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From Central Counter to Local Living: Pass-Through of Monetary Policy to Mortgage Lending Rates in Districts

Jiří Gregor, Jan Janků and Martin Melecký[1]

Abstract

This paper studies the pass-through from the market benchmark rate (proxied by the 5-year swap rate) to interest rates on all newly issued residential mortgage loans in the Czech Republic—an EU country. It tests for and explains the potential spatial heterogeneity in the pass-through to local mortgage rates highlighted by the literature for the US (Scharfstein & Sunderam, 2016). This spatial pass-through has not been studied in the context of the EU with its specific mortgage loan market structure. Using unique data on residential mortgages in the Czech Republic over 2016-2021, we show that the pass-through varies notably across districts and is significantly driven by local mortgage market concentration (bank market power) and the unemployment rate. We find a lower aggregate pass-through than previous studies (about 0.5). The most important pricing factors for residential mortgage loans appear to be the loan-to-value ratio, the net income of the borrower, the loan maturity, and the length of the fixed-rate period.

Abstrakt

Tento článek zkoumá úrokovou transmisi z tržní referenční sazby (aproximované 5letým úrokovým swapem) do úrokových sazeb všech nově poskytnutých hypotečních úvěrů zajištěných obytnou nemovitostí v České republice. Článek se zaměřuje především na potenciální regionální heterogenitu transmise, na kterou upozorňuje literatura pro USA (Scharfstein a Sunderam, 2016). Tato regionální transmise nebyla v EU s její specifickou strukturou hypotečního trhu doposud zkoumána. S využitím unikátního souboru dat o hypotečních úvěrech zajištěných obytnou nemovitosti v České republice v průběhu letech 2016–2021 ukazujeme, že transmise se výrazně liší napříč okresy a je významně ovlivňována koncentrací lokálního hypotečního trhu (tržní silou bank) a mírou nezaměstnanosti. Nacházíme nižší celkovou transmisi než předchozí studie (okolo 0,5). Mezi nejvýznamnější faktory, které ovlivňují ceny hypotečních úvěrů na obytné nemovitosti, patří poměr výše úvěru a hodnoty zajištění (LTV), čistý příjem dlužníka, délka splatnosti úvěru a délka fixace úrokové sazby.

JEL Codes: E43, G21, G51, R32.

Keywords: Banking market concentration, districts and regions, heterogeneity, interest rate pass-through, mortgage lending rates

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1. Introduction

Amid rising concerns in the global community about the distributional impacts of monetary policy (Hauptmeier et al., 2020; Antoniades, 2021), the pass-through of monetary policy rates via money and capital market rates to local mortgage rates is of keen interest to policymakers and central bankers. The urgency for a deeper understanding of interest rate pass-through and its heterogeneity has been intensified by the sharp rise in monetary policy rates globally. The rising interest rates are a response to the global increase in inflation and an effort to normalize the macrofinancial environment after a long period of low interest rates. This normalization was already attempted before 2020, including by the US and some EU countries, but ended with the onset of the COVID-19 crisis. In this context, the Czech Republic was one of the first countries to restart normalization during the COVID period. Concerned about rising inflation and inflation expectations, the Czech National Bank (CNB) started hiking its policy rate in June 2021 and raised it from 0.25% to 3.75% by the end of 2021.

This paper studies the pass-through from the 5-year interest rate swap (5y IRS) to rates on newly issued residential mortgage loans in the Czech Republic. It tests for and tries to explain the potential spatial heterogeneity in this pass-through, which has been highlighted by the literature in the context of the US (Scharfstein & Sunderam, 2016) but not the EU considering the specific structure of its mortgage loan markets. For our estimations, we use a unique dataset based on the CNB regulatory survey of mortgage lenders, comprising detailed information about new residential mortgage loans granted by individual banks from January 1, 2016 to July 31, 2021. We employ the standard OLS method with fixed effects (FE) for districts of the Czech Republic (77 districts). We control for a variety of borrower, loan, bank, and regional characteristics and cluster the standard errors at the bank level to allow spillovers across banks because of common business policies for lending.

Using individual-loan, high-frequency data, we estimate the aggregate pass-through at about 0.5—at the lower end of the range of pass-throughs previously estimated for the Czech Republic. The most economically significant determinants of the mortgage lending rate are: (i) increasing loan-to-value (LTV) ratio, which is associated with decreasing mortgage rates—thanks to economies of scale—up to the 80% soft prudential limit, after which LTV increases loan risk and pricing; (ii) greater net income, which indicates a higher capacity of the borrower to repay the loan and withstand shocks; (iii) longer loan maturity, which helps borrowers lower their DSTI; and (iv) longer fixed-rate period (up to the general 10-year mark), which reduces mortgage rates because of periods of an inverted yield curve in our sample and a lower risk for banks that the client will migrate to the competition during fixed-rate periods.

