis of new mortgage loans, which distinguished between the totally new, refinanced and refixed loans within the overall volume of new mortgage loans. It reported four

groups of new mortgages as of 1 March 2015. First, 43% of the total volume were new loans. Second, 35% of total loans were concluded with the new interest rate on the outstanding portion of the loan with the same financial service provider (refixed loans). Third, 14% of total loans have been negotiated on the unpaid principal of the loan with the new provider (refinanced loans). Fourth, the remaining 8% share were mortgages with increased principal. (CNB 2015) further states that the largest increase in lending was recorded by small banks, namely by more than 80%. It can be attributed to the fact that small banks most significantly compress the interest rate compared to other types of banks and they were attracting clients to refinance their loans.
Moreover, CNB expected in 2017 that *"Interest income can be expected to be adversely affected for some time to come by refixation and refinancing of mortgage loans, which will cause the average interest margin on the stock of such loans to move closer to that on new loans, which is significantly lower."* (CNB 2017)

#### Increasing Interest Rates (2017-2020)

The last considered period begins in 2017 when the CNB ended its unconventional monetary policy of exchange rate commitment and then started increasing its policy rates in relatively fast way. This continued until the beginning of 2020 when CNB changed the course again due to the outbreak of Covid-19 pandemic and decreased the policy rates in two steps to 0.25% from its peak of 2.25% in February 2020.
Due to the protracted Covid-19 pandemic situation continuing in 2021, the future development of monetary policy and market interest rates is rather uncertain. There are two main possible scenarios, that the rates will either remain low for longer time (situation resembling the period 2012-2017) or that the rates will start to go up similarly as in period 2017-2020. Therefore, it is relevant to consider both periods as a model situation for both possible future scenarios.

### 4.4.2 Results of Theoretical Modelling in the 2011-2016 period

#### Theoretical Modelling (without Mortgage Prepayment)

Table 4.1 displays the bank's financing costs for the 2016-2021 period, assuming constant annual funding costs of 1.25% since 2016.[5] It is clear that the funding costs fall over time due to a decrease in market rates (from 1.73% at the end of 2016 to 1.25% at the end of 2021). In the calculations below, for simplicity, we assume a flat yield curve (for example, in 2012, the assumed interest rate for all maturities amounts 2.00%, in 2013 at 1.75% etc.). We also incorporate in the calculations a 5-year mortgage fixation, i.e. that only a portion of the banking portfolio is fixed in each year. Specifically, in 2016, 10% of mortgages are fixed, 20% of mortgages are fixed in 2017 and so on. Based on such an approximation, it is possible to obtain the average financing costs for the given years:

$$r_p = \sum_{t=1}^{T} r_t w_t$$

where $r_p$ are average funding costs of the Bank in a given year $t$, $r_t$ is the interest rate in the given year $t$, $w_t$ is the weight in the portfolio (i.e. share of fixed mortgages originated in the given year $t$) and $T$ is the end of the observed period (number of years).

For the year rate $r_p$ it holds that is equal to the weighted average of the applicable rate in the given year and its weight in the portfolio. After computations, the average rate $r_{2011-2016}$ for the 2011-2016 period reached 1.73%:

$$r_{2011-2016} = r_{2011}w_{2011} + r_{2012}w_{2012} + ... + r_{2016}w_{2016} =$$

$$= 2.00\% \cdot 10\% + 2.00\% \cdot 20\% + ... + 1.25\% \cdot 10\% = 1.73\%$$

#### Theoretical Modelling (with Mortgage Prepayment)

In our models, three types of banks have been created, each with a different funding structure.[6] Benchmark is Bank 1, which cuts financing costs from

[5] These are real-time expert estimates.

[6] This is an illustrative example of an analysis of different levels of risk from different banks, which is reflected in the cost of financing. Assuming the same risk, banks should theoretically have the same financing costs (i.e. the possibility of financing for the same

Table 4.1: Funding costs of the Bank for the 2016-2021 period

| Year | Interest rate | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|
| **2011** | 2.00% | 10% | | | | | |
| **2012** | 2.00% | 20% | 10% | | | | |
| **2013** | 1.75% | 20% | 20% | 10% | | | |
| **2014** | 1.75% | 20% | 20% | 20% | 10% | | |
| **2015** | 1.50% | 20% | 20% | 20% | 20% | 10% | |
| **2016** | 1.25% | 10% | 20% | 20% | 20% | 20% | 10% |
| **2017** | 1.25% | | 10% | 20% | 20% | 20% | 20% |
| **2018** | 1.25% | | | 10% | 20% | 20% | 20% |
| **2019** | 1.25% | | | | 10% | 20% | 20% |
| **2020** | 1.25% | | | | | 10% | 20% |
| **2021** | 1.25% | | | | | | 10% |
| **Funding costs** | | **1.73%** | **1.58%** | **1.45%** | **1.35%** | **1.28%** | **1.25%** |

*Source:* Authors
*Note:* We assume that interest rates reached the minimum in 2016 and will not decrease afterwards.

2.00% in 2011 to 1.25% in 2016. Bank 2 in this period reports 1.5 times the rates of Bank 1, while Bank 3 has its funding at 2 times the rates of Bank 1 (Table 4.2).

Table 4.2: Funding costs of Bank 1, Bank 2 and Bank 3 for the 2011-2016 period

| | Funding costs | | |
|---|---|---|---|
| **Year** | **Bank 1** | **Bank 2** | **Bank 3** |
| **2011** | 2.00% | 3.00% | 4.00% |
| **2012** | 2.00% | 3.00% | 4.00% |
| **2013** | 1.75% | 2.63% | 3.50% |
| **2014** | 1.75% | 2.63% | 3.50% |
| **2015** | 1.50% | 2.25% | 3.00% |
| **2016** | 1.25% | 1.88% | 2.50% |

*Source:* Authors

Table 4.3 summarizes the results of modelling the impact of early repayment of mortgages on Bank 1 income and a 20% share of prepaid mortgages[7], accord-

market yield curve). The only difference is in the yield curve (riskier banks should pay more upward on the credit margin). The increase and fall in interest rates on the market would then be the same for all banks, it would be a parallel shift in the yield curve.

[7] The Czech consumer credit law approved in 2016 allows the client to prepay up to 25% of the mortgage a year free of charge. However, we don't expect that the 25% ratio would have materialized, so provide a robust scenario analysis for 10%, 20% and 50% shares of prepaid mortgages.

ing to which the accumulated loss on the Bank's interest income would reach 0.27% at the end of 2021.

Table 4.3: Impact of early repayment of mortgages on Bank's income (Bank 1, 20% share of prepaid mortgages)

| Bank 1 | | | | | | Calculated loss | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Interest rate** | **Structure of funding costs in 2016** | **Ratio of prepaid mortgages** | **Volume** | **Difference** | **2016** | **2017** | **2018** | **2019** | **2020** | **2021** |
| **2011** | 2.00% | 10% | 20% | 2.00% | 0.75% | 0.02% | | | | | |
| **2012** | 2.00% | 20% | 20% | 4.00% | 0.75% | 0.03% | 0.03% | | | | |
| **2013** | 1.75% | 20% | 20% | 4.00% | 0.50% | 0.02% | 0.02% | 0.02% | | | |
| **2014** | 1.75% | 20% | 20% | 4.00% | 0.50% | 0.02% | 0.02% | 0.02% | 0.02% | | |
| **2015** | 1.50% | 20% | 20% | 4.00% | 0.25% | 0.01% | 0.01% | 0.01% | 0.01% | 0.01% | |
| **2016** | 1.25% | 10% | 20% | 2.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| **Loss in a given year** | | | | | | **0.10%** | **0.08%** | **0.05%** | **0.03%** | **0.01%** | **0.00%** |
| **Cumulative loss for the whole period** | | | | | | **0.10%** | **0.18%** | **0.23%** | **0.26%** | **0.27%** | **0.27%** |

*Source:* Authors

Table 4.4 shows the results of modelling the impact of early repayment of mortgages on Bank 3 income and a 20% share of prepaid mortgages. It displays that the cumulative loss on the Bank 3's interest income would reach 0.53% at the end of 2021 (0.16% by 2017), which may be a significant loss for this type of bank.[8]

Figure 4.6 illustrates the impact of early repayment of mortgages on Bank 1, 2 and 3 returns for the various proportions of early repayment mortgages (10%, 20%, 50%) for the period 2016-2021. It is clear that different types of banks have different impacts that are generally linear. The results show that, in the extreme case, Bank 3, at 50% early repayment, could accumulate a loss in interest rate margin of 1.33% in the period 2016-2021.

### Empirical Modelling (with Mortgage Prepayment)

The above theoretical modelling can be verified by an empirical analysis. Looking at the history of interest rates in the Czech Republic over the period 2000-2020, we find that the largest drops in rates were recorded in the 2001-2006

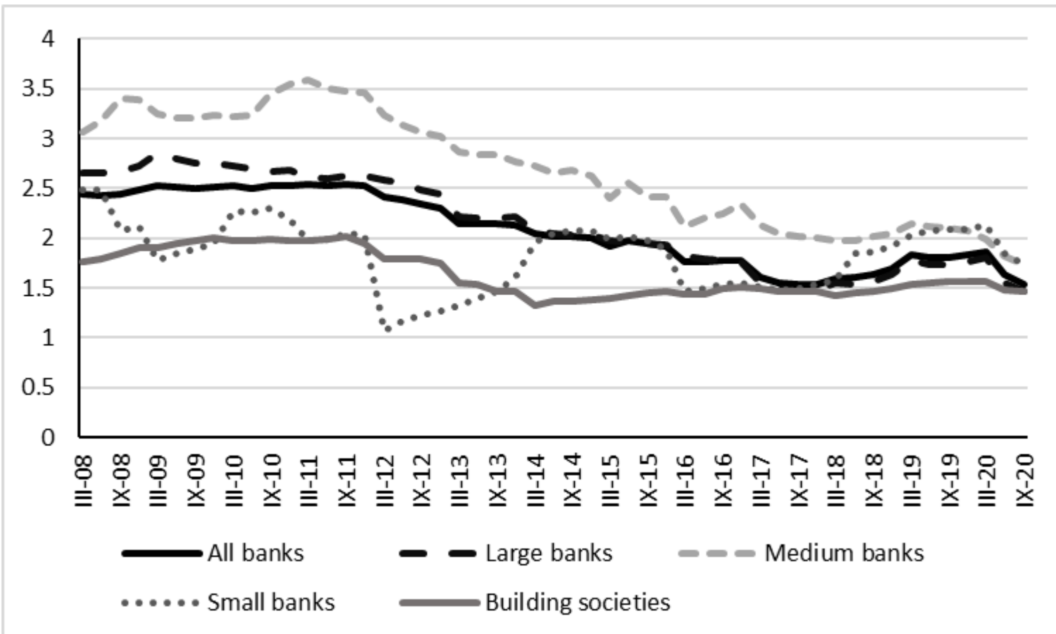
[8] For comparison, Wüstenrot hypoteční banka a.s., a small Czech bank, reported an overall interest margin of 1.79% as of December 31, 2014. The computed 0.53% loss would represent 29.6% of the 1.79% total margin. Overall, the net interest rate margin of the Czech banking sector fell down from 2.48% as of 31 December 2008 to 1.53% as of 30 September 2020 (i.e. a 37.3% decrease, see Figure 4.5).

Table 4.4: Impact of early repayment of mortgages on Bank's income (Bank 3, 20% share of prepaid mortgages)

| Bank 3 | | | | | | Calculated loss | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Interest rate** | **Structure of funding costs in 2016** | **Ratio of prepaid mortgages** | **Volume** | **Difference** | **2016** | **2017** | **2018** | **2019** | **2020** | **2021** |
| **2011** | 4.00% | 10% | 20% | 2.00% | 1.50% | 0.03% | | | | | |
| **2012** | 4.00% | 20% | 20% | 4.00% | 1.50% | 0.06% | 0.06% | | | | |
| **2013** | 3.50% | 20% | 20% | 4.00% | 1.00% | 0.04% | 0.04% | 0.04% | | | |
| **2014** | 3.50% | 20% | 20% | 4.00% | 1.00% | 0.04% | 0.04% | 0.04% | 0.04% | | |
| **2015** | 3.00% | 20% | 20% | 4.00% | 0.50% | 0.02% | 0.02% | 0.02% | 0.02% | 0.02% | |
| **2016** | 2.50% | 10% | 20% | 2.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| **Loss in a given year** | | | | | | **0.19%** | **0.16%** | **0.10%** | **0.06%** | **0.02%** | **0.00%** |
| **Cumulative loss for the whole period** | | | | | | **0.19%** | **0.35%** | **0.45%** | **0.51%** | **0.53%** | **0.53%** |

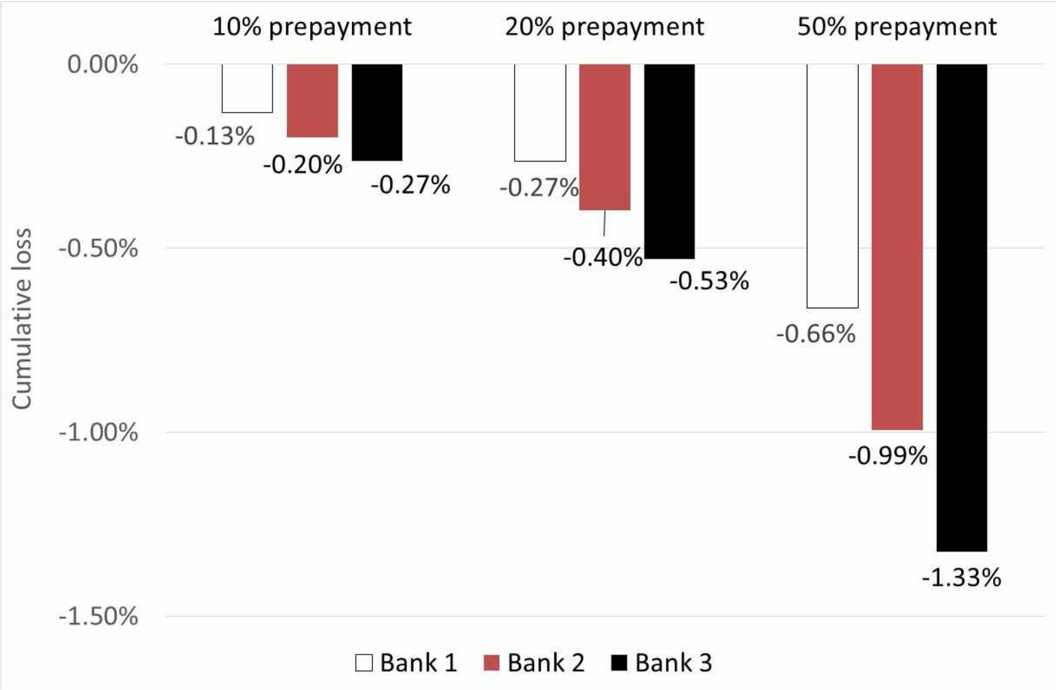
*Source:* Authors

Figure 4.5: Quarterly development of net interest margin of Czech banks (%)




*Source:* Authors based on CNB data

Figure 4.6: The impact of early repayment of mortgages on Banks 1, 2 and 3 income for different ratio of early repayments (10%, 20%, 50%) in the period 2016-2021




*Source:* Authors

period when the 1Y PRIBOR dropped from 5.85% to 2.55% (Table 4.5) and in 2008-2013, where 1Y PRIBOR dropped from 4.24% to 0.87% (Table 4.6). On the other hand, in period 2017-2020 the 1Y PRIBOR experienced a period of relatively fast increase (Table 4.8). In such a case the banks could theoretically gain from prepayments by reinvesting the cash from prepaid mortgages to new mortgages with higher rates. On the other hand, these gains may be limited by lower incentives for the clients to repay their mortgages.

By applying the above-mentioned market rates and assuming a 20% prepayment of mortgages, it can be calculated that the total cumulative expected loss would be 0.24% in the period 2001-2006 (Table 4.5) and respectively 0.78% in the 2008-2013 period (Table 4.6).

In Table 4.7 we present results for period 2011-2016, i.e. a period in which the rates were already very low and decreased only modestly towards the zero lower bound. Finally, Table 8 shows results for period 2016-2020 during which the rates started to rise. Assuming constant rate of prepayment, we can see

Table 4.5: Loss of bank income based on actual 1Y PRIBOR market rates in 2001-2006

| | | | | | | Calculated loss | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Market interest rate (1Y PRIBOR)** | **Structure of funding costs in 2006** | **Ratio of prepaid mortgages** | **Volume** | **Difference** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** |
| **2001** | 5.85% | 10% | 20% | 2.00% | 3.30% | 0.07% | | | | | |
| **2002** | 4.47% | 20% | 20% | 4.00% | 1.92% | 0.08% | 0.08% | | | | |
| **2003** | 2.54% | 20% | 20% | 4.00% | -0.01% | 0.00% | 0.00% | 0.00% | | | |
| **2004** | 2.35% | 20% | 20% | 4.00% | -0.20% | -0.01% | -0.01% | -0.01% | -0.01% | | |
| **2005** | 2.81% | 20% | 20% | 4.00% | 0.26% | 0.01% | 0.01% | 0.01% | 0.01% | 0.01% | |
| **2006** | 2.55% | 10% | 20% | 2.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| **Loss in a given year** | | | | | | **0.14%** | **0.08%** | **0.00%** | **0.00%** | **0.01%** | **0.00%** |
| **Cumulative loss for the whole period** | | | | | | **0.14%** | **0.22%** | **0.23%** | **0.23%** | **0.24%** | **0.24%** |

*Source:* Authors

Table 4.6: Loss of bank income based on actual 1Y PRIBOR market rates in 2008-2013

| | | | | | | Calculated loss | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Market interest rate (1Y PRIBOR)** | **Structure of funding costs in 2013** | **Ratio of prepaid mortgages** | **Volume** | **Difference** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** |
| **2008** | 4.24% | 10% | 20% | 2.00% | 3.37% | 0.07% | | | | | |
| **2009** | 3.89% | 20% | 20% | 4.00% | 3.02% | 0.12% | 0.12% | | | | |
| **2010** | 2.13% | 20% | 20% | 4.00% | 1.26% | 0.05% | 0.05% | 0.05% | | | |
| **2011** | 1.80% | 20% | 20% | 4.00% | 0.93% | 0.04% | 0.04% | 0.04% | 0.04% | | |
| **2012** | 1.72% | 20% | 20% | 4.00% | 0.85% | 0.03% | 0.03% | 0.03% | 0.03% | 0.03% | |
| **2013** | 0.87% | 10% | 20% | 2.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| **Loss in a given year** | | | | | | **0.31%** | **0.24%** | **0.12%** | **0.07%** | **0.03%** | **0.00%** |
| **Cumulative loss for the whole period** | | | | | | **0.31%** | **0.55%** | **0.67%** | **0.75%** | **0.78%** | **0.78%** |

*Source:* Authors

that in such a case the cumulative expected loss becomes negative, i.e. the bank experiences gain in margin of 0.65 percentage points.