Importantly, we find significant heterogeneity in the pass-through at the district level, driven by both demand-side and supply-side structural factors—after we control for unobservable district-level fixed effects. On the supply side, banks in more concentrated markets price loans at a significantly higher mortgage rate than similar loans in less concentrated markets. Also, the pass-through to mortgage rates is significantly weaker in districts with higher bank concentration. A higher unemployment rate in a district is associated with banks pricing mortgage loans at a significantly higher risk premium and mortgage lending rates in the district being more inelastic (stable) over time. Interestingly, the unemployment rate contributes about three times more to the district-level variation in the pass-through than loan market concentration does.

The literature finds the interest rate pass-through to be mostly incomplete and likely varying across time and space (Andries & Billon, 2016; Gregor et al., 2021). For example, during turbulent periods such as the Global Financial Crisis (GFC), the pass-through may weaken (Aristei & Gallo, 2014). Likewise, varying bank competition, changing credit risk, or other location-specific factors can make the pass-through vary across countries or regions (van Leuvensteijn et al., 2013; Gambacorta et al., 2015; Holton & d'Acri, 2015). Our paper contributes to the existing empirical literature on regional pass-through by using loan-level data on residential mortgage rates rather than county-level aggregated data (Scharfstein & Sunderam, 2016) or bank-level aggregated data (Uchino, 2014). Further, our analysis is not biased by mixing fixed-rate and adjustable loan contracts over time. We use only newly originated and priced residential mortgage loans, while controlling for loan contract features, borrower characteristics, and key lending bank indicators.

The remainder of the paper is organized as follows. Section 2 provides a brief literature review and further highlights the contribution of the paper to the literature. Section 3 describes the mortgage loan market in the Czech Republic and the empirical literature related to it. Section 4 discusses the data and summary statistics of the variables used in our analysis. Section 5 explains the estimation approach and methodology. Section 6 discusses the main estimation results. Section 7 carries out robustness tests. Section 8 concludes.

2. Literature Review

Under optimal conditions, the interest rate pass-through could equal one, indicating complete pass-through of the reference rate to a particular lending rate.[2] However, in reality the pass-through tends to be mostly incomplete (Andries & Billon, 2016; Gregor et al., 2021).

The pass-through tends to be stronger in developed countries with more efficient markets, such as the US, the UK, Australia, and Canada (Panagopoulos et al., 2010; Apergis & Cooray, 2015), than in emerging markets and developing economies, such as the Dominican Republic (Grigoli & Mota, 2017), China (Li & Liu, 2019), Indonesia (Pontines & Siregar, 2019), Morocco (Bennouna, 2019), and Russia (Nguyen et al., 2017). Nevertheless, it is still mostly incomplete. In the EU and the Euro Area, empirical research also concurs that the interest rate pass-through is slow in the short term and incomplete in the long term (Egert et al., 2007; Aristei & Gallo, 2014; Havranek et al., 2016). In addition, substantial heterogeneity in the interest rate pass-through prevails across Euro Area countries (Sorensen & Werner, 2006; Belke et al., 2013; Holton & d'Acri, 2015).

Some papers underscore the issue of time-varying pass-through. In particular, studies covering the period of the Global Financial Crisis (GFC; Aristei & Gallo, 2014; Hristov et al., 2014) find a weaker interest rate pass-through than before the GFC—especially in the Euro Area periphery (ECB, 2013; Illes & Lombardi, 2013). Only a few studies have examined the interest rate pass-through in the post-GFC period, including the period when policy rates were hitting their zero lower bound. This literature deals with the added complexity of unconventional monetary policy—using

[2] While one strand of the literature focuses on the pass-through from monetary policy rates, another examines that from money market rates to bank lending rates—abstracting from the pass-through from the policy rate to money market rates and assuming it is nearly complete for practical purposes (Moazzami, 1999; Gambacorta & Iannotti, 2007; Payne & Waters, 2008).

shadow policy rates or other proxies for policy rates to simulate movements in the reference rate—and highlights the issue of weakening pass-through (von Borstel et al., 2016; Horvath et al., 2018).