Table 4.7: Loss of bank income based on actual 1Y PRIBOR market rates in 2011-2016

| | | | | | | Calculated loss | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Market interest rate (1Y PRIBOR)** | **Structure of funding costs in 2016** | **Ratio of prepaid mortgages** | **Volume** | **Difference** | **2016** | **2017** | **2018** | **2019** | **2020** | **2021** |
| **2011** | 1.80% | 10% | 20% | 2.00% | 1.34% | 0.03% | | | | | |
| **2012** | 1.72% | 20% | 20% | 4.00% | 1.26% | 0.05% | 0.05% | | | | |
| **2013** | 0.87% | 20% | 20% | 4.00% | 0.41% | 0.02% | 0.02% | 0.02% | | | |
| **2014** | 0.60% | 20% | 20% | 4.00% | 0.14% | 0.01% | 0.01% | 0.01% | 0.01% | | |
| **2015** | 0.51% | 20% | 20% | 4.00% | 0.05% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | |
| **2016** | 0.46% | 10% | 20% | 2.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| **Loss in a given year** | | | | | | **0.10%** | **0.07%** | **0.02%** | **0.01%** | **0.00%** | **0.00%** |
| **Cumulative loss for the whole period** | | | | | | **0.10%** | **0.18%** | **0.20%** | **0.21%** | **0.21%** | **0.21%** |

*Source:* Authors

Table 4.8: Loss of bank income based on actual 1Y PRIBOR market rates in 2015-2020

| | | | | | | Calculated loss | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Market interest rate (1Y PRIBOR)** | **Structure of funding costs in 2020** | **Ratio of prepaid mortgages** | **Volume** | **Difference** | **2020** | **2021** | **2022** | **2023** | **2024** | **2025** |
| **2015** | 0.51% | 10% | 20% | 2.00% | -1.76% | -0.04% | | | | | |
| **2016** | 0.46% | 20% | 20% | 4.00% | -1.81% | -0.07% | -0.07% | | | | |
| **2017** | 0.44% | 20% | 20% | 4.00% | -1.83% | -0.07% | -0.07% | -0.07% | | | |
| **2018** | 0.97% | 20% | 20% | 4.00% | -1.30% | -0.05% | -0.05% | -0.05% | -0.05% | | |
| **2019** | 2.07% | 20% | 20% | 4.00% | -0.21% | -0.01% | -0.01% | -0.01% | -0.01% | -0.01% | |
| **2020** | 2.27% | 10% | 20% | 2.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| **Loss in a given year** | | | | | | **-0.24%** | **-0.21%** | **-0.13%** | **-0.06%** | **-0.01%** | **0.00%** |
| **Cumulative loss for the whole period** | | | | | | **-0.24%** | **-0.45%** | **-0.58%** | **-0.64%** | **-0.65%** | **-0.65%** |

*Source:* Authors

## 4.5 Conclusion

In this paper we deal with prepayment risk in banking and provide empirical evidence from the Czech banking sector. The prepayment risk of a loan represents an embedded option for a client to refinance his mortgage for a lower interest rate. The client may have incentive to repay the remaining amount of the loan before its maturity, especially in case he can refinance the loan with a new loan with a lower interest rate. Conversely, it holds that the client's profit means a loss to the bank as a mortgage provider. In the empirical part, our analysis quantifies the impact of early repayment of the mortgage on the balance sheets of different types of banks, which differ in the structure of their financing. In particular, the effect of prepaying mortgages on the interest margins of model banks was examined. Our results show that this effect could become to be significant especially in the decreasing interest rate environment when the clients have incentives to repay their existing mortgage with higher rate by a new one with lower rate. On the contrary, in the period of increasing interest rates the bank could gain on the prepayments, if they are able to provide new loans for the higher rates, but at the same time the prepayment risk decreases due to lower incentives for clients to prepay. The prepayment risk was strengthened by the Czech consumer credit law approved in 2016, which allows the client to prepay up to 25% of the mortgage a year free of charge. Based on our modelling, we compute the impact of early repayment of the mortgage on the balance sheets of three different types of banks. The results of theoretical modelling have shown that these risks forced by banks might have substantial effect and they are likely to be one of the factors contributing to the decreasing net interest margin of the Czech banking sector.

# Chapter 5

# Liquidity Positions of EU banks in the Low Interest Rate Environment under LCR Constraint[1]

## 5.1 Introduction

The outbreak of the global financial crisis of 2007-2009 was accompanied with disruptions to the interbank money market in developed countries in North America and Europe triggered by negative news on a subprime mortgage market in the United States that started to generate losses and spill over the contagion to the whole financial sector via securitised assets held by many players on the financial market. The suspicion that the counterparties on the financial market may have large exposures to the "toxic assets" linked to the subprime mortgages lead to an increase in the credit spreads and thus to the freezing of the market as it became difficult for banks to obtain liquidity from the interbank market.

This "Black Swan" event as named by Williams & Taylor (2009) was particularly difficult situation for wholesale banks that relied more on the short-term funding from the interbank market in contrast to the retail banks that use client deposits as the main source of their funding. Hence many of such banks had to obtain liquidity from the central banks playing the role of the "lender of last resort" (LOLR).

The experience from the outbreak of the global financial crisis lead the regula-

[1] This chapter is aimed to be published as an own paper of the author after the defense of this dissertation thesis.

tors to an update of the banking regulation in the form of recommendations of the Basel Committee on Banking Supervision known as Basel III. Besides the main focus of Basel III on strenghthening the capital adequacy requirements, Basel III introduced also two new measures of liquidity risk - the liquidity coverage ratio (LCR) and the net stable funding ratio (NSFR).

In the European Union the Basel III reforms were implemented via the Capital Requirements Regulation (CRR) and Capital Requirements Directive IV (CRD IV). However, in case of the two liquidity ratios only LCR was implemented as part of the CRR while NSFR was not legally binding until 2021. As defined in the Article 460 of CRR the LCR requirement was set as gradually increasing starting in 2015 at 60%, following with 70% in 2016, 80% in 2017 and reaching the final 100% in 2018. The NSFR is supposed to be finally implemented as binding constraint by the new version of the EU regulation CRR II/CRD V as of 2021 as mentioned in Komarkova *et al.* (2020).

This paper aims to empirically observe the impact of introduction of the Basel III liquidity requirements in the European Union and the gradual phasing-in of the LCR requirement on the liquidity positions of European banks. Moreover, the period after the financial crisis of 2007-2009 has been characterized by unprecendented situation of low and even negative interest rate environment that put a big pressure on banks' profitability along with the strenghthened requirements to hold more liquid assets bearing a low yield.

The paper is organized as follows. Section 5.2 provides a review of existing literature on liquidity risk in banking and its regulation, in Section 5.3 we describe the used dataset and selection of variables, and then in Section 5.4 the used econometric framework and construction of the model is discussed. The results of estimation are presented in Section 5.5. Section 5.6 concludes the paper.

## 5.2 Literature Review and Hypotheses Formulation

The existing literature on the liquidity risk uses various approaches and differs in the aspects of the topic on which the authors focus. Some papers deal with the systemic nature of the liquidity risk in a sense that individual banks may optimize their liquidity strategy in a way that may lead to suboptimal situations when considering the banking sector as a whole.

Such approach is represented e.g. by Bonfim & Kim (2012) who analyse if there exists herding behaviour in the liquidity risk in banking. They consider the impact of peers' liquidity indicators (using predicted values of these liquidity indicators as instruments to deal with potential endogeneity) along with other bank specific variables such as capital ratio, bank size, profitability measures (return on assets and net interest margin), cost-to-income ratio and net loans-to-total assets ratio as a measure to what extent is a bank specialized in lending.

Bonfim & Kim (2012) observe that the herding effects, i.e. dependency on the liquidity positions of peers, are significant only for the largest banks. The authors provide four possible explanation for this observations. First, that large banks compete mainly with other large banks and thus replicate the risk-taking strategies with the aim of profit maximization. Another reason may be that large banks are able to access more diversified funding sources with lower funding costs which leads again to similar liquidity and funding strategies. Similar liquidity strategies may be also result of more sophisticated risk management tools used by the large banks in contrast to smaller banks. Finally, the herding behaviour in liquidity steering may arise from the too-big-to-fail phenomenon that large banks are likely to be bailed out in case of systemic distress contrary to the small banks.

Huang & Ratnovski (2011) model a "dark side" of the wholesale funding of banks showing that the wholesale funding may improve efficiency of the bank in case the provider of the wholesale funding is conducting monitoring of the bank. On the other hand, if the wholesale funding provider relies on external monitoring of the bank he might be misled by a noisy public signal and stop funding for a healthy bank and thus cause an inefficient liquidation of the bank.

Hoerova *et al.* (2018) represent another approach to the topic of liquidity risk in banking. They discuss the costs and benefits of liquidity risk regulation and more specifically the tools that can be used for it. First, they mention that strenghthening the solvency of the bank (as happened e.g. by tightening the capital requirements in Basel III) should by definition lead to decrease in liquidity risk since equity is a "stable liquidity" and it can also improve the depositors' confidence in the bank. Second, they discuss the LOLR function of a central bank as another intervention to address liquidity risk in banking. However, they point to the problem of asymmetric information which makes this tool inefficient due to costs arising either from bailing out insolvent banks or not bailing out illiquid but solvent banks by the LOLR.

Therefore, Hoerova *et al.* (2018) empirically asses the potential impact of binding LCR and NSFR had it been already in place prior to the financial crisis of 2007-2009. They find out that while leverage ratio would have been effective at reducing bank failures, LCR and NSFR would significantly limit the emergency liquidity take-up by European banks. On the other hand, the banks would have still required substantial central bank liquidity assistance. Hence they conclude that capital requirements and LOLR interventions are essential in managing solvency and liquidity risk, but at the same time the liquidity regulation is also very useful because it further improves the management of potential liquidity stress and also helps in reducing the macroeconomic costs of the regulation.

Imbierowicz & Rauch (2014) analyse the relationship between liquidity and credit risk in banks as these two are the most important factors for the banks' survival. Using various econometric approaches they do not find consistent relationship between these two risks. However, they still conclude that joint management of both risks can substantially increase bank stability and help avoid financial crises such as the one in 2007-2009.

Significant group of papers focuses on (estimated) NSFR as a measure of long-term liquidity of the banks and its lower levels before the introduction of Basel III. King (2013) uses balance-sheet data as of end-year 2009 to estimate NSFR for a sample of 549 banks from 15 countries such as United States, Japan, United Kingdom, China, France, Germany and other (including both developed and emerging markets). He then asseses the impact of varying levels of NSFR on the profitability measures of the banks. He finds that representative bank in 10 of the examined countries has a NSFR below the 100% threshold. Also he estimates that strategies to improve the NSFR would lead to 70-88 bps reduction in NIM. Dietrich *et al.* (2014) analyze sample of 921 Western European banks between 1996 and 2010. They find that a majority of banks was historically not fulfilling the NSFR minimum requirements. On the other hand, they conclude that even though some banks will be forced to shift their business models and will thus face certain short-run cost disadvantage, the improvement does not have to result in lower profitability in the long run.

DeYoung & Jang (2016) asses the liquidity management of U.S. banks on the sample of annual data from 1992 through 2012. They find that the banks actively managed their liquidity positions in the manner of traditional loan-to-core deposit ratio as well as in a certain measure similar to NSFR. More specifically, small and medium-sized commercial banks operated during the observed period with more liquid balance-sheets than the large banks. On the other hand, the large banks showed higher ability to improve the liquidity position in a short run.

Komarkova *et al.* (2020) asses the relationship between capital and liquidity requirements, i.e. the capital adequacy, leverage ratio, LCR and NSFR, in a context of the Czech banking sector. They consider two scenarios, one in the upward phase of the financial cycle and one in the downward phase taking into account also the assumed increase or decrease of the countercyclical capital buffer by the CNB and thus increasing the capital requirement in the upward phase or decreasing in the downward phase. The findings suggest that the capital ratios are in general more binding especially for the smaller banks and also in case of the downward phase of the finanical cycle. The interaction of capital and liquidity requirements is analyzed also by DeYoung *et al.* (2018) who conclude that compliance with regulatory capital requirements leads naturally to better NSFRs.

Other studies on the topic of liquidity risk include Leykun (2016) who examine the determinants of liquidity risk of Ethiopian banks, Tran *et al.* (2019) who considers the determinants of banks' liquidity risk in Vietnam and Vodová (2011) who considers the liquidity of banks in Slovakia. Deans *et al.* (2012) and Tripe & Shi (2012) then consider the changes in liability structure of banks in New Zealand and Australia in the changed environment after the financial crisis and introduction of new Basel III rules for liquidity.

Compliance of banks with the regulatory limits during the phase-in of the LCR requirement in the EU is assessed in EBA (2016). The report provides a comparative analysis on a group of selected 171 banks from the EU showing that 155 of them have been already compliant with the 100% fully phased-in LCR minimum as of December 2015, while on the other hand three of the 171 were not even fulfilling the 70% minimum requirement valid for the year 2016 and needed to increase their liquidity buffers by EUR 1.1 billion to meet this requirement. The comparative analysis also shows that smaller banks and banks with specialized business models are more sensitive towards the LCR requirement.

EBA (2020) showed that banks have made significant efforts to increase the level of LCR and decrease the shortfall in liquid assets and that they entered the period of Covid-19 pandemic with LCRs well above the 100% minimum. The weighted average as of December 2019 was 147% for the observed group of 130 banks. This figure even increased to 165.9% in June 2020. The analysis also showed that Global Systemically Important Institutions (G-SIIs) and Other Systemically Important Institutions (O-SIIs), i.e. banks considered to be too-big-to-fail, reported lower LCRs on average than smaller banks, but also with lower dispersion of the reported values. These results were confirmed in EBA (2021) that reported further increase of average LCR to 176% owing mainly to additional liquidity support provided by monetary authorities while the expected adverse effects of Covid-19 on the LCR levels did not materialize. Based on the previous literature on the liquidity risk we formulate the following three hypothesis we aim to test in this paper.

**Hypothesis #1 (increase in liquid assets holdings):** The LCR of a bank measures the coverage of the expected net outflows of cash (expected cash outflows minus expected cash inflows) over the 30-day horizon by holdings of liquid assets (cash and bonds that can be easily sold or put in repo) to cover these net outflows. Hence we assume that the introduction of binding LCR requirement should therefore lead to an increase in holdings of liquid assets proxied by the variable *liquid assets to deposits* & *short-term funding* as further discussed in Section 5.3.

**Hypothesis #2 (decrease in loan-to-deposit ratio):** The ratio of loans to deposit is the basic liquidity indicator of a bank. Higher loan-to-deposit ratio, especially in case it is higher than 100%, is a sign of a worse liquidity situation of a bank (and higher reliance on funding from wholesale market). Hence we assume that the liquidity regulation aiming to improve the banks' liquidity position should lead to a decrease in the loan-to-deposit ratio (proxied by variable *net loans to deposits* & *short-term funding*) further described in Section 5.3.

**Hypothesis #3 (different impact by bank specialisation):** We assume that the introduction of the binding LCR requirement will have significant impact mainly on the banks with more diversified business models with higher share of wholesale activities while it should have only limited impact on more traditional banks focusing on collecting deposits and providing loans. We consider five types of banks in our sample: bank holdings & holding companies, commercial banks, savings banks, cooperative banks and real estate & mortgage banks. We expect that the impact should be mainly on the first two types of banks while the other three types are expected to show insignificant impact of the LCR constraint.

## 5.3 Empirical Analysis

### 5.3.1 Dataset

The used dataset is based mainly on the Orbis Bank Focus database and includes 707 banks from 27 EU member countries. Data were selected for active banks from EU28 countries whose specialization was ranked as bank holdings & holding companies, commercial banks, cooperative banks, real estate & mortgage banks, or savings banks. The data were then filtered by variables assumed for use in the model to achieve a balanced panel for 2012-2018 with no missing observations.

The dataset was extended by a set of country specific variables, i.e. GDP growth rate, inflation rate, 3M interbank rate, 10Y government bond yield and the ratio of issued government bonds to the GDP for a given country. We then computed a proxy variable for a slope of the yield curve as difference between the 10Y government bond yield and 3M interbank rate and a dummy variable *negative rate* indicating negative 3M interbank rate for a given country for a given year. The source for most of the country specific variables was Eurostat except for the 3M interbank rate which was obtained from Reuters (CZK and EUR countries) or ECB statistical data warehouse (other non-EUR countries). We created also dummy variables for each of the banking specialisations except for commercial banks which are considered the base group.

### 5.3.2 Variable selection

The models use two different liquidity indicators as dependent variables - *liquid assets to deposits* & *short-term funding* and *net loans to deposits* & *short-term funding*. The dependent variables are described in Table 5.1.

The explanatory variables can be divided into two groups - the bank specific variables and the country specific variables. The bank specific variables serve as proxies for individual characteristics of the banks such as size (*natural logarithm of total assets of the bank*), profitability and efficiency (*return on average assets* and *cost to income ratio*), credit risk (*net loans to total asset ratio* and *loan loss reserves to gross loans ratio*) and capital (*equity to total assets*). The bank specific variables are further described in Table 5.2.

The country specific variables include certain macroeconomic characteristics such as GDP growth rate and inflation rate of a given country, interest rate

structure represented by the short-term rate (3M interbank rate) and the slope of the yield curve (proxied by difference between 10Y government bond yield and 3M interbank rate) and the ratio of issued government debt to the GDP of a given country as a proxy for the supply of liquid assets. We include also the dummy variable for existence of negative short-term interest rate and finally the quasi-dummy variable for the LCR requirement. The country specific variables are described in Table 5.3.
Finally, we define a set of bank specific dummy variables described in Table 5.4 which indicate the five specialisation types of banks. But as we use the fixed effects as the main estimation approach, we use these variables rather as a breakouts to separate estimations for each of the types than as a dummy variables included in the model.

Table 5.1: Dependent variables

| | | |
|---|---|---|
| *Liquid assets to deposits & short-term funding* | Measure of the liquid asset buffer of the bank. Represents the percentage ratio of liquid assets to the deposits and other short-term funding as defined in the Orbis Bank Focus database. | $la\_dstf$ |
| *Net loans to deposits & short-term funding* | Serves as a proxy for a loan-to-deposit ratio, a basic liquidity indicator of a bank. Based on a definition by Orbis Bank Focus database. | $nl\_dstf$ |

*Note:* Source of all dependent variables is Orbis Bank Focus database.

### 5.3.3 Descriptive Analysis

Our dataset includes 707 banks located in 27 EU member countries (including United Kingdom as it was in the observed period still a member of the EU). We excluded the only one bank from Estonia remaining in the sample after filtering for the missing observations on bank specific variables due to unavailability of 10Y government bond yield data for Estonia. Split by the bank specialisation the sample includes 203 bank holdings & holding companies, 1932 commercial banks, 2016 cooperative banks, 329 real estate & mortgage banks and 469 savings banks. Numbers of banks by individual countries are provided in Table D.3. Summary statistics of all variables are provided in Table D.1.
In Figure 5.1 we provide an overview of the development of average liquidity indicators in the sample. We can see that the indicator *liquid assets to deposits & short-term funding* improved mainly in the last two years. This

Table 5.2: Bank specific variables

| | | |
|---|---|---|
| *Natural logarithm of total assets of the bank* | This variable serves commonly as an approximation of the size of a bank. Transformation by natural logarithm is used in order to smooth out large differences in size of individual banks. | *lta* |
| *Return on average assets* | ROAA is one of the common profitability measures of a bank. Hence for our purpose we use this variable as a proxy for banks' profitability. The expected sign of the estimated coefficient is most likely to be negative as higher profitability might be attained at the expense of liquidity, but the relationship is likely to be more complex. | *roaa* |
| *Net loans to total assets ratio* | Indicates to what extent the assets consist of lending to the clients. Hence it is a proxy for credit risk, but it could be considered also a liquidity indicator. The sign of the estimated coefficient is expected to be negative as higher share of loans leaves less space for liquid assets holdings. | *nl_ta* |
| *Equity to total assets ratio* | Leverage ratio measuring the level of bank's capital. The expected sign should be negative as the better capitalization should by definition decrease the solvency risk and thus also the probability of liquidity stress for the bank as discussed in Horerova *et al.* (2018) or Komarkova *et al.* (2020). | *eq_ta* |
| *Cost to income ratio* | Indicator of bank's operational efficiency. The impact on liquidity is ambiguous. | *cir* |
| *Loan loss reserves to gross loans ratio* | Measures the quality of a bank's assets by evaluating the part of loans put aside for potential charge-off. The link to the liquidity position is somewhat unclear, but it serves as another control proxy variable for a credit risk. | *llr_gl* |

*Note:* Source of all variables is Orbis Bank Focus database.

observation suggests that the LCR requirement became binding for significant number of banks only when it arrived at its final level of 100%. In other words, in the phase-in period the LCR requirement was likely not binding for many banks which is consistent with the findings of EBA (2016). They were thus not forced to increase their liquid assets holdings until the LCR requirement became higher. The indicator *net loans to deposits* & *short-term funding* shows another pattern in the liquidity policy of the banks. We can see that in the early years of the sample the banks were improving their liquidity position mainly via decreasing the ratio of loans to deposits from maximum of approximately

Table 5.3: Country specific variables

| | | |
|---|---|---|
| *Short-term interest rate* | The average annual 3M interbank rate. For CZK and EUR countries obtained from Reuters and for other non-EUR countries from the statistical data warehouse of ECB. | *st_ir* |
| *Slope of the yield curve* | Approximated by spread between 3M interbank rate and 10Y government bond yield. | *spread* |
| *Real annual GDP growth rate* | Annual growth rate of real GDP obtained from Eurostat. | *gdp* |
| *Inflation rate* | Annual inflation rate obtained from Eurostat. | $infl$ |
| *Government debt to GDP ratio* | A ratio of total amount of issued government bonds to the GDP of a given country. The impact is expected to be positive as higher ratio means higher supply of liquid assets. On the other hand, this assumption is based on relatively strong assumption that the banks liquid asset buffers consist predominantly of government bonds issued by domestic country. | *gov_debt* |
| *Negative rate* | Equals 1 for each country that had a negative short-term interest rate in a given year. | *negrate* |
| *LCR requirement* | A quasi-dummy variable indicating the gradual phase-in of the binding LCR percentage requirement. Equals 0 for years 2012-2014, 60 for 2015, 70 for 2016, 80 for 2017 and 100 for 2018. | *LCR_req* |

*Note:* Country specific variables were obtained from Eurostat, ECB, Reuters or based on author's calculation.

Table 5.4: Bank specialisation dummy variables

| | | |
|---|---|---|
| *Bank holdings & holding companies* | Equals 1 for specialisation Bank holdings & holding companies. | *bhhc* |
| *Cooperative banks* | Equals 1 for specialisation Cooperative banks. | *coop* |
| *Real estate & mortgage banks* | Equals 1 for specialisation Real estate & mortgage banks. | *rem* |
| *Savings banks* | Equals 1 for specialisation Savings banks. | *savings* |

*Note:* Variables calculated by authors based on Orbis Bank Focus data.

93% in 2012 to a minimum of approximately 81% in 2017, but then it increased again to about 87%. This pattern may be also related to a "cleaning up" of the balance sheets, i.e. writing off the bad loans by the banks. For information, we included in the chart also the development of the *equity to total assets ratio*, showing relatively stable capital position of the banks in the sample, and the gradual phase-in of the LCR requirement.

Figure 5.2 shows the development of *liquid assets to deposits* & *short-term funding* split by bank specialisations. We can see that bank holdings & holding companies and commercial banks which can be considered a larger banks with better access to interbank markets show consistently higher levels of liquid asset buffers. Moreover these two types seem to be most impacted by the LCR requirement as they show big increase in this variable in the year 2018 when LCR was fully implemented.

In Figure 5.3 we then show *net loans to deposits* & *short-term funding* by specialisation. We can see that the real estate & mortgage banks show significantly higher level during the whole period. This is related to their business model when they focus mainly on providing the mortgage loans funded by issuance of covered bonds rather than by retail deposits as in case of other types of banks. We see quite substantial decrease of the loan to deposit ratio in case of cooperative banks from 98% in 2012 to 74% in 2017, increasing again to 89% in 2018. In case of other three types we see a relatively stable ratio oscilating around 80%.

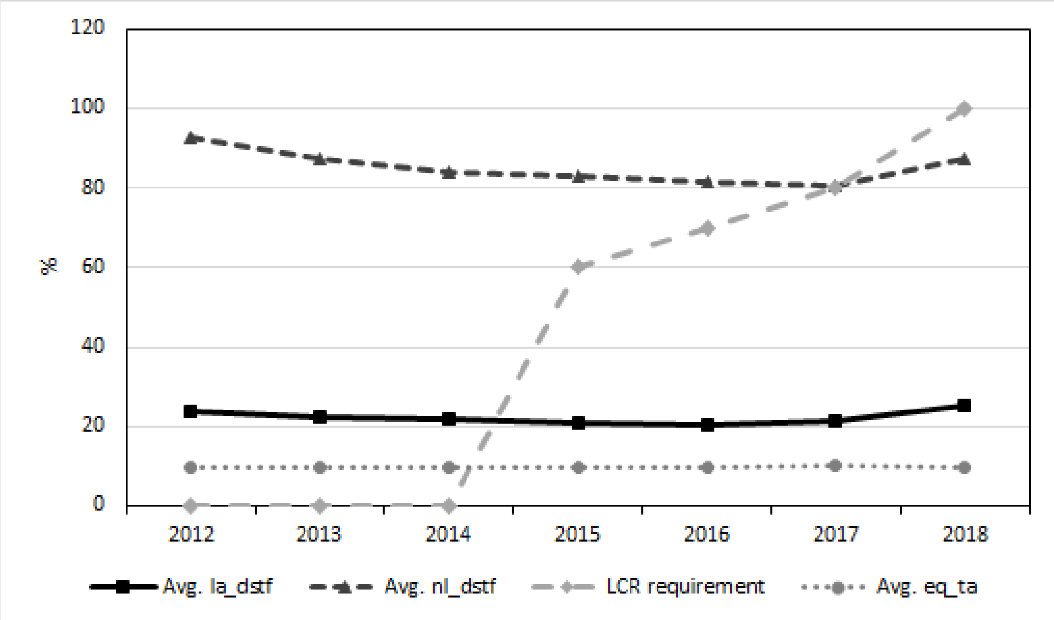
## 5.4 Methodology

We used a standard methodology for estimation with panel data. We considered using methods such as pooled OLS, fixed effects (within or LSDV estimator) or random effects (FGLS estimator) which allow under certain assumptions to estimate at least consistently a model of the following form:

$$y_{it} = \alpha + \boldsymbol{x'_{it}}\boldsymbol{\beta} + c_i + \epsilon_{it} \tag{5.1}$$

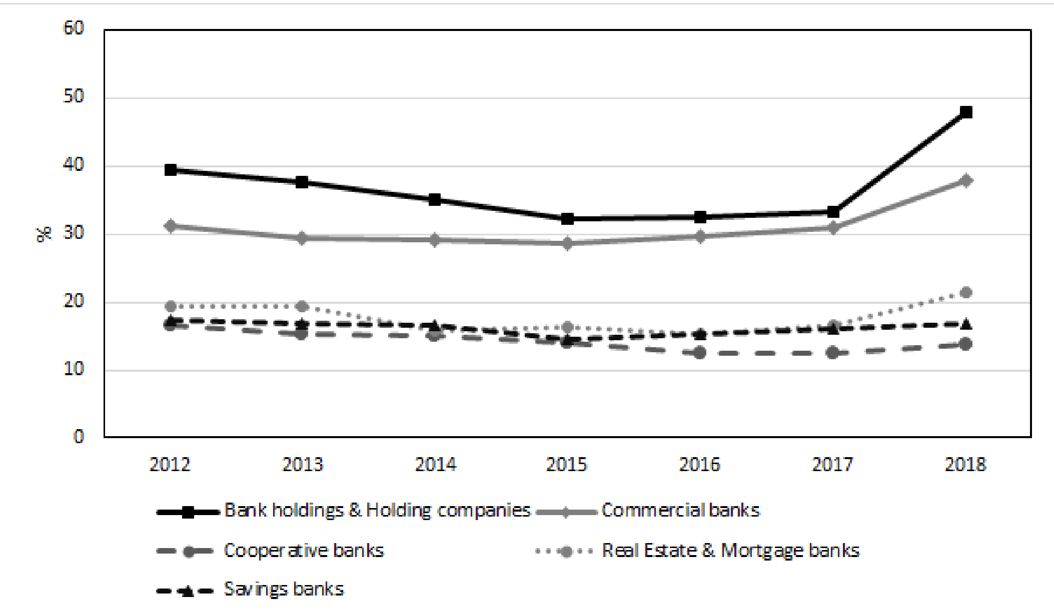
where $i = 1, \ldots, N$ (cross-sectional units) and $t = 1, \ldots, T$ (time periods), $c_i$ is the unobservable group-specific fixed or random effect and $\epsilon_{it} \sim i.i.d.\, N(0, \sigma_\epsilon^2)$.

Figure 5.1: Average liquidity and capital indicators and the LCR requirement (%) in EU in 2012-2018



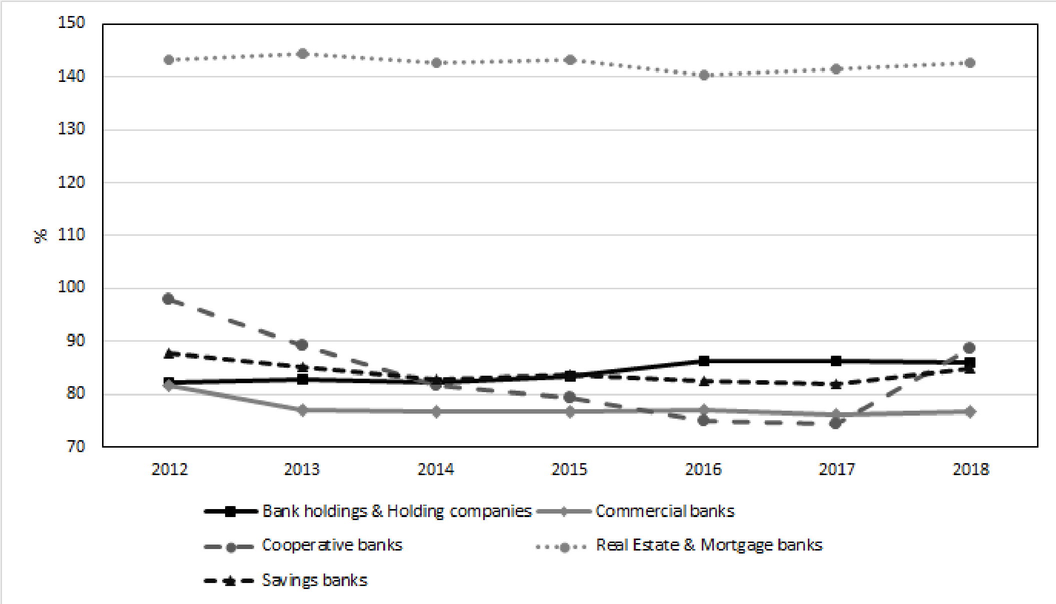

*Source:* Authors based on Orbis Bank Focus.

Figure 5.2: Average liquid assets to deposit & ST funding ratio (%) by bank specialisation in 2012-2018




*Source:* Authors based on Orbis Bank Focus.

Figure 5.3: Average net loans to deposit & ST funding ratio (%) by bank specialisation in 2012-2018




*Source:* Authors based on Orbis Bank Focus.

The basic setup of the estimated model for *liquid assets to deposits & short-term funding* is as follows:

$$la\_dstf_{it} = \alpha + \boldsymbol{x'_{it}}\boldsymbol{\beta} + \boldsymbol{z'_{it}}\gamma + \delta LCR\_req_t + (c_i + \epsilon_{it}) \quad (5.2)$$

where $\boldsymbol{x'_{it}}$ is a vector of bank-specific variables described in Table 5.2 and $\boldsymbol{z'_{it}}$ is a vector of the country-specific variables described in Table 5.3, $LCR\_req_t$ is the LCR requirement as the main variable of interest and the error term consists of the fixed effects component $c_i$ and the exogenous component $\epsilon_{it}$.
Similarly, for *net loans to deposits & short-term funding* the model is defined as follows:

$$nl\_dstf_{it} = \alpha + \boldsymbol{x'_{it}}\boldsymbol{\beta} + \boldsymbol{z'_{it}}\gamma + \delta LCR\_req_t + (c_i + \epsilon_{it}) \quad (5.3)$$

where $\boldsymbol{x'_{it}}$ is a vector of bank-specific variables described in Table 5.2 and $\boldsymbol{z'_{it}}$ is a vector of the country-specific variables described in Table 5.3, $LCR\_req_t$ is the LCR requirement as the main variable of interest, $c_i$ is the fixed effects component and $\epsilon_{it}$ the exogenous component.
We estimate the above specified models by both fixed effects and random ef-

fects and use the Hausman test to check whether the random effects provide consistent results. We then use the fixed effects estimation also for subsamples for each bank specialisation.

## 5.5 Results and Findings

### 5.5.1 Empirical Results

In this section we present the estimation results for both liquidity indicators used as the dependent variable in our models. Table 5.5 shows the estimation results for both the fixed effects and the random effects estimation with both dependent variables.