The pass-through may also vary significantly across regions within one country because mortgage loan markets are locally specific (Montagnoli et al., 2016; Uchino 2014; Scharfstein & Sunderam, 2016). For instance, focusing on business lending rates and deposit rates, Montagnoli et al. (2016) find significant heterogeneity between the North and South of Italy. They show that the speed of adjustment and the mark-up for bank lending rates differ in the North compared with the South. Outside the EU, Uchino (2014), using a sample of 106 regional banks in Japan, finds a significant negative correlation between regional (prefecture) market concentration and the long-run pass-through, pointing to the existence of geographical market segmentation. Scharfstein & Sunderam (2016), using data from loan applications for refinancing or new home purchases in 500 US counties, find that high concentration in local mortgage lending reduces the sensitivity of mortgage rates (and refinancing activity) to mortgage-backed security (MBS) yields (i.e., it lowers the pass-through from the yields).

Overall, the heterogeneity of interest rate pass-through within single countries is under-researched. One reason is limited data availability at a regional level (Dow & Montagnoli, 2007). Nevertheless, Montagnoli et al. (2016) emphasize that the financial factors may differ across regions and changing the policy rate can affect the cost and availability of credit more in some regions than others. Although some papers have studied the interest rate pass-through in the Czech Republic at the national level (Horvath & Podpiera, 2012; Havranek et al., 2016; Gregor & Melecký, 2018; Ehrenbergerová et al., 2020), to our knowledge, no paper examines regional variations in interest rate pass-through for the Czech Republic or EU countries at the district level.

Banking market concentration and bank competition are highlighted as influential factors for the interest rate channel of monetary policy (van Leuvensteijn et al., 2013; Leroy & Lucotte, 2015; Chileshe & Akanbi, 2016). Country-level studies show that a more concentrated banking sector makes banks less receptive to adjusting their retail rates to market or policy rates (implying lower pass-through). For example, Sander & Kleimeier (2006) and Holton & d'Acri (2018) find that higher banking market concentration (lower competition) is associated with slower and incomplete pass-through—that is, pass-through that is delayed and significantly lower than one. Using different measures of bank competition, Mojon (2000) concurs that the pass-through is slower when bank competition measures are low. Representing a cost shock to banks, changes in monetary policy rates are passed on by banks to retail lending rates symmetrically to the extent that there is effective competition among banks (Egert et al., 2007).

A few studies use bank-level or loan-level micro data to corroborate the findings of macroeconomic studies on the effects of banking market concentration and competition on the interest rate pass-through. These include Gambacorta (2008), who finds, using data on Italian banks, that the lending rate pass-through is slower for banks in more concentrated markets with weaker competition. Scharfstein & Sunderam (2016), using loan-level data on US mortgage loans, find a lower pass-through in US counties with more concentrated local markets and a higher local market power of lenders. Therefore, we try to contribute to this literature in the context of the EU mortgage loan market.

3. Mortgage Market in the Czech Republic

The mortgage market in the Czech Republic started to develop more robustly after the turn of the 21st century. The flow of new mortgage loans accelerated prior to 2008, but rising lending rates in the run-up to the Global Financial Crisis (GFC) and tightening bank credit standards slowed the pace. After a decline from 2008 to 2012, the flow of new mortgage loans resumed—except for minor slumps at the turn of 2019 due to interest rate hikes and the introduction of new macroprudential policy measures (Figure 1).[3]

Figure 1: Stock and Flow of Mortgage Loans

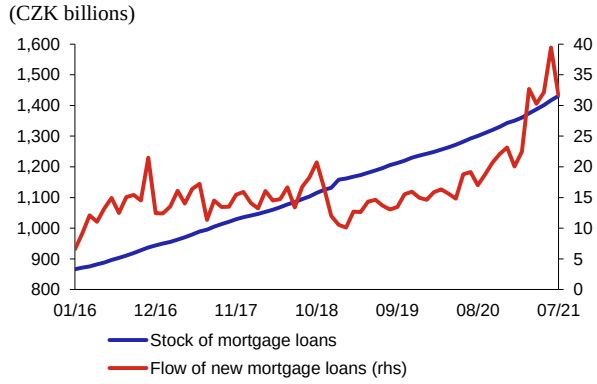
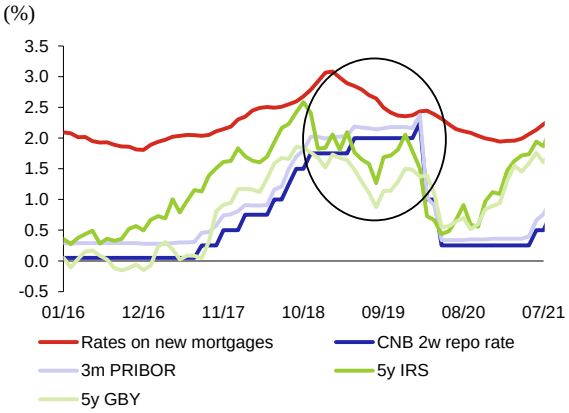


Figure 2: Monetary Policy and Market Interest Rates vs. Mortgage Lending Rate



Note: The black circle highlights the inverse yield curve period.
Source: CNB.