We can see that our main variable of interest - the LCR requirement - is significant for all four models. For the models with dependent variable *liquid assets to deposits* & *short-term funding* the estimated impact is positive while for the models with dependent variable *net loans to deposits* & *short-term funding* the estimated impact is negative. This result is in line with our expectation because in both cases the result supports the hypothesis that the binding LCR requirement should improve the liquidity position of the bank.

It is worth mentioning that this result is also consistent with the findings of EBA (2016), although this report showed that most banks were already fulfilling the 100% requirement in December 2015. The results in the EBA report on the other hand showed that there were still 16 banks out of 171 observed banks that were not fulfilling the 100% requirement at that time. Moreover, these were all smaller banks (denoted as Group 2 banks in the EBA report) which were likely underrepresented due to smaller sample size used in the EBA report in contrast to this paper (171 banks in the EBA report, 707 banks in this paper).

The estimated coefficients for bank specific variables show somewhat mixed results. The *logarithm of total assets* has significant positive impact on both dependent variables. It means that larger banks tend to have higher liquid asset buffers, but at the same time they use larger portion of their deposit funding for providing the clients' loans. Hence we cannot simply conclude that larger banks have in general better liquidity positions. On the other hand, we can quite clearly see that the link between bank's profitability and liquidity is not very strong. The ROAA is mostly insignificant and the *cost to income ratio* is significant negative only for the *net loans to deposits & short-term funding.* The link with credit risk on the contrary is quite strong. We can see that the *loan loss reserves to gross loans* ratio is significant negative for both ratios. This result suggests that banks with lower quality of loans tend to have lower liquid assets buffers. The notion that higher credit risk is related to higher liquidity risk is further supported by the significance of estimated coefficients at *net loans to total assets.* However, the interpretation of these coefficients is not straightforward. The higher the share of bad loans the lower this ratio. On the other hand, the more of total assets is composed of loans the less space for liquid assets remains. In this context the estimated coefficients for dependent variable *liquid assets to deposits & short-term funding* are negative while for *net loans to deposits & short-term funding* are positive which is overall quite unsurprising result.

The *equity to total assets ratio* has significant positive impact on both variables. This results shows that the higher the capital buffer the lower the share of deposits on liability side of the balance sheet. Therefore, the liquid asset buffer appears higher when expressed as a ratio to deposits and short-term funding. Similarly the higher the capital buffer, the higher the share of net loans is funded by the capital instead of deposits and other ST funding.

The estimation result for country specific variables are somewhat mixed. For GDP growth we see significant impact only on *net loans to deposits & short-term funding* and the impact is negative. For inflation we see significant positive impact on *liquid assets to deposits & short-term funding.* This might be due to higher expected outflows in times of higher inflation. The link with the *government debt to GDP ratio* seems to be quite weak, especially in case of the liquid asset buffer we do not see a significant impact. On the other hand, the negative impact on net loans suggest for a presence of the crowding out effect of the government debt. Finally, the *negative rate* dummy variable shows quite clear negative impact on the liquid asset buffer suggesting that the existence of negative ST interbank rate incetivises the banks to hold less liquid assets which are likely to bear the negative yield.

The estimation diagnostics reported in the bottom of Table 5.5 show overall significance of the models, though not very high level of R-squared. We provide also the results of Hausman test checking the consistency of random effects. The null hypothesis is rejected meaning inconsistency of random effects estimation. We thus stick to the fixed effects as a superior method in further estimations.

In Table 5.6 we provide results of separate estimation on subsamples for each of the bank specialiasiton types. We can see that LCR requirement remains significant positive for all types, althought there are slight differences in estimated magnitudes. For other variables there are not big differences compared to the estimation result for the whole sample except the fact that some time certain variables are insignificant for one or few types. The most interesting differences are significant negative impact of ROAA on the liquid asset buffer in case of cooperative and savings banks and significant impact of the interest rate structure on these two types. Moreover in case of cooperative banks we see a really high coefficient for the *negative rate* dummy suggesting that this type of banks' liquidity position is really negatively impacted by the presence of negative interest rate. Finally, we see a significant negative impact of *government debt to GDP ratio* in case of the bank holdings & holding companies.
Table 5.7 then shows the estimation results by specialisations for the *net loans to deposits* & *short-term funding*. Similarly as for the liquid assets the result show the main differences in significance in comparison to the estimation with the whole sample for cooperative and savings banks in case of ROAA and *negative rate* dummy and in case of the cooperative banks also of the interest rate structure variables. These results are another source of evidence that negative rates worsen the liquidity positions mainly in case of cooperative banks and to lesser extent also in case of savings banks.
As a further robustness check we have conducted estimations with clustered standard errors and the clustering has been done on both the country level as well as a bank level. Comparison of these estimations to baseline estimation with classic standard errors is provided in Table D.4 and Table D.5. The results do not change substantially, although in certain cases the estimated coefficients lose their significance. In case of the *LCR requirement* the impact is no longer significant for *net loans to deposits* & *short-term funding* in case of clustering at country levels.

### 5.5.2 Summary of Results

In this section we assess the hypotheses formulated in Section 5.2 and decide based on our empirical results whether they were rejected or not.
**Hypothesis #1 (increase in liquid assets holdings) - not rejected:** The estimation on the whole sample as well as separately for each bank specialisa-

Table 5.5: Fixed effects and random effects estimation results (whole sample)

| | FE<br>la_dstf | RE<br>la_dstf | FE<br>nl_dstf | RE<br>nl_dstf |
|---|---|---|---|---|
| lta | 3.773*** | 2.305*** | 3.862*** | 3.212*** |
| | (0.964) | (0.246) | (1.166) | (0.476) |
| roaa | 0.0155 | 0.250 | -0.550* | -0.626** |
| | (0.240) | (0.235) | (0.290) | (0.291) |
| nl_ta | -0.606*** | -0.645*** | 1.216*** | 1.253*** |
| | (0.0257) | (0.0201) | (0.0310) | (0.0284) |
| eq_ta | 1.284*** | 1.019*** | 1.936*** | 1.756*** |
| | (0.0969) | (0.0739) | (0.117) | (0.103) |
| cir | -0.00874 | 0.000494 | -0.0251** | -0.0367*** |
| | (0.00940) | (0.00902) | (0.0114) | (0.0113) |
| llr_gl | -0.383*** | -0.306*** | -0.621*** | -0.616*** |
| | (0.0796) | (0.0684) | (0.0962) | (0.0915) |
| st_ir | 0.930* | -0.408 | 0.869 | 0.342 |
| | (0.511) | (0.452) | (0.618) | (0.594) |
| spread | 0.271 | -0.286 | -0.0305 | -0.0162 |
| | (0.243) | (0.211) | (0.294) | (0.280) |
| gdp | -0.182 | -0.392*** | -0.757*** | -0.988*** |
| | (0.153) | (0.145) | (0.184) | (0.182) |
| infl | 0.897*** | 1.207*** | -0.270 | 0.0662 |
| | (0.207) | (0.194) | (0.250) | (0.241) |
| gov_debt | -0.0402 | -0.116*** | -0.390*** | -0.100*** |
| | (0.0485) | (0.0178) | (0.0587) | (0.0325) |
| negrate | -6.245*** | -6.354*** | -0.950 | 0.167 |
| | (0.795) | (0.752) | (0.962) | (0.944) |
| LCR_req | 0.102*** | 0.0927*** | -0.0387*** | -0.0508*** |
| | (0.0103) | (0.00949) | (0.0125) | (0.0121) |
| Constant | -8.363 | 25.36*** | -27.07 | -39.59*** |
| | (15.58) | (5.036) | (18.83) | (9.124) |
| Observations | 4949 | 4949 | 4949 | 4949 |
| F/Wald statistic | 71.61*** | 1617.16*** | 212.3*** | 3099.44*** |
| R-squared | 0.180 | 0.176 | 0.395 | 0.390 |
| Hausman test | - | 100.88*** | - | 255.14*** |

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

*Source:* Author's calculation in Stata 11.2.

Table 5.6: FE estimation results for liquid assets to deposits & ST funding by specialisations

| | *bhhc* | *comm* | *coop* | *rem* | *savings* |
|---|---|---|---|---|---|
| | la_dstf | la_dstf | la_dstf | la_dstf | la_dstf |
| lta | 1.481 | 6.542*** | -1.670 | 12.12*** | -2.579 |
| | (6.766) | (1.617) | (1.026) | (4.144) | (2.322) |
| roaa | 0.470 | -0.0313 | -0.922*** | -1.029 | -1.199** |
| | (1.149) | (0.386) | (0.310) | (1.894) | (0.595) |
| nl_ta | -1.232*** | -0.871*** | -0.266*** | -1.531*** | -0.759*** |
| | (0.152) | (0.0554) | (0.0218) | (0.116) | (0.0569) |
| eq_ta | -0.568 | 1.795*** | 0.791*** | 0.599 | -0.380 |
| | (0.709) | (0.152) | (0.122) | (0.430) | (0.265) |
| cir | 0.0862 | -0.0354** | -0.00175 | 0.0438 | 0.0416** |
| | (0.0964) | (0.0153) | (0.0102) | (0.0449) | (0.0199) |
| llr_gl | 1.518 | -0.414*** | -0.153** | -0.192 | -0.448** |
| | (1.140) | (0.138) | (0.0770) | (0.284) | (0.216) |
| st_ir | 9.848** | 0.710 | 4.907*** | 1.040 | 3.779*** |
| | (4.134) | (0.786) | (1.406) | (1.532) | (1.209) |
| spread | -0.599 | 0.469 | -0.832** | 1.191 | 2.701*** |
| | (1.557) | (0.384) | (0.364) | (1.273) | (0.762) |
| gdp | -0.187 | -0.132 | -1.147*** | 0.306 | 0.482 |
| | (1.188) | (0.256) | (0.255) | (0.351) | (0.334) |
| infl | 1.295 | 0.869** | 0.0559 | -0.578 | 0.357 |
| | (1.136) | (0.363) | (0.294) | (0.761) | (0.398) |
| gov_debt | -1.483*** | -0.117 | 0.0147 | 0.0707 | 0.227*** |
| | (0.321) | (0.0879) | (0.0587) | (0.194) | (0.0874) |
| negrate | 2.737 | -3.690*** | -11.56*** | -4.938* | -2.929* |
| | (4.316) | (1.397) | (1.309) | (2.566) | (1.584) |
| LCR_req | 0.143*** | 0.0829*** | 0.180*** | 0.119*** | 0.0907*** |
| | (0.0456) | (0.0172) | (0.0218) | (0.0297) | (0.0226) |
| Constant | 154.0 | -30.82 | 45.90*** | -73.80 | 88.57** |
| | (129.6) | (27.04) | (16.12) | (70.02) | (39.03) |
| Observations | 203 | 1932 | 2016 | 329 | 469 |
| F | 8.264*** | 38.65*** | 32.03*** | 16.76*** | 18.17*** |
| R-squared | 0.400 | 0.234 | 0.195 | 0.447 | 0.378 |

Standard errors in parentheses
$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

*Source:* Author's calculation in Stata 11.2.

Table 5.7: FE estimation results for net loans to deposits & ST funding by specialisations

| | *bhhc* | *comm* | *coop* | *rem* | *savings* |
|---|---|---|---|---|---|
| | nl_dstf | nl_dstf | nl_dstf | nl_dstf | nl_dstf |
| lta | 9.132*** | 5.390*** | 3.158*** | 9.747 | 4.665** |
| | (3.066) | (1.867) | (1.219) | (9.151) | (2.297) |
| roaa | 0.881* | -0.611 | -1.232*** | 3.303 | -1.331** |
| | (0.521) | (0.445) | (0.368) | (4.183) | (0.588) |
| nl_ta | 1.127*** | 1.243*** | 1.364*** | 1.436*** | 1.107*** |
| | (0.0689) | (0.0639) | (0.0259) | (0.257) | (0.0562) |
| eq_ta | 0.0101 | 1.948*** | 2.192*** | 0.537 | 1.442*** |
| | (0.321) | (0.176) | (0.145) | (0.949) | (0.262) |
| cir | -0.0105 | -0.0218 | -0.0554*** | 0.164 | -0.0303 |
| | (0.0437) | (0.0177) | (0.0121) | (0.0992) | (0.0197) |
| llr_gl | -0.531 | -0.159 | -0.822*** | -1.039* | -1.151*** |
| | (0.517) | (0.159) | (0.0914) | (0.627) | (0.213) |
| st_ir | -2.835 | -0.206 | -6.368*** | 11.45*** | -1.537 |
| | (1.873) | (0.908) | (1.669) | (3.382) | (1.196) |
| spread | -0.211 | 0.0513 | -2.611*** | -2.589 | 0.0484 |
| | (0.706) | (0.443) | (0.432) | (2.811) | (0.753) |
| gdp | -1.311** | -0.361 | -2.886*** | -0.547 | -1.120*** |
| | (0.538) | (0.295) | (0.303) | (0.776) | (0.331) |
| infl | -0.722 | 0.276 | 1.937*** | -6.477*** | -0.183 |
| | (0.515) | (0.419) | (0.350) | (1.681) | (0.394) |
| gov_debt | -0.218 | 0.0105 | -0.286*** | -1.807*** | -0.402*** |
| | (0.145) | (0.102) | (0.0697) | (0.428) | (0.0865) |
| negrate | 2.154 | -0.00717 | 10.12*** | -6.061 | 4.355*** |
| | (1.956) | (1.613) | (1.555) | (5.667) | (1.567) |
| LCR_req | -0.0549*** | -0.0251 | -0.223*** | -0.0149 | -0.115*** |
| | (0.0207) | (0.0198) | (0.0258) | (0.0657) | (0.0224) |
| Constant | -117.1** | -93.85*** | -18.90 | -22.35 | -41.24 |
| | (58.72) | (31.22) | (19.14) | (154.6) | (38.61) |
| Observations | 203 | 1932 | 2016 | 329 | 469 |
| F | 26.55*** | 42.14*** | 598.6*** | 7.359*** | 74.09*** |
| R-squared | 0.682 | 0.250 | 0.819 | 0.262 | 0.712 |

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

*Source:* Author's calculation in Stata 11.2.

tion showed significant positive impact of the variable LCR requirement in all cases. Together with the pattern visible in Figure 5.1 and Figure 5.2 where we saw an increase of *liquid assets to deposits* & *short-term funding* especially in 2018 when the LCR requirement was fully implemented at 100% level it gives us clear evidence that the LCR requirement contributed to the increase of the liquid asset holdings of the observed banks.

**Hypothesis #2 (decrease in loan-to-deposit ratio) - not rejected:** The estimation results for the other dependent variable, *net loans to deposits* & *short-term funding*, show also quite clearly that the LCR requirement contributed to better liquidity positions of the observed banks when measured in terms of loan-to-deposit ratio. The estimated coefficient of LCR requirement was always significant negative for both the estimation with the whole sample as well as for the estimations for each of the specialisations.

**Hypothesis #3 (different impact by bank specialisation) - rejected:** The third hypothesis assumed that the impact of LCR requirement will be significant mainly for the specialisation types *bank holdings* & *holding companies* and *commercial banks*. However, we found very similar results also for the other observed specialisation types suggesting that the other types of banks also had to adjust their liquidity positions to comply with the LCR requirement. We thus reject this hypothesis.

### 5.5.3 Further Research Opportunities

This paper aims to assess the impact of introduction of binding LCR requirement on the liquidity positions of EU banks in times of low and even negative interest rate environment present in the observed period of 2012-2018. In this section we discuss further research opportunities related to the banks' liquidity under regulatory constraints and the interest rate environment.

First opportunity for further research will arise from the introduction of the binding NSFR requirement in 2021. Such research should focus on the impact of this regulation on the balance sheet structures of the observed banks. However, the methodology will have to be more sophisticated than in case of the LCR requirement. First, due to the fact that NSFR is a measure of long-run ability to maintain solid liquidity position and thus proper assessment of the impact will probably require using a dynamic estimation approach. Second, the NSFR requirement will not be gradually phased-in as in case of LCR and

hence it will not allow for using such kind of a quasi-dummy variable as used in this paper.
Another opportunity for further observation is in case the interest rate environment returns to higher levels due to rising inflation after the Covid-19 pandemic. As an example we can mention the tightening of the monetary policy by CNB in 2021. Although it seems so far that ECB is likely to keep its policy rates low for some time yet, it may be also eventually forced to respond to rising inflation by tightening its monetary policy and even ending the negative interest rate environment in the Eurozone. In such case it would be interesting to look at the liquidity positions of the EU banks how they interact with the liquidity regulation in higher interest rate environment.

## 5.6 Conclusion

In this paper we analysed the determinants of liquidity positions of EU banks in the period 2012-2018. We focused mainly on the impact of gradual phase-in of binding LCR requirement in the context of low and even negative interest rate environment. We controlled for other bank specific as well as country specific (macroeconomic) factors. For this purpose we used a large dataset of 707 banks from 27 EU member countries (including United Kingdom).
The main contribution of the paper may be summarized in following three points. First is the assesment of the LCR introduction whether it really lead to improvement in liquidity buffers of EU banks. We found significant positive impact of the LCR requirement on the proxy variable for liquid asset buffer as well as significant negative impact on the proxy for loan-to-deposit ratio. Both these results support the conclusion that binding LCR requirement improves the liquidity positions of the banks.
Second, we were able to estimate the models separately for five specialisation types of banks. Although we expected that LCR requirement will have significant impact most likely only in case of bank holdings & holding companies and commercial banks as the two types of banks with more diversified business model and better access to interbank market, the estimation results showed significant impact of similar magnitude also for the other three considered types of banks - cooperative banks, real estate & mortgage banks and savings banks.
Third, the dataset allowed us to consider also the impact of low and even negative interest rate environment. We found a significant negative impact of the

existence of negative interest rate environment on liquidity positions of banks. This impact was particularly strong in case of cooperative and savings banks. To sum up, we used a standard methodology for unique panel dataset of EU banks that allowed us to consider the impact of liquidity regulation and low and negative interest rate environment on the liquidity positions of the observed banks and we found that both these factors had significant impact, positive in the former case and negative in the latter case.

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# Appendix A

# Appendix to Chapter 2

Table A.1: Summary statistics

| Variable | Mean | Std. Dev. | Min. | Max. |
|---|---|---|---|---|
| nim | 2.09 | 1.55 | -0.53 | 31.65 |
| st_ir | 0.47 | 0.79 | -0.49 | 8.05 |
| spread | 2.40 | 1.78 | -0.41 | 21.93 |
| gdp | 0.70 | 2.09 | -9.10 | 25.60 |
| infl | 1.30 | 1.32 | -1.50 | 5.70 |
| unem | 9.74 | 3.59 | 4.00 | 27.50 |
| hi | 0.06 | 0.04 | 0.03 | 0.37 |
| lta | 15.19 | 2.51 | 10.31 | 21.75 |
| llr_gl | 4.69 | 4.45 | -2.20 | 46.41 |
| eq_ta | 9.56 | 5.03 | -3.93 | 63.57 |
| cir | 66.55 | 29.28 | 0.03 | 851.20 |
| nl_ta | 59.47 | 17.57 | 1.80 | 97.57 |
| nl_dstf | 91.37 | 47.68 | 3.78 | 827.06 |
| la_dstf | 23.05 | 25.18 | 0.04 | 391.832 |
| bhhc | 0.04 | 0.20 | 0.00 | 1.00 |
| coop | 0.43 | 0.50 | 0.00 | 1.00 |
| rem | 0.07 | 0.26 | 0.00 | 1.00 |
| savings | 0.08 | 0.27 | 0.00 | 1.00 |
| large | 0.21 | 0.41 | 0.00 | 1.00 |
| small | 0.36 | 0.48 | 0.00 | 1.00 |
| Number of observations | | 3774 | | |
| Number of groups | | 629 | | |
| Observations per group | | 6 | | |

*Source:* Authors' calculation in Stata 11.2.

Table A.2: Cross-correlation table

| Variables | nim | st_ir | spread | gdp | infl | unem | hi | lta | llr_gl | eq_ta | cir | nl_ta | nl_dstf | la_dstf | bhhc | coop | rem | savings | large | small |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| nim | 1.00 | | | | | | | | | | | | | | | | | | | |
| st_ir | 0.13 | 1.00 | | | | | | | | | | | | | | | | | | |
| | (0.00) | | | | | | | | | | | | | | | | | | | |
| spread | 0.06 | 0.09 | 1.00 | | | | | | | | | | | | | | | | | |
| | (0.00) | (0.00) | | | | | | | | | | | | | | | | | | |
| gdp | -0.04 | 0.05 | -0.61 | 1.00 | | | | | | | | | | | | | | | | |
| | (0.01) | (0.00) | (0.00) | | | | | | | | | | | | | | | | | |
| infl | 0.06 | 0.59 | 0.36 | -0.28 | 1.00 | | | | | | | | | | | | | | | |
| | (0.00) | (0.00) | (0.00) | (0.00) | | | | | | | | | | | | | | | | |
| unem | -0.02 | -0.14 | 0.54 | -0.35 | -0.20 | 1.00 | | | | | | | | | | | | | | |
| | (0.13) | (0.00) | (0.00) | (0.00) | (0.00) | | | | | | | | | | | | | | | |
| hi | 0.04 | 0.02 | -0.02 | 0.13 | -0.05 | 0.05 | 1.00 | | | | | | | | | | | | | |
| | (0.01) | (0.30) | (0.33) | (0.00) | (0.00) | (0.00) | | | | | | | | | | | | | | |
| lta | -0.26 | 0.09 | -0.21 | 0.24 | 0.02 | -0.12 | 0.23 | 1.00 | | | | | | | | | | | | |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.26) | (0.00) | (0.00) | | | | | | | | | | | | | |
| llr_gl | 0.14 | -0.10 | 0.18 | -0.06 | -0.24 | 0.37 | 0.11 | -0.14 | 1.00 | | | | | | | | | | | |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | | | | | | | | | | | | |
| eq_ta | 0.29 | -0.02 | 0.03 | -0.03 | -0.02 | 0.02 | -0.09 | -0.49 | 0.04 | 1.00 | | | | | | | | | | |
| | (0.00) | (0.27) | (0.03) | (0.07) | (0.26) | (0.22) | (0.00) | (0.00) | (0.01) | | | | | | | | | | | |
| cir | -0.02 | 0.01 | -0.00 | 0.02 | 0.08 | -0.12 | -0.09 | -0.07 | -0.01 | 0.08 | 1.00 | | | | | | | | | |
| | (0.19) | (0.44) | (0.93) | (0.14) | (0.00) | (0.00) | (0.00) | (0.00) | (0.38) | (0.00) | | | | | | | | | | |
| nl_ta | 0.14 | 0.12 | 0.08 | -0.02 | 0.09 | -0.02 | 0.06 | -0.01 | -0.08 | -0.10 | -0.15 | 1.00 | | | | | | | | |
| | (0.00) | (0.00) | (0.00) | (0.14) | (0.00) | (0.34) | (0.00) | (0.41) | (0.00) | (0.00) | (0.00) | | | | | | | | | |
| nl_dstf | -0.01 | 0.13 | 0.05 | -0.06 | 0.11 | -0.04 | 0.05 | 0.05 | -0.15 | -0.04 | -0.19 | 0.59 | 1.00 | | | | | | | |
| | (0.40) | (0.00) | (0.00) | (0.00) | (0.00) | (0.01) | (0.00) | (0.00) | (0.00) | (0.01) | (0.00) | (0.00) | | | | | | | | |
| la_dstf | -0.12 | 0.00 | -0.17 | 0.12 | 0.06 | -0.21 | 0.06 | 0.21 | -0.07 | 0.11 | 0.07 | -0.52 | -0.00 | 1.00 | | | | | | |
| | (0.00) | (0.79) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.82) | | | | | | | |
| bhhc | 0.07 | 0.04 | -0.09 | 0.09 | 0.03 | -0.12 | 0.03 | 0.23 | -0.11 | 0.00 | 0.03 | -0.11 | -0.03 | 0.12 | 1.00 | | | | | |
| | (0.00) | (0.02) | (0.00) | (0.00) | (0.03) | (0.00) | (0.04) | (0.00) | (0.00) | (0.92) | (0.08) | (0.00) | (0.10) | (0.00) | | | | | | |
| coop | 0.00 | -0.12 | 0.26 | -0.33 | -0.02 | 0.25 | -0.34 | -0.52 | 0.08 | 0.20 | -0.06 | -0.01 | 0.03 | -0.25 | -0.18 | 1.00 | | | | |
| | (0.87) | (0.00) | (0.00) | (0.00) | (0.19) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.54) | (0.11) | (0.00) | (0.00) | | | | | |
| rem | -0.17 | 0.03 | -0.17 | 0.16 | 0.02 | -0.23 | -0.00 | 0.13 | -0.20 | -0.16 | -0.09 | 0.25 | 0.36 | 0.02 | -0.06 | -0.24 | 1.00 | | | |
| | (0.00) | (0.07) | (0.00) | (0.00) | (0.20) | (0.00) | (0.98) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.13) | (0.00) | (0.00) | | | | |
| savings | 0.01 | -0.01 | -0.06 | 0.02 | -0.02 | -0.04 | -0.03 | 0.06 | 0.01 | -0.04 | 0.01 | 0.12 | -0.02 | -0.06 | -0.06 | -0.26 | -0.08 | 1.00 | | |
| | (0.71) | (0.41) | (0.00) | (0.17) | (0.35) | (0.01) | (0.05) | (0.00) | (0.41) | (0.01) | (0.50) | (0.00) | (0.14) | (0.00) | (0.00) | (0.00) | (0.00) | | | |
| large | -0.19 | 0.06 | -0.08 | 0.14 | -0.00 | 0.04 | 0.18 | 0.77 | -0.14 | -0.33 | -0.07 | -0.06 | 0.07 | 0.17 | 0.21 | -0.33 | 0.08 | -0.05 | 1.00 | |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.91) | (0.01) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | | |
| small | 0.18 | -0.11 | 0.24 | -0.27 | -0.02 | 0.20 | -0.24 | -0.75 | 0.09 | 0.38 | 0.02 | -0.05 | -0.00 | -0.14 | -0.14 | 0.55 | -0.13 | -0.20 | -0.39 | 1.00 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.19) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.22) | (0.00) | (0.85) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | |

*Note:* p-values in parentheses.

*Source:* Authors' calculation in Stata 11.2.

Table A.3: Comparison of S-GMM, FE, and Pooled OLS with lagged dependent variable

| | FE<br>nim | S-GMM<br>nim | Pooled OLS<br>nim |
|---|---|---|---|
| L.nim | 0.110 | 0.862*** | 0.928*** |
| | (0.0951) | (0.0159) | (0.0748) |
| st_ir | 0.328*** | 0.143*** | 0.110** |
| | (0.0971) | (0.0231) | (0.0442) |
| st_ir_sq | -0.0332*** | -0.0268*** | -0.0256*** |
| | (0.00834) | (0.00541) | (0.00774) |
| spread | 0.0820*** | -0.0226* | -0.0545*** |
| | (0.0236) | (0.0128) | (0.0206) |
| spread_sq | -0.00391*** | -0.000912 | 0.000805 |
| | (0.00109) | (0.000751) | (0.000868) |
| gdp | 0.0156** | 0.00848** | 0.00801 |
| | (0.00701) | (0.00418) | (0.00520) |
| infl | 0.0134 | 0.0547*** | 0.0735*** |
| | (0.0295) | (0.0106) | (0.0168) |
| unem | -0.0289 | 0.00247 | 0.0112* |
| | (0.0194) | (0.00301) | (0.00592) |
| hi | -1.116 | 0.490** | 0.206 |
| | (1.053) | (0.208) | (0.199) |
| lta | -0.240 | -0.0210** | -0.0145 |
| | (0.195) | (0.00819) | (0.0149) |
| llr_gl | -0.000603 | 0.00746*** | 0.00535 |
| | (0.00667) | (0.00195) | (0.00401) |
| eq_ta | 0.0174 | 0.00588** | 0.00850 |
| | (0.0168) | (0.00262) | (0.00595) |
| cir | -0.00258*** | -0.000778** | -0.000298 |
| | (0.000747) | (0.000309) | (0.000562) |
| nl_ta | 0.0157*** | 0.00436*** | 0.00334* |
| | (0.00422) | (0.000819) | (0.00195) |
| nl_dstf | -0.00102 | -0.000283 | -0.000188 |
| | (0.000653) | (0.000204) | (0.000396) |
| la_dstf | 0.000760 | -0.000109 | 0.0000810 |
| | (0.00106) | (0.000505) | (0.000492) |
| bhhc | - | 0.0274 | 0.110 |
| | | (0.0462) | (0.136) |
| coop | - | -0.0835*** | -0.0745*** |
| | | (0.0190) | (0.0271) |
| rem | - | -0.116*** | -0.0493 |
| | | (0.0373) | (0.0692) |
| savings | - | -0.0486** | -0.0533** |
| | | (0.0230) | (0.0227) |
| large | - | 0.0603** | 0.0501 |
| | | (0.0286) | (0.0404) |
| small | - | 0.00796 | -0.0139 |
| | | (0.0230) | (0.0368) |
| Constant | 4.744 | 0.216 | -0.0360 |
| | (3.028) | (0.148) | (0.316) |
| Observations | 3145 | 3145 | 3145 |
| F/Wald statistic | 58.12*** | 13576.7*** | 619.46*** |
| R-squared | 0.209 | - | 0.887 |

*Note:* Standard errors in parentheses. Wald statistic for system GMM.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

*Source:* Authors' calculation in Stata 11.2.

Table A.4: Static panel methods estimation results (estimation without lagged dependent variable)

| | RE<br>nim | FE<br>nim | Pooled OLS<br>nim |
|---|---|---|---|
| st_ir | 0.113*** | 0.0936** | 0.395*** |
| | (0.0275) | (0.0274) | (0.0656) |
| st_ir_sq | -0.0114** | -0.0116** | -0.0385** |
| | (0.00500) | (0.00498) | (0.0126) |
| spread | 0.0891*** | 0.0844*** | -0.0917** |
| | (0.0179) | (0.0184) | (0.0359) |
| spread_sq | -0.00374*** | -0.00394*** | 0.00558** |
| | (0.000890) | (0.000908) | (0.00209) |
| gdp | -0.0142** | -0.00936 | -0.0524** |
| | (0.00641) | (0.00645) | (0.0145) |
| infl | -0.000859 | 0.00689 | -0.00438 |
| | (0.0124) | (0.0125) | (0.0290) |
| unem | -0.0283*** | -0.0245** | -0.0475*** |
| | (0.00697) | (0.00749) | (0.00959) |
| hi | -0.279 | -1.474 | 1.020* |
| | (0.805) | (1.033) | (0.551) |
| lta | -0.0400 | 0.104** | -0.192*** |
| | (0.0359) | (0.0489) | (0.0230) |
| llr_gl | 0.0104** | 0.00747* | 0.0566*** |
| | (0.00413) | (0.00429) | (0.00569) |
| eq_ta | 0.0167** | 0.0154** | 0.0639*** |
| | (0.00436) | (0.00471) | (0.00529) |
| cir | -0.00235*** | -0.00197*** | -0.00377*** |
| | (0.000374) | (0.000378) | (0.000783) |
| nl_ta | 0.0209*** | 0.0220*** | 0.0208*** |
| | (0.00190) | (0.00206) | (0.00214) |
| nl_dstf | -0.00130** | -0.00121** | -0.00281*** |
| | (0.000510) | (0.000527) | (0.000695) |
| la_dstf | 0.000498 | 0.00135 | -0.00266** |
| | (0.000885) | (0.000912) | (0.00128) |
| bhhc | 0.807** | - | 0.841*** |
| | (0.270) | | (0.117) |
| coop | -0.716*** | - | -0.597*** |
| | (0.138) | | (0.0648) |
| rem | -1.276*** | - | -1.020*** |
| | (0.213) | | (0.102) |
| savings | -0.311 | - | -0.286** |
| | (0.203) | | (0.0890) |
| large | -0.385** | - | 0.354** |
| | (0.182) | | (0.0974) |
| small | 0.557** | - | 0.0902 |
| | (0.162) | | (0.0814) |
| Constant | 1.857** | -0.656 | 4.125*** |
| | (0.612) | (0.789) | (0.407) |
| Number of observations | 3774 | 3774 | 3774 |
| F/Wald statistic | 811.11*** | 45.67*** | 60.00*** |
| R-squared | 0.188 | 0.180 | 0.251 |
| Hausman test | 91.83*** | - | - |

*Note:* Standard errors in parentheses. Wald statistic used for random effects models.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

*Source:* Authors' calculation in Stata 11.2.

Table A.5: Number of banks by countries

| Country | Number of banks |
|---|---|
| Austria | 23 |
| Belgium | 5 |
| Cyprus | 3 |
| Czech Republic | 6 |
| Germany | 57 |
| Denmark | 34 |
| Spain | 12 |
| Finland | 6 |
| France | 47 |
| United Kingdom | 42 |
| Greece | 5 |
| Hungary | 5 |
| Ireland | 6 |
| Italy | 300 |
| Lithuania | 5 |
| Luxembourg | 8 |
| Latvia | 2 |
| Malta | 4 |
| Netherlands | 13 |
| Poland | 13 |
| Portugal | 6 |
| Sweden | 15 |
| Slovenia | 6 |
| Slovakia | 6 |
| Total | 629 |

*Source:* Authors based on Orbis Bank Focus

# Appendix B

# Appendix to Chapter 3

Table B.1: Summary statistics

| Variable | Mean | Std. Dev. | Min. | Max. |
|---|---|---|---|---|
| nim | 2.90 | 2.11 | -0.53 | 31.65 |
| st_ir | 0.43 | 0.59 | -0.49 | 8.05 |
| spread | 2.15 | 1.38 | -0.41 | 21.93 |
| gdp | 1.33 | 1.73 | -9.10 | 25.60 |
| infl | 1.44 | 1.16 | -1.50 | 5.70 |
| unem | 8.40 | 3.18 | 4.00 | 27.50 |
| lta | 15.31 | 2.10 | 10.31 | 21.75 |
| llr_gl | 3.26 | 3.73 | -2.20 | 46.41 |
| eq_ta | 10.34 | 4.49 | -3.93 | 63.57 |
| cir | 65.22 | 24.66 | 0.03 | 851.20 |
| nl_ta | 61.61 | 16.39 | 1.80 | 98.73 |
| nl_dstf | 84.54 | 38.09 | 2.40 | 827.06 |
| la_dstf | 16.83 | 22.31 | 0.01 | 391.32 |
| bhhc | 0.17 | 0.37 | 0 | 1 |
| coop | 0.24 | 0.42 | 0 | 1 |
| rem | 0.04 | 0.19 | 0 | 1 |
| savings | 0.06 | 0.24 | 0 | 1 |
| large | 0.17 | 0.37 | 0 | 1 |
| small | 0.20 | 0.40 | 0 | 1 |
| negrate | 0.16 | 0.37 | 0 | 1 |
| capbas | 0.49 | 0.50 | 0 | 1 |
| Number of observations | | 6930 | | |
| Number of groups | | 1155 | | |
| Observations per group | | 6 | | |

*Source:* Authors' calculation in Stata 11.2.