The interest rate pass-through to mortgage loan rates is typically lower than that to corporate lending rates (Gregor & Melecký, 2018). Outside the Czech Republic, this is confirmed by Belke et al. (2013) for 12 Euro Area countries and Gregor et al. (2021) in a meta-analysis of the empirical literature. Naturally, the pass-through to mortgage rates tends to be higher from reference rates where the maturity of the underlying debt instrument is nearer to the average fixed-rate period of mortgage loan rates (Liu et al., 2008). The empirical literature estimates that, in the Czech Republic, the pass-through to mortgage lending rates ranges from 0.36 to 0.90 depending on the type of reference rate used, the estimation strategy, and the time lag considered in the estimations—a rather wide range that leaves policymakers with some uncertainty (Table 1). Using a capital market rate as the reference rate in their estimation of the pass-through, Havranek et al. (2016) and Ehrenbergerová et al. (2020) find higher pass-through to mortgage loan rates in the post-GFC period.

The pass-through has also varied over time—especially during the zero lower bound (ZLB) period, which disturbed the relationships between interest rates in the Czech Republic and around the world.

[3] In mid-2018, the CNB introduced two new borrower-based macroprudential instruments: the debt-to-income (DTI) ratio and the debt service-to-income (DSTI) ratio. Both instruments were effective from October 2018 until the outbreak of the COVID crisis, when the established limits were abolished (for DTI in April and for DSTI in July 2021).

Given the lack of variability in the policy rate, the typical empirical option was to focus on the money/capital market rate and its relation to the mortgage lending rate.

In 2017, the CNB started normalizing monetary policy by gradually raising its policy rate from technical zero. The interest rate pass-through channel regained its importance. Due to an inverse yield curve in 2019, the pass-through from the monetary policy rate to mortgage rates temporarily weakened again. Nevertheless, the relationship between the government bond yield, the 5-year interest swap rate, and the mortgage rate appears to be close (Figure 2). Most recently, in view of the COVID-19 crisis, the CNB cut the policy rate to near zero again (0.25)—ending the first attempt to normalize monetary policy since the European sovereign debt crisis. In response to rising inflation, the CNB returned to normalization in 2021, when policy rates rose sharply in the second half of the year. They have been rising ever since, partly due to the energy and food price crisis and rising inflation in the EU and beyond.

Table 1: Pass-Through to the Mortgage Rate in the Czech Republic

	Pass-through to mortgage rate	Period (mm/yy)	Estimation strategy	Reference rate
Horvath & Podpiera (2012)	0.90	01/04 - 06/06	PMG estimator	1m PRIBOR
	0.36	07/06 - 12/08	PMG estimator	
	0.62	01/04 - 12/08	DOLS-Swamy estimator	
Havranek et al. (2016)	0.45	01/04 - 08/08	PMG estimator	10y government bond yield
	0.84	09/08 - 12/13	PMG estimator	
Gregor & Melecký (2018)	0.56	01/04 - 11/17	ARDL approach	2w repo rate
Ehrenbergerová et al. (2020)	0.66	01/04 - 06/19	OLS FE	Interest rate swap (weighted average of different maturities)

Note: Only the main estimates of each paper are considered.

4. Data

We use a unique dataset based on the CNB regulatory survey of mortgage lenders, comprising detailed information about all new mortgage loans granted by individual banks from January 1, 2016 to July 31, 2021.[4] The dataset contains 420,195 loan-level observations at daily frequency. The survey helps monitor banks' compliance with Act No. 6/1993 Coll., on the Czech National Bank, and the CNB's recommendations on the management of risks associated with the provision of retail loans secured by residential property.[5] The survey data includes detailed information on borrowers and loans, such as level of income, source of income, age of applicant, volume of other debt, loan interest rate, loan volume, loan collateral, fixed-rate period of mortgage, and loan maturity.[6] Because the dataset contains information about the district of the real estate acquired (zip code), it allows for the study of district-level differences. However, the zip code variable is missing in several cases, and we drop these observations from the estimation sample.[7] After removing the missing values for our key variables of interest, we end up with 346,902 loan-level observations. A description and the summary statistics of the data used are given in Tables A1 and A2 in Appendix A, and categorical variables are shown in Figure A1 in Appendix A.