Table B.2: Cross-correlation table

| Variables | nim | st_ir | spread | gdp | infl | unem | lta | llr_gl | eq_ta | cir | nl_ta | nl_dstf | la_dstf | bhhc | coop | rem | savings | large | small | negrate | capbas |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| nim | 1.00 | | | | | | | | | | | | | | | | | | | | |
| st_ir | 0.03 | 1.00 | | | | | | | | | | | | | | | | | | | |
| | (0.00) | | | | | | | | | | | | | | | | | | | | |
| spread | -0.05 | 0.06 | 1.00 | | | | | | | | | | | | | | | | | | |
| | (0.00) | (0.00) | | | | | | | | | | | | | | | | | | | |
| gdp | 0.14 | -0.01 | -0.59 | 1.00 | | | | | | | | | | | | | | | | | |
| | (0.00) | (0.51) | (0.00) | | | | | | | | | | | | | | | | | | |
| infl | 0.11 | 0.47 | 0.31 | -0.22 | 1.00 | | | | | | | | | | | | | | | | |
| | (0.00) | (0.00) | (0.00) | (0.00) | | | | | | | | | | | | | | | | | |
| unem | -0.19 | -0.10 | 0.55 | -0.46 | -0.06 | 1.00 | | | | | | | | | | | | | | | |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | | | | | | | | | | | | | | | | |
| lta | -0.13 | 0.08 | -0.20 | 0.22 | -0.00 | -0.13 | 1.00 | | | | | | | | | | | | | | |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.86) | (0.00) | | | | | | | | | | | | | | | |
| llr_gl | -0.02 | -0.06 | 0.24 | -0.22 | -0.21 | 0.48 | -0.13 | 1.00 | | | | | | | | | | | | | |
| | (0.19) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | | | | | | | | | | | | | | |
| eq_ta | 0.35 | -0.03 | -0.01 | 0.06 | 0.01 | -0.07 | -0.32 | -0.01 | 1.00 | | | | | | | | | | | | |
| | (0.00) | (0.01) | (0.47) | (0.00) | (0.28) | (0.00) | (0.00) | (0.42) | | | | | | | | | | | | | |
| cir | -0.11 | 0.01 | 0.02 | -0.00 | 0.06 | -0.05 | -0.08 | 0.01 | 0.02 | 1.00 | | | | | | | | | | | |
| | (0.00) | (0.43) | (0.14) | (0.70) | (0.00) | (0.00) | (0.00) | (0.27) | (0.10) | | | | | | | | | | | | |
| nl_ta | 0.23 | 0.09 | 0.02 | 0.05 | 0.03 | -0.11 | -0.06 | -0.13 | -0.02 | -0.14 | 1.00 | | | | | | | | | | |
| | (0.00) | (0.00) | (0.11) | (0.00) | (0.01) | (0.00) | (0.00) | (0.00) | (0.12) | (0.00) | | | | | | | | | | | |
| nl_dstf | 0.01 | 0.13 | 0.08 | -0.12 | 0.04 | 0.04 | 0.01 | -0.03 | -0.02 | -0.17 | 0.59 | 1.00 | | | | | | | | | |
| | (0.64) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.29) | (0.01) | (0.07) | (0.00) | (0.00) | | | | | | | | | | |
| la_dstf | -0.21 | 0.02 | -0.07 | -0.04 | 0.01 | 0.00 | 0.20 | 0.08 | 0.04 | 0.08 | -0.50 | 0.01 | 1.00 | | | | | | | | |
| | (0.00) | (0.04) | (0.00) | (0.00) | (0.21) | (0.87) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.59) | | | | | | | | | |
| bhhc | 0.13 | -0.01 | -0.11 | 0.18 | 0.06 | -0.21 | 0.10 | -0.18 | 0.03 | 0.03 | -0.02 | -0.10 | -0.06 | 1.00 | | | | | | | |
| | (0.00) | (0.33) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.02) | (0.01) | (0.18) | (0.00) | (0.00) | | | | | | | | |
| coop | -0.21 | -0.07 | 0.31 | -0.46 | -0.08 | 0.41 | -0.43 | 0.27 | 0.05 | -0.01 | -0.08 | 0.12 | -0.02 | -0.25 | 1.00 | | | | | | |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.26) | (0.00) | (0.00) | (0.04) | (0.00) | | | | | | | |
| rem | -0.17 | 0.04 | -0.13 | 0.06 | -0.01 | -0.11 | 0.10 | -0.10 | -0.17 | -0.07 | 0.17 | 0.36 | 0.08 | -0.09 | -0.11 | 1.00 | | | | | |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.54) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | | | | | | |
| savings | -0.05 | -0.01 | -0.03 | -0.02 | -0.02 | 0.01 | 0.05 | 0.03 | -0.04 | 0.02 | 0.10 | 0.02 | -0.03 | -0.12 | -0.14 | -0.05 | 1.00 | | | | |
| | (0.00) | (0.67) | (0.01) | (0.19) | (0.08) | (0.50) | (0.00) | (0.00) | (0.00) | (0.17) | (0.00) | (0.15) | (0.01) | (0.00) | (0.00) | (0.00) | | | | | |
| large | -0.16 | 0.05 | -0.04 | 0.05 | -0.02 | 0.09 | 0.75 | -0.05 | -0.22 | -0.06 | -0.12 | 0.06 | 0.23 | 0.00 | -0.17 | 0.09 | -0.03 | 1.00 | | | |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.12) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.76) | (0.00) | (0.00) | (0.01) | | | | |
| small | -0.10 | -0.07 | 0.29 | -0.39 | -0.08 | 0.35 | -0.62 | 0.26 | 0.19 | 0.05 | -0.10 | 0.08 | 0.03 | -0.22 | 0.65 | -0.03 | -0.11 | -0.22 | 1.00 | | |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.01) | (0.00) | (0.00) | (0.01) | (0.00) | (0.00) | | | |
| negrate | -0.21 | -0.43 | -0.24 | 0.06 | -0.51 | 0.24 | -0.09 | 0.31 | -0.06 | 0.01 | -0.10 | 0.01 | 0.08 | -0.17 | 0.26 | 0.05 | 0.04 | 0.02 | 0.23 | 1.00 | |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.41) | (0.00) | (0.38) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.14) | (0.00) | | |
| capbas | 0.38 | -0.05 | -0.24 | 0.43 | 0.17 | -0.50 | 0.14 | -0.43 | 0.16 | -0.01 | 0.11 | -0.21 | -0.22 | 0.38 | -0.55 | -0.13 | -0.09 | -0.06 | -0.48 | -0.43 | 1.00 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.30) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | |

*Note:* p-values in parentheses.

*Source:* Authors' calculation in Stata 11.2.

Table B.3: Comparison of S-GMM, FE, and Pooled OLS with lagged dependent variable

| | FE<br>nim | S-GMM<br>nim | Pooled OLS<br>nim |
|---|---|---|---|
| L.nim | 0.238*** | 0.846*** | 0.941*** |
| | (0.0708) | (0.0286) | (0.0270) |
| st_ir | 0.162** | 0.108*** | 0.132** |
| | (0.0793) | (0.0325) | (0.0524) |
| st_ir_sq | -0.0259*** | -0.0223*** | -0.0258*** |
| | (0.00831) | (0.00633) | (0.00823) |
| spread | 0.0366 | -0.00847 | -0.0163 |
| | (0.0229) | (0.0131) | (0.0139) |
| spread_sq | -0.00196* | -0.000895 | -0.000514 |
| | (0.00104) | (0.000822) | (0.000710) |
| gdp | 0.0196*** | 0.0145*** | 0.00934** |
| | (0.00616) | (0.00518) | (0.00425) |
| infl | 0.0674*** | 0.0591*** | 0.0513*** |
| | (0.0149) | (0.0112) | (0.0118) |
| unem | 0.0188* | -0.00322 | 0.000736 |
| | (0.0113) | (0.00337) | (0.00293) |
| lta | -0.229*** | -0.0108 | -0.00388 |
| | (0.0839) | (0.00926) | (0.00716) |
| llr_gl | 0.00309 | 0.0128*** | 0.00821** |
| | (0.00676) | (0.00403) | (0.00335) |
| eq_ta | 0.0232** | 0.0128** | 0.00984** |
| | (0.0105) | (0.00551) | (0.00447) |
| cir | -0.00266*** | -0.00114** | -0.000547 |
| | (0.000706) | (0.000461) | (0.000601) |
| nl_ta | 0.0141*** | 0.00535*** | 0.00337*** |
| | (0.00334) | (0.000920) | (0.00101) |
| nl_dstf | -0.000711 | -0.0000578 | 0.0000360 |
| | (0.000586) | (0.000301) | (0.000183) |
| la_dstf | 0.000756 | -0.000244 | 0.000376 |
| | (0.00104) | (0.000507) | (0.000377) |
| bhhc | - | 0.0285 | 0.0382 |
| | | (0.0225) | (0.0287) |
| coop | - | -0.106*** | -0.0758*** |
| | | (0.0282) | (0.0207) |
| rem | - | -0.177*** | -0.0462 |
| | | (0.0565) | (0.0354) |
| savings | - | -0.0608*** | -0.0425** |
| | | (0.0235) | (0.0191) |
| large | - | 0.0261 | 0.0217 |
| | | (0.0380) | (0.0291) |
| small | - | 0.0194 | -0.00109 |
| | | (0.0315) | (0.0305) |
| negrate | -0.0339 | -0.00686 | 0.0425* |
| | (0.0366) | (0.0227) | (0.0246) |
| capbas | - | 0.0902** | 0.00190 |
| | | (0.0379) | (0.0639) |
| Constant | 4.426*** | 0.0216 | -0.223* |
| | (1.442) | (0.170) | (0.124) |
| Number of observations | 5775 | 5775 | 5775 |
| F/Wald statistic | 58.41*** | 26351.05*** | 2345.8*** |
| R-squared | 0.208 | - | 0.941 |

*Note:* Robust standard errors in parentheses. Wald statistic for system GMM.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

*Source:* Authors' calculation in Stata 11.2.

Table B.4: Static panel methods estimation results (estimation without lagged dependent variable)

| | RE | FE | Pooled OLS |
|---|---|---|---|
| | | nim | |
| st_ir | -0.0698** | -0.0611* | -0.186** |
| | (0.0321) | (0.0324) | (0.0855) |
| st_ir_sq | -0.00763 | -0.00920* | 0.0182 |
| | (0.00510) | (0.00507) | (0.0158) |
| spread | 0.000270 | 0.00962 | -0.191*** |
| | (0.0158) | (0.0160) | (0.0388) |
| spread_sq | -0.000000132 | -0.000757 | 0.0113*** |
| | (0.000878) | (0.000873) | (0.00252) |
| gdp | 0.0100* | 0.0107* | -0.000520 |
| | (0.00584) | (0.00581) | (0.0172) |
| infl | 0.105*** | 0.0997*** | 0.171*** |
| | (0.00986) | (0.0101) | (0.0248) |
| unem | 0.0208** | 0.0273*** | -0.0510*** |
| | (0.00594) | (0.00620) | (0.0100) |
| lta | -0.135*** | -0.127*** | -0.160*** |
| | (0.0275) | (0.0319) | (0.0219) |
| llr_gl | 0.0188*** | 0.0111** | 0.120*** |
| | (0.00418) | (0.00425) | (0.00681) |
| eq_ta | 0.0236*** | 0.0139** | 0.123*** |
| | (0.00370) | (0.00384) | (0.00515) |
| cir | -0.00304*** | -0.00272*** | -0.00977*** |
| | (0.000352) | (0.000351) | (0.000860) |
| nl_ta | 0.0249*** | 0.0250*** | 0.0233*** |
| | (0.00158) | (0.00165) | (0.00210) |
| nl_dstf | -0.000660 | -0.000793 | 0.000963 |
| | (0.000518) | (0.000526) | (0.000836) |
| la_dstf | 0.00125 | 0.00222** | -0.00584*** |
| | (0.000835) | (0.000855) | (0.00127) |
| bhhc | -0.0821 | - | -0.0168 |
| | (0.142) | | (0.0601) |
| coop | -0.851*** | - | -0.748*** |
| | (0.169) | | (0.0756) |
| rem | -1.632*** | - | -1.480*** |
| | (0.265) | | (0.123) |
| savings | -0.500** | - | -0.509*** |
| | (0.211) | | (0.0900) |
| large | -0.0938 | - | 0.310** |
| | (0.168) | | (0.0967) |
| small | 0.248 | - | -0.0373 |
| | (0.181) | | (0.0910) |
| negrate | -0.158*** | -0.139*** | -0.494*** |
| | (0.0324) | (0.0326) | (0.0959) |
| capbas | 1.193*** | - | 0.896*** |
| | (0.136) | | (0.0741) |
| Constant | 2.773*** | 2.971*** | 3.361*** |
| | (0.493) | (0.547) | (0.402) |
| Number of observations | 6930 | 6930 | 6930 |
| F/Wald statistic | 1498.46*** | 69.02*** | 167.6*** |
| R-squared | 0.276 | 0.152 | 0.348 |
| Hausman test | 265.62*** | - | - |

*Note:* Standard errors in parentheses. Wald statistic used for random effects models.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

*Source:* Authors' calculation in Stata 11.2.

Table B.5: Number of banks by countries

| **Country** | **Number of banks** |
|---|---|
| Austria | 23 |
| Belgium | 5 |
| Cyprus | 3 |
| Czech Republic | 6 |
| Germany | 57 |
| Denmark | 34 |
| Spain | 12 |
| Finland | 6 |
| France | 47 |
| United Kingdom | 42 |
| Greece | 5 |
| Hungary | 5 |
| Ireland | 6 |
| Italy | 300 |
| Lithuania | 5 |
| Luxembourg | 8 |
| Latvia | 2 |
| Malta | 4 |
| Netherlands | 13 |
| Poland | 13 |
| Portugal | 6 |
| Sweden | 15 |
| Slovenia | 6 |
| Slovakia | 6 |
| United States of America | 526 |
| Total | 1,155 |

*Source:* Authors based on Orbis Bank Focus

# Appendix C

# Appendix to Chapter 4

No additional tables or figures for Chapter 4 are provided in this appendix.

# Appendix D

# Appendix to Chapter 5

Table D.1: Summary statistics

| Variable | Mean | Std. Dev. | Min. | Max. |
|---|---|---|---|---|
| la_dstf | 22.12 | 22.35 | 0.06 | 467.16 |
| nl_dstf | 85.22 | 40.32 | 0.03 | 849.25 |
| lta | 15.16 | 2.31 | 9.83 | 21.71 |
| roaa | 0.37 | 1.01 | -13.52 | 13.02 |
| nl_ta | 60.39 | 17.38 | 0.03 | 99.66 |
| eq_ta | 9.72 | 4.91 | -3.30 | 69.30 |
| cir | 66.45 | 25.95 | 1.95 | 587.41 |
| llr_gl | 4.91 | 4.73 | 0.00 | 43.92 |
| st_ir | 0.19 | 0.70 | -0.50 | 8.06 |
| spread | 2.06 | 1.58 | -0.41 | 21.92 |
| gdp | 1.07 | 2.02 | -7.10 | 25.20 |
| infl | 1.14 | 1.06 | -1.60 | 5.70 |
| gov_debt | 77.88 | 29.76 | 10.30 | 110.90 |
| LCR_req | 44.29 | 39.95 | 0.00 | 100.00 |
| negrate | 0.50 | 0.50 | 0.00 | 1.00 |
| bhhc | 0.04 | 0.20 | 0.00 | 1.00 |
| coop | 0.41 | 0.49 | 0.00 | 1.00 |
| rem | 0.07 | 0.25 | 0.00 | 1.00 |
| savings | 0.10 | 0.29 | 0.00 | 1.00 |
| Number of observations | | 4949 | | |
| Number of groups | | 707 | | |
| Observations per group | | 7 | | |

*Source:* Author based on Orbis Bank Focus

Table D.2: Cross-correlation table

| Variables | la_dstf | nl_dstf | lta | roaa | nl_ta | eq_ta | cir | llr_gl | st_ir | spread | gdp | infl | gov_debt | LCR_req | negrate | bhhc | coop | rem | savings |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| la_dstf | 1.00 | | | | | | | | | | | | | | | | | | |
| nl_dstf | -0.15 | 1.00 | | | | | | | | | | | | | | | | | |
| | (0.00) | | | | | | | | | | | | | | | | | | |
| lta | 0.19 | 0.17 | 1.00 | | | | | | | | | | | | | | | | |
| | (0.00) | (0.00) | | | | | | | | | | | | | | | | | |
| roaa | 0.12 | 0.01 | 0.00 | 1.00 | | | | | | | | | | | | | | | |
| | (0.00) | (0.40) | (0.76) | | | | | | | | | | | | | | | | |
| nl_ta | -0.54 | 0.60 | 0.06 | -0.02 | 1.00 | | | | | | | | | | | | | | |
| | (0.00) | (0.00) | (0.00) | (0.20) | | | | | | | | | | | | | | | |
| eq_ta | 0.14 | -0.08 | -0.40 | 0.27 | -0.11 | 1.00 | | | | | | | | | | | | | |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | | | | | | | | | | | | | | |
| cir | 0.10 | -0.22 | -0.08 | -0.44 | -0.17 | 0.02 | 1.00 | | | | | | | | | | | | |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.25) | | | | | | | | | | | | | |
| llr_gl | -0.02 | -0.17 | -0.22 | -0.28 | -0.15 | 0.10 | 0.07 | 1.00 | | | | | | | | | | | |
| | (0.16) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | | | | | | | | | | | | |
| st_ir | 0.02 | 0.02 | 0.07 | -0.03 | -0.01 | 0.05 | -0.00 | 0.09 | 1.00 | | | | | | | | | | |
| | (0.09) | (0.08) | (0.00) | (0.02) | (0.60) | (0.00) | (0.76) | (0.00) | | | | | | | | | | | |
| spread | -0.16 | 0.00 | -0.22 | -0.18 | -0.01 | 0.06 | 0.00 | 0.27 | 0.05 | 1.00 | | | | | | | | | |
| | (0.00) | (0.92) | (0.00) | (0.00) | (0.36) | (0.00) | (0.77) | (0.00) | (0.00) | | | | | | | | | | |
| gdp | 0.10 | -0.06 | 0.22 | 0.15 | 0.01 | -0.02 | 0.02 | -0.02 | -0.13 | -0.58 | 1.00 | | | | | | | | |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.35) | (0.11) | (0.28) | (0.20) | (0.00) | (0.00) | | | | | | | | | |
| infl | 0.08 | 0.06 | 0.08 | 0.00 | 0.04 | -0.03 | 0.05 | -0.22 | 0.32 | 0.17 | -0.32 | 1.00 | | | | | | | |
| | (0.00) | (0.00) | (0.00) | (0.94) | (0.00) | (0.05) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | | | | | | | | |
| gov_debt | -0.22 | -0.08 | -0.36 | -0.08 | -0.07 | 0.04 | -0.00 | 0.12 | -0.27 | 0.33 | -0.42 | -0.07 | 1.00 | | | | | | |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.82) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | | | | | | | |
| LCR_req | 0.01 | -0.05 | 0.00 | 0.07 | 0.05 | 0.00 | 0.05 | 0.02 | -0.47 | -0.32 | 0.49 | -0.18 | 0.02 | 1.00 | | | | | |
| | (0.71) | (0.00) | (0.84) | (0.00) | (0.00) | (0.79) | (0.00) | (0.27) | (0.00) | (0.00) | (0.00) | (0.00) | (0.24) | | | | | | |
| negrate | -0.07 | -0.02 | -0.07 | 0.02 | 0.05 | -0.01 | 0.02 | 0.03 | -0.59 | -0.30 | 0.36 | -0.30 | 0.13 | 0.82 | 1.00 | | | | |
| | (0.00) | (0.13) | (0.00) | (0.17) | (0.00) | (0.31) | (0.14) | (0.06) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | | | | | |
| bhhc | 0.14 | -0.01 | 0.27 | 0.07 | -0.12 | -0.05 | 0.03 | -0.11 | 0.03 | -0.08 | 0.07 | 0.05 | -0.08 | 0.00 | -0.04 | 1.00 | | | |
| | (0.00) | (0.71) | (0.00) | (0.00) | (0.00) | (0.00) | (0.07) | (0.00) | (0.07) | (0.00) | (0.00) | (0.00) | (0.00) | (1.00) | (0.00) | | | | |
| coop | -0.29 | -0.03 | -0.41 | -0.02 | -0.02 | 0.14 | -0.08 | 0.09 | -0.19 | 0.26 | -0.32 | -0.06 | 0.60 | -0.00 | 0.12 | -0.17 | 1.00 | | |
| | (0.00) | (0.03) | (0.00) | (0.11) | (0.11) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (1.00) | (0.00) | (0.00) | | | |
| rem | -0.05 | 0.38 | 0.11 | -0.00 | 0.26 | -0.16 | -0.11 | -0.20 | 0.03 | -0.16 | 0.11 | 0.05 | -0.19 | 0.00 | -0.03 | -0.06 | -0.22 | 1.00 | |
| | (0.00) | (0.00) | (0.00) | (0.96) | (0.00) | (0.00) | (0.00) | (0.00) | (0.04) | (0.00) | (0.00) | (0.00) | (0.00) | (1.00) | (0.03) | (0.00) | (0.00) | | |
| savings | -0.09 | -0.01 | 0.08 | 0.01 | 0.13 | -0.00 | 0.06 | -0.10 | -0.03 | -0.13 | 0.04 | 0.02 | -0.16 | 0.00 | 0.03 | -0.07 | -0.27 | -0.09 | 1.00 |
| | (0.00) | (0.53) | (0.00) | (0.31) | (0.00) | (0.86) | (0.00) | (0.00) | (0.02) | (0.00) | (0.00) | (0.20) | (0.00) | (1.00) | (0.04) | (0.00) | (0.00) | (0.00) | |

*Note:* p-values in parentheses.

*Source:* Author's calculation in Stata 11.2.

Table D.3: Number of banks by countries

| Country | Number of banks |
|---|---|
| Austria | 21 |
| Belgium | 6 |
| Bulgaria | 9 |
| Cyprus | 5 |
| Czech Republic | 5 |
| Germany | 72 |
| Denmark | 27 |
| Spain | 10 |
| Finland | 5 |
| France | 106 |
| United Kingdom | 41 |
| Greece | 7 |
| Croatia | 15 |
| Hungary | 6 |
| Ireland | 5 |
| Italy | 279 |
| Lithuania | 4 |
| Luxembourg | 11 |
| Latvia | 1 |
| Malta | 5 |
| Netherlands | 18 |
| Poland | 14 |
| Portugal | 5 |
| Romania | 7 |
| Sweden | 13 |
| Slovenia | 5 |
| Slovakia | 5 |
| Total | 707 |

*Source:* Author based on Orbis Bank Focus

Table D.4: Clustered standard errors estimation results for *liquid assets to deposits & short-term funding*

| | FE<br>*Classic SE*<br><br>la_dstf | RE<br>*Classic SE*<br><br>la_dstf | FE<br>*Clustered SE*<br>*(country level)*<br>la_dstf | RE<br>*Clustered SE*<br>*(country level)*<br>la_dstf | FE<br>*Clustered SE*<br>*(bank level)*<br>la_dstf | RE<br>*Clustered SE*<br>*(bank level)*<br>la_dstf |
|---|---|---|---|---|---|---|
| lta | 3.773*** | 2.305*** | 3.773 | 2.305*** | 3.773* | 2.305*** |
| | (0.964) | (0.246) | (2.948) | (0.654) | (2.175) | (0.642) |
| roaa | 0.0155 | 0.250 | 0.0155 | 0.250 | 0.0155 | 0.250 |
| | (0.240) | (0.235) | (0.512) | (0.635) | (0.454) | (0.558) |
| nl_ta | -0.606*** | -0.645*** | -0.606*** | -0.645*** | -0.606*** | -0.645*** |
| | (0.0257) | (0.0201) | (0.207) | (0.167) | (0.0695) | (0.0514) |
| eq_ta | 1.284*** | 1.019*** | 1.284** | 1.019** | 1.284* | 1.019* |
| | (0.0969) | (0.0739) | (0.569) | (0.484) | (0.745) | (0.569) |
| cir | -0.00874 | 0.000494 | -0.00874 | 0.000494 | -0.00874 | 0.000494 |
| | (0.00940) | (0.00902) | (0.0106) | (0.0142) | (0.0110) | (0.0126) |
| llr_gl | -0.383*** | -0.306*** | -0.383*** | -0.306** | -0.383** | -0.306** |
| | (0.0796) | (0.0684) | (0.0746) | (0.131) | (0.170) | (0.149) |
| st_ir | 0.930* | -0.408 | 0.930 | -0.408 | 0.930 | -0.408 |
| | (0.511) | (0.452) | (1.134) | (1.074) | (1.156) | (0.710) |
| spread | 0.271 | -0.286 | 0.271 | -0.286 | 0.271 | -0.286 |
| | (0.243) | (0.211) | (0.375) | (0.378) | (0.381) | (0.191) |
| gdp | -0.182 | -0.392*** | -0.182 | -0.392 | -0.182 | -0.392* |
| | (0.153) | (0.145) | (0.176) | (0.245) | (0.168) | (0.211) |
| infl | 0.897*** | 1.207*** | 0.897** | 1.207*** | 0.897** | 1.207*** |
| | (0.207) | (0.194) | (0.402) | (0.468) | (0.356) | (0.275) |
| gov_debt | -0.0402 | -0.116*** | -0.0402 | -0.116** | -0.0402 | -0.116*** |
| | (0.0485) | (0.0178) | (0.0909) | (0.0561) | (0.0783) | (0.0233) |
| negrate | -6.245*** | -6.354*** | -6.245** | -6.354*** | -6.245*** | -6.354*** |
| | (0.795) | (0.752) | (2.456) | (1.787) | (2.146) | (1.894) |
| LCR_req | 0.102*** | 0.0927*** | 0.102*** | 0.0927*** | 0.102*** | 0.0927*** |
| | (0.0103) | (0.00949) | (0.0290) | (0.0221) | (0.0369) | (0.0301) |
| Constant | -8.363 | 25.36*** | -8.363 | 25.36 | -8.363 | 25.36 |
| | (15.58) | (5.036) | (43.89) | (19.09) | (42.14) | (16.96) |
| Observations | 4949 | 4949 | 4949 | 4949 | 4949 | 4949 |
| F/Wald statistic | 71.61*** | 1617.16*** | 57.10*** | 918.93*** | 21.22*** | 471.09*** |
| R-squared | 0.180 | 0.176 | 0.180 | 0.176 | 0.180 | 0.176 |

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

*Source:* Author's calculation in Stata 11.2.

Table D.5: Clustered standard errors estimation results for *net loans to deposits & short-term funding*

| | FE<br>*Classic SE*<br><br>nl_dstf | RE<br>*Classic SE*<br><br>nl_dstf | FE<br>*Clustered SE*<br>*(country level)*<br>nl_dstf | RE<br>*Clustered SE*<br>*(country level)*<br>nl_dstf | FE<br>*Clustered SE*<br>*(bank level)*<br>nl_dstf | RE<br>*Clustered SE*<br>*(bank level)*<br>nl_dstf |
|---|---|---|---|---|---|---|
| lta | 3.862*** | 3.212*** | 3.862** | 3.212*** | 3.862** | 3.212*** |
| | (1.166) | (0.476) | (1.560) | (1.079) | (1.518) | (0.583) |
| roaa | -0.550* | -0.626** | -0.550** | -0.626*** | -0.550** | -0.626** |
| | (0.290) | (0.291) | (0.220) | (0.228) | (0.272) | (0.249) |
| nl_ta | 1.216*** | 1.253*** | 1.216*** | 1.253*** | 1.216*** | 1.253*** |
| | (0.0310) | (0.0284) | (0.0557) | (0.0578) | (0.0349) | (0.0324) |
| eq_ta | 1.936*** | 1.756*** | 1.936*** | 1.756*** | 1.936*** | 1.756*** |
| | (0.117) | (0.103) | (0.301) | (0.298) | (0.404) | (0.361) |
| cir | -0.0251** | -0.0367*** | -0.0251 | -0.0367 | -0.0251** | -0.0367*** |
| | (0.0114) | (0.0113) | (0.0202) | (0.0227) | (0.0114) | (0.0115) |
| llr_gl | -0.621*** | -0.616*** | -0.621*** | -0.616*** | -0.621*** | -0.616*** |
| | (0.0962) | (0.0915) | (0.161) | (0.156) | (0.135) | (0.121) |
| st_ir | 0.869 | 0.342 | 0.869 | 0.342 | 0.869 | 0.342 |
| | (0.618) | (0.594) | (1.249) | (1.318) | (0.916) | (0.848) |
| spread | -0.0305 | -0.0162 | -0.0305 | -0.0162 | -0.0305 | -0.0162 |
| | (0.294) | (0.280) | (0.269) | (0.562) | (0.362) | (0.388) |
| gdp | -0.757*** | -0.988*** | -0.757 | -0.988 | -0.757*** | -0.988*** |
| | (0.184) | (0.182) | (0.489) | (0.603) | (0.217) | (0.241) |
| infl | -0.270 | 0.0662 | -0.270 | 0.0662 | -0.270 | 0.0662 |
| | (0.250) | (0.241) | (0.441) | (0.523) | (0.442) | (0.382) |
| gov_debt | -0.390*** | -0.100*** | -0.390* | -0.100 | -0.390*** | -0.100** |
| | (0.0587) | (0.0325) | (0.219) | (0.0710) | (0.103) | (0.0430) |
| negrate | -0.950 | 0.167 | -0.950 | 0.167 | -0.950 | 0.167 |
| | (0.962) | (0.944) | (1.923) | (1.894) | (1.009) | (0.975) |
| LCR_req | -0.0387*** | -0.0508*** | -0.0387 | -0.0508 | -0.0387*** | -0.0508*** |
| | (0.0125) | (0.0121) | (0.0314) | (0.0341) | (0.0140) | (0.0134) |
| Constant | -27.07 | -39.59*** | -27.07 | -39.59** | -27.07 | -39.59*** |
| | (18.83) | (9.124) | (30.15) | (16.78) | (26.37) | (11.82) |
| Observations | 4949 | 4949 | 4949 | 4949 | 4949 | 4949 |
| F/Wald statistic | 212.31*** | 3099.44*** | 441.33*** | 9541.52*** | 155.03*** | 2244.87*** |
| R-squared | 0.395 | 0.390 | 0.395 | 0.390 | 0.395 | 0.390 |

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

*Source:* Author's calculation in Stata 11.2.

# Appendix E

# Responses to Advisor's and Opponents' reports

## E.1 Responses to report of prof. RNDr. Jiří Witzany, Ph.D.

1) *"The dissertation looks at performance of banks in the low or even negative interest rate environment characteristic for the decade after the global financial crisis. I have only a small formal remark regarding the abstract that is using an undefined shortcut 'ZLB.' The shortcuts are defined later in the section 'Acronyms,' however, it would be useful if the shortcuts definitions were ordered alphabetically."*
In the final version of the dissertation, the abbreviation ZLB was replaced by "zero lower bound (ZLB)" in the text of the abstract. The acronyms were ordered alphabetically.

2) *Prof. Witzany's main remark aims at the length of the observed period in both chapter 2 and 3, which is only 2011-2016: "The first paper applies various regression techniques on a panel of 629 banks from EU countries for the 2011-2016 period investigating the relationship between the net interest margin (NIM) of the banks and market interest rates while controlling for a number of bank specific, country specific and macroeconomic variables. The results show a positive, and even concave, dependence of NIM on the interest rates, and some other interesting dependencies, in particular a positive dependence on the concentration measured by the Herfindahl index. In my opinion, the empirical analysis has been done*

*very well and the results are interesting, however my main concern is the length of the time period spanned by the dataset. Since the basic time period is one year, there are only 5 annual observations for each bank. ... The second question is why the author did not use a longer time period, in particular beyond 2016 and possibly also before 2011 allowing to compare the sensitivities in normal interest rate environment and in the low interest rate environment?*
*The second paper extends the second by enlarging the panel dataset with (526) US banks. The empirical analysis and the results are very similar to the previous paper with an additional observation on significantly larger average NIM of banks in capital-based markets (US+UK) than in the bank-based market (EU-UK). The time span is still 2011-2016 with annual observations and so there are the same questions as for the first paper."*
I agree that it would be more appropriate to have a longer time span, e.g. to include also the period before the 2007-2009 crisis. However, the period was limited by the availability of data in the Orbis Bank Focus database at the time the data for these two papers were obtained.

3) *"Even though the panel is large (629 bank) it is questionable whether it can capture the sensitivity of banks on the short-term interest rate which is for most banks the EUR interest rate observed only over 5 years. Interestingly, the short interest rate and even its squared value coefficients are significant, but can the author exclude a possibility of some kind of spurious regression result?"*
The spurious regression problem is quite unlikely in this case.

- The first reason is, as the previous literature, e.g. Borio et al. (2017) or Bikker & Vervliet (2017), shows, that there exists strong theoretical and empirical evidence of this kind of relationship between the short-term market rate and net interest margin.

- Secondly, we have conducted estimations with time dummy variables for each year and most of them were insignificant. (Except for the difference between 2014 and 2015, where the rate decreased below zero; but this effect is normally captured in the models by the negative rate dummy. The results are presented in Table E.1.)

4) *"The second paper extends the first by enlarging the panel dataset with (526) US banks. The empirical analysis and the results are very similar to the previous paper with an additional observation on significantly larger average NIM of banks in capital-based markets (US+UK) than in the bank-based market (EU-UK). ... It is surprising why the author does not compare sensitivities of NIM on the interest rates and possibly other factors between the two markets?"*
We have also estimated the model with an included interaction term between the ST rate and capital-based market dummy (see Table E.1). The coefficient is significant negative, confirming the higher sensitivity to the ST rate in bank-based markets. (However, the Hansen test in this case rejects the null hypothesis and this result suggests the misspecification of the model.)

Table E.1: Estimation with time dummies and interaction term

| | (1) nim | (2) nim | Time dummies nim | Interaction term nim |
|---|---|---|---|---|
| L.nim | 0.846*** | 0.846*** | 0.839*** | 0.839*** |
| | (0.0286) | (0.0283) | (0.0358) | (0.0313) |
| st_ir | 0.108*** | 0.0984*** | 0.0938*** | 0.143*** |
| | (0.0325) | (0.0292) | (0.0351) | (0.0303) |
| st_ir_sq | -0.0223*** | -0.0218*** | -0.0194*** | -0.0275*** |
| | (0.00633) | (0.00620) | (0.00641) | (0.00610) |
| spread | -0.00847 | -0.0204*** | -0.0140* | -0.0281*** |
| | (0.0131) | (0.00729) | (0.00784) | (0.00792) |
| spread_sq | -0.000895 | | | |
| | (0.000822) | | | |
| gdp | 0.0145*** | 0.0144*** | 0.00326 | 0.0124** |
| | (0.00518) | (0.00529) | (0.00456) | (0.00510) |
| infl | 0.0591*** | 0.0607*** | 0.0487*** | 0.0628*** |
| | (0.0112) | (0.0105) | (0.0139) | (0.00992) |
| unem | -0.00322 | -0.00255 | -0.00330 | -0.000973 |
| | (0.00337) | (0.00339) | (0.00423) | (0.00344) |
| lta | -0.0108 | -0.0103 | -0.0103 | -0.0148 |
| | (0.00926) | (0.00932) | (0.00894) | (0.00991) |
| llr_gl | 0.0128*** | 0.0130*** | 0.0111*** | 0.0120*** |
| | (0.00403) | (0.00388) | (0.00398) | (0.00410) |
| eq_ta | 0.0128** | 0.0130** | 0.0116** | 0.0118** |
| | (0.00551) | (0.00536) | (0.00564) | (0.00555) |
| cir | -0.00114** | -0.00116** | -0.00131*** | -0.00113** |
| | (0.000461) | (0.000459) | (0.000501) | (0.000463) |
| nl_ta | 0.00535*** | 0.00530*** | 0.00571*** | 0.00578*** |
| | (0.000920) | (0.000915) | (0.00107) | (0.00100) |
| nl_dstf | -0.0000578 | 0.00000289 | -0.000204 | -0.000377 |
| | (0.000301) | (0.000296) | (0.000279) | (0.000310) |
| la_dstf | -0.000244 | -0.000292 | -0.000117 | -0.0000678 |
| | (0.000507) | (0.000502) | (0.000506) | (0.000501) |
| bhhc | 0.0285 | 0.0284 | 0.0226 | 0.0287 |
| | (0.0225) | (0.0225) | (0.0236) | (0.0234) |
| coop | -0.106*** | -0.103*** | -0.114*** | -0.103*** |
| | (0.0282) | (0.0287) | (0.0305) | (0.0293) |
| rem | -0.177*** | -0.183*** | -0.182*** | -0.175*** |
| | (0.0565) | (0.0553) | (0.0636) | (0.0581) |
| savings | -0.0608*** | -0.0613*** | -0.0630** | -0.0590** |
| | (0.0235) | (0.0234) | (0.0251) | (0.0239) |
| large | 0.0261 | 0.0228 | 0.0201 | 0.0365 |
| | (0.0380) | (0.0385) | (0.0381) | (0.0397) |
| small | 0.0194 | 0.0223 | 0.0271 | 0.0266 |
| | (0.0315) | (0.0317) | (0.0334) | (0.0339) |
| negrate | -0.00686 | -0.0182 | 0.0166 | -0.00358 |
| | (0.0227) | (0.0191) | (0.0339) | (0.0188) |
| capbas | 0.0902** | 0.0910** | 0.133*** | 0.147*** |
| | (0.0379) | (0.0377) | (0.0471) | (0.0507) |
| y2012 | | | -0.000899 | |
| | | | (0.0394) | |
| y2013 | | | -0.0386 | |
| | | | (0.0308) | |
| y2014 | | | 0.0517** | |
| | | | (0.0214) | |
| y2015 | | | -0.00415 | |
| | | | (0.0134) | |
| stircap | | | | -0.134** |
| | | | | (0.0546) |
| Constant | 0.0216 | 0.0277 | 0.0611 | 0.109 |
| | (0.170) | (0.167) | (0.174) | (0.187) |
| Observations | 5775 | 5775 | 5775 | 5775 |
| Number of groups | 1155 | 1155 | 1155 | 1155 |
| Number of instruments | 32 | 31 | 35 | 32 |
| Wald statistic | 26351.0*** | 26136.3*** | 26128.07*** | 24328.41*** |
| Arellano-Bond AR(1) | -1.83* | -1.83* | -1.82* | -1.83* |
| Arellano-Bond AR(2) | 0.54 | 0.53 | 0.53 | 0.55 |
| Hansen test | 13.26 | 12.77 | 12.22 | 17.73*** |

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

## E.2 Responses to report of doc. Ing. Zdeněk Tůma, CSc.

1) *"Chapter 2 deals with the relationship between ZLB and NIM. Previous studies on this topic did not address a potential impact of the market structure/concentration and Petr's research enhances the analysis with this aspect. I suggest to explain better the role of ZLB: the concentration in the market as well as other explanatory variables used in the analysis should be relevant for NIM regardless of the level of interest rates. Why is the environment of ZLP important for this analysis?"*
I fully agree that the other explanatory variables should be relevant for NIM regardless of the level of interest rates. The relationship between NIM and the interest rate structure in ZLB situation is the main topic of this work, hence the other variables, including the market concentration, are included in the models in order to produce consistent estimates of the impact of the main variables of interest.

2) *"The author tackles highly complex issue in Chapter 3: he strives to find the link between NIM and the nature of financial markets, bank based vs capital based. I like the paper, it is certainly very interesting research. Though, I am not sure whether the distinction between both systems (bank vs capital based) is so strict. The capital market in the EU is not small and – it is important – companies have the option to go to the market for financing. Secondly, there might be other factors influencing the analysis (and not captured by it), and it is the higher flexibility of economic policies in the US. The US authorities responded much more quickly to the crisis (incl. the support of the banking/financial sector) and it could influence performance/NIM of banks. I would appreciate it if Petr could respond during the pre-defence to the question regarding the potential role of economic/monetary policies."*
The distinction between a bank-based and a capital-based market always depends to a certain extent on the authors' decision. In our paper we have set the dummy variable indicating the capital-based markets based on previous literature (described in Subsection 3.2.1), which usually considers the United States and United Kingdom to be capital-based markets, while continental Europe is considered to be bank-based. Regarding the impact of economic and monetary policies, their impact on the banks' net

interest margin should be well proxied by the included variables of the short-term market rate and slope of the yield curve which are strongly influenced by the central banks' policies via the monetary transmission mechanism.

3) *"The chapter 4 covers a very specific topic of ALM, namely the prepayment risk. This risk does not have to materialize in the period of stable interest rates but it can become quite substantial during decreasing interest rates. It is interesting to observe that in spite of the massive harmonization in banking regulation, this is the area with significant national differences. Petr rightly points that this problem became acute after the interpretation of the law on consumer credit by the Czech National Bank; this interpretation does not recognize financial costs related to loans with longer fixation. An obvious solution is to define costs better in the law. But if this does not happen, what could be the impact on the market and (loan) products. Will longer fixations cease to exist or is there any other remedy for this risk?"*
The impact will strongly depend on the future development of market interest rates and on the existing fixation structure of banks' mortgage portfolios. If the clients prefer using longer fixations in a period of relatively high interest rates believing that the rates will go down in the future, it may pose a serious risk to the banking sector, since the banks will hedge those mortgage portfolios with long fixations at the high rates, but when the clients would prepay in large percentage, it will lead to severe losses from the hedging instruments with high rates, either because these instruments will remain as loss making in banks' off-balance sheet or due to unwinding of those positions for the negative clean market value.

4) *"The last chapter deals with the impact of new regulation regarding liquidity. Liquidity was not regulated before the financial crisis and its shortage was one of triggers of the financial crisis. It is clear that the new tough regulation of liquidity cannot be implemented 'over night'; this paper provides empirical research in this – quite new – area and takes into account different business models of banks. The conclusion that the liquidity regulation has improved liquidity across the banking sector is not surprising. I am aware that the following question was not subject of the research*

*in the paper but I would be interested in Petr's view: can CBDC replace the regulation of liquidity as the central bank could always provide enough liquidity into the economy if it is needed?"*
This is quite a complicated question with many aspects. I agree that CBDCs could potentially be used instead of a lender-of-last-resort policy to provide liquidity to the economy. On the other hand, CBDCs could well lead to the deterioration of the liquidity positions of banks if consumers were able to deposit unlimited amounts of their money as CBDC directly with the central bank, and thus the commercial banks would lose the deposits as a source of funding.

## E.3 Responses to report of prof. David Tripe, Ph.D.

1) *"The dissertation has identified some useful literature on bank net interest margins, particularly in a low interest rate environment, and in response to differing levels of market concentration. A more extensive review of literature on competition (rather than just concentration) and the management of administered interest rates under conditions of monopolistic competition would have allowed a more complete picture of how interest margins might respond under such conditions.*
*In relation to competition, it would be good to see some reference to Berger & Hannan (1989), who look at the effects of concentration on prices and not just profitability, but it would be better to see some demonstration of awareness of the limitations of concentration as a measure of competition, even if the alternative methods identified are not applied. There is extensive literature on this, but a good summary can be found in Degryse* et al. *(2015).*
*Because banking markets are generally characterised by monopolistic competition, it is reasonable to expect that there may be some lag between changes in underlying prices and the prices promoted to consumers. This is compounded by the effect of what Nabar* et al. *(1993) refer to as menu costs: these effects together might explain the stickiness observed in some cases in relevant administered rates moving in response to underlying money market rates. See also Mester & Saunders (1995) and Tripe* et al. *(2005)."*
I have added a footnote in Section 2.1 in which the recommended literature is mentioned.

2) *"The final chapter of the dissertation looks at issues related to liquidity, and in particular, the effects of the adoption of the Liquidity Coverage Ratio (LCR). This is one of the measures adopted in response to the GFC, and in this regard, I was surprised to not see reference to Huang & Ratnovski (2011). Other references that would have been useful for this chapter include King (2013); Dietrich* et al. *(2014); DeYoung & Jang (2016) and DeYoung* et al. *(2018). I was also disappointed that the analysis looked only at the asset side of the balance sheet, and not at the liability side: evidence from both Australia and New Zealand shows that*

*there have been some significant changes to liability structure in response to the new rules (Tripe & Shi (2012); Deans* et al. *(2012)."*
I am grateful to Prof. Tripe for suggesting these useful sources that will definitely improve the last chapter of this dissertation, which focuses on the impact of the binding LCR introduction on banks' liquidity positions, although most of them are focused mainly on NSFR instead of LCR. I have included the suggested papers in the literature review of Chapter 5.

3) *"The standard definition of net interest margin is net interest income divided by average interest-bearing assets, although other measures are sometimes used. It would be good to confirm just what measure is used in this thesis (I cannot find it stated). This would help clarify the meaning of the discussion of the interest income margin and interest expense margin in the first line on page 32 (note the more precise discussion by Claessens* et al. *(2018)). See also the discussion on page 6 of Entrop* et al. *(2015), although note that I don't support the definition of NIM that they have used."*
The standard definition of net interest income divided by interest-earning assets as presented in the Orbis Bank Focus database is used in our paper. The discussion in the first line of page 32 relates solely to the paper of Claessens *et al.* (2018) and their methodology and findings.

4) *"On page 9, line 16, I think the reference should be to non-interest income, rather than to interest income."*
Yes, indeed. It has been corrected in the final version.

5) *"In Chapter 2, the squares of the short-term interest rate and the slope of the yield curve are included amongst the (country-specific) explanatory variables. Some comment would appear to be required on how the negative values of the underlying variables affect their squares and how this has been dealt with."*
Quadratic modelling is used to model the non-linear or, more precisely, positive concave impact of the interest rate structure. Moreover the negative rate dummy is included as another way to capture the effect of the negative rate.
The quadratic modelling is based on a following logic. Suppose we have a simple regression model where we model the relationship of dependent

variable $y$ and independent variable $x$ as quadratic:

$$y_{it} = \beta_0 + \beta_1 x_{it} + \beta_2 x_{it}^2 + \epsilon_{it} \tag{E.1}$$

Moreover, we assume the positive concave relationship, i.e. $\beta_1 > 0$ and $\beta_2 < 0$. The marginal effect of increase in $x$ on $y$ will then be

$$\frac{\Delta y_{it}}{\Delta x_{it}} \approx \beta_1 + 2\beta_2 x_{it} \tag{E.2}$$

Hence for the case when $x_{it} < 0$ it holds that $\beta_1 + 2\beta_2 x_{it} > 0$, while for $x_{it} > 0$ we can get to the point where the marginal effect of increase in the independent variable will become negative. However, when I looked to the data for both Chapter 2 and Chapter 3 and our estimated results, I found out that this happens only when the short-term rate becomes higher than approximately 4.8%.
To sum up, the quadratic modelling appears to be useful method to model the fact that the lower the market rate the higher the sensitivity of NIM to it regardless whether the short-term interest rate decreases below zero.

6) *"On page 33, lines 8 and 9, there is a somewhat peculiar sentence which reads 'Levine (2002) concludes that there is no support for either the bank-based or market-based view'. The sentence needs to be rewritten so that its meaning is clear."*
Perhaps the sentence could have been formulated more precisely. However, as this paper has been already published, I suggest leaving it as it is. When I read it together with the previous sentence ( *"Fourth, the differences between bank-based and capital-based financial markets (in some studies capital-based markets are referred to as "market-based") were considered, e.g., in a book by Demirgüç-Kunt & Levine (1999) and in a paper by Levine (2002), in which he runs a broad data-based cross-country examination of which type of the financial market performs better in promotion of economic growth. Levine (2002) concludes that there is no support for either the bank-based or market-based view."*) the meaning seems clear to me.

7) *"For Chapter 3, it is generally the case that interest margins in the USA*

*are much higher than those in the other countries in the study. This should be confirmed for this study, and if it is true, I suggest that it would be good as a robustness test to run the data set without US banks (particularly as they comprise such a large proportion of the overall data set)."*
The regressions without U.S. banks are done in Chapter 2 with the same set of variables except for the capital-based market dummy. In my view, this constitutes exactly the requested robustness test.

8) *"For Chapter 4, it would be good to have some descriptive information on the extent to which Czech banks use interest rate swaps to manage the interest rate risk associated with fixed term mortgage loans. Has their use of swaps changed following the change in rules around prepayment penalties in 2016?"*
This is a very relevant question. However, it is not easy to provide an answer, since the Czech banks are not obliged to report externally in such detail that would allow a quantitative analysis. I can only say that from my experience as a bank employee I know that the banks hedge their loan portfolios with interest rate swaps to a large extent, but they leave a certain small percentage of the volume underhedged due to the prepayment risk.

9) *"Evidence from the US market suggests that interest spreads on mortgages are wider than they might be otherwise because of limitations on banks' ability to charge penalties for prepayment of fixed rate loans (see e.g. Saunders & Cornett (2017)). This reflects the cost of the implicit option given to mortgage borrowers. Has there been a widening of spreads in the Czech Republic following the change in rules around prepayment penalties in 2016?"*
Such an effect has not been visible in the Czech Republic. The interest rate margins on loans have, rather, been decreasing in recent years, especially in periods of increasing market rates in 2017-2019 and 2021-2022 when the pressure from market competition did not allow banks to increase their external rates enough to keep the margins stable.

## E.4 Responses to remarks raised by the committee during pre-defense

*"The committee recommended the dissertation thesis for defense after incorporating all the comments of the commission and opponents. Some of the remarks from the committee members were as follows: they recommend adding clustering standard errors for at least one regression of choice and to change the title of the chapter 4 (Prepayment Risk in Banking). Moreover, Magda Pečená recommends reconsidering the concept and message of the 4th essay on liquidity. European Banking Authority (EBA) has closely monitored the impact of introduction of LCR (and its phase-in) since 2015 (see e.g. 2016 – The EBA Report on liquidity measures under Article 509(1) and the review of the phase-in of the liquidity coverage requirement under Article 461(1) of the CRR, EBA/op/2016/22 and 2020 – EBA Report on liquidity measures under Article 509(1) of the CRR, EBA/Rep/2020/37). The reports support the message, that vast majority of banks improved their liquidity position already shortly after GFC, and by 2015 the weighted average of the LCRs (of surveyed banks) was already above 130%, far above the minimum final limit of 100%. So, the introduction of LCR, especially the phase-in feature, had very limited impact on the actual liquidity position of the banks. The reports analyse the drivers of the liquidity and discuss many relevant issues that shall be considered when preparing any partial analysis."*

1) I changed the title of Chapter 4 to "*Prepayment Risk in Banking: Impact Assessment of the Changing Interest Rate in the Czech Republic*".

2) I conducted the estimations with clustered standard errors for models in Chapter 5 and added the results to the Appendix as Table D.4 and Table D.5.

3) I am thankful to Magda Pečená for suggesting the useful EBA reports. I added them to the literature review. Moreover, I added discussion on how the results from EBA reports relate to the results in my paper to Subsection 5.3.3: "*In Figure 5.1 we provide an overview of the development of average liquidity indicators in the sample. We can see that the indicator liquid assets to deposits & short-term funding improved mainly in the last two years. This observation suggests that the LCR requirement became binding for significant number of banks only when it arrived at its*

*final level of 100%. In other words, in the phase-in period the LCR requirement was likely not binding for many banks which is consistent with the findings of EBA (2016). They were thus not forced to increase their liquid assets holdings until the LCR requirement became higher.*" and to Subsection 5.5.1 "*It is worth mentioning that this result is also consistent with the findings of EBA (2016), although this report showed that most banks were already fulfilling the 100% requirement in December 2015. The results in the EBA report on the other hand showed that there were still 16 banks out of 171 observed banks that were not fulfilling the 100% requirement at that time. Moreover, these were all smaller banks (denoted as Group 2 banks in the EBA report) which were likely underrepresented due to smaller sample size used in the EBA report in contrast to this paper (171 banks in the EBA report, 707 banks in this paper).*" Last but not least, I would also like to mention that the EBA report is conducting only comparative analysis while in this paper regression models are used to assess not only the impact of LCR introduction, but also of the low interest rate environment on the liquidity positions of banks, and to control for the possible impact of other relevant variables.