[4] Refinanced loans and loan increases are not taken into account.
[5] See https://www.cnb.cz/en/financial-stability/macroprudential-policy/requirements-for-ltv-dsti-and-dti-limits/.
[6] All information about the borrower and loan are collected at the time of mortgage origination.
[7] In the survey, the zip code is not a key variable, so there is a lower frequency of completion.

The dependent variable is the mortgage lending rate on individual loans (contracted by individual borrowers). In our estimations, we use 77 districts (okres) as the territorial unit.[8] The mortgage rate varies across individual loans, the upper band of the distribution being thicker (Figure 3). The district-level comparison of the median mortgage rate suggests the existence of a stable spread between some districts. For instance, when we compare the capital city of Prague[9] with the border district Česká Lípa (the district with the highest median mortgage rate on average), we find that the spread is about 15 basis points (Figure 4). This spread persists even when we disaggregate mortgage loans by risk characteristics such as debt service-to-income (DSTI) ratio or probability of default (PD).[10] Overall, if we compare the median mortgage rate between 2016 and 2021 across districts, we observe significant differences. While the highest mortgage rates are applied in the western districts and partly also in the northern border districts, such as Děčín, Náchod, and Jeseník, the lowest interest rates are provided in and around the largest cities, such as Prague and Brno (Figure A3 in Appendix A).

Figure 3: Median Mortgage Lending Rate

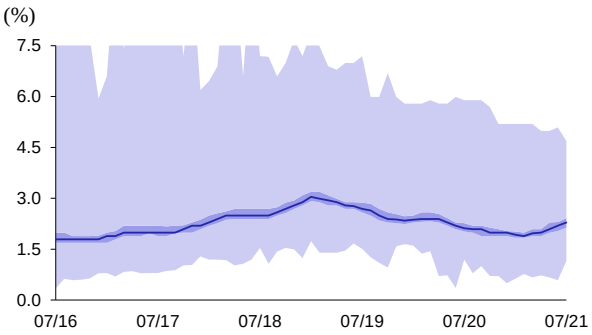
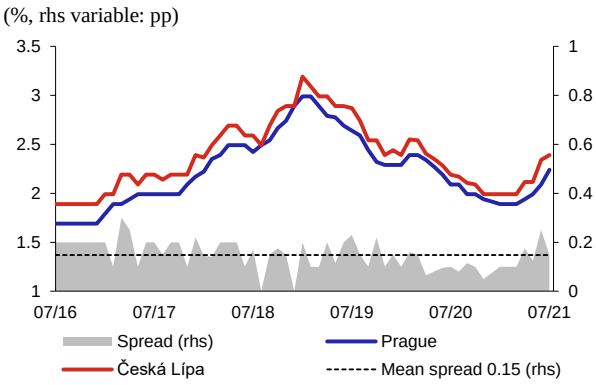


Figure 4: District Differences in Median Mortgage Rates



Note: The dark blue area in Figure 3 represents p25-p75 and the light blue area shows the min-max range. The Y-axis maximum of 7.5 cuts off some extreme mortgage rates.

Source: CNB.

For the reference rate from which we estimate the pass-through to mortgage rates, we use the 5-year interest swap rate (*5y IRS*). Interest rate swaps capture the monetary policy stance and approximate the funding costs of banks better than interbank rates such as PRIBOR. Unlike the interbank rate, the swap rate does not include a (varying) risk premium and is thus better suited to measuring the strength of monetary policy pass-through to lending rates (Ehrenbergerová et al., 2020). IRS are a popular instrument for trading interest rate risk (BIS, 2019), and IRS rates are widely used by banks to price mortgage rates (Maechler, 2020). Typically, banks hedge the interest rate risk of their lending through a fixed-rate payer IRS transaction for the loan maturity and roll over the liquidity provision. Therefore, the reference rate that determines the lending cost is approximated well by the IRS curve (Baeriswyl et al., 2021).

[8] We often use the map of the Czech Republic at the district level, and Figure A4 in Appendix A includes the names of each district. However, in the rest of the paper, we use unnamed maps.

[9] A substantial proportion of loans are granted in the capital city of Prague (more than 10%; see Figure A2 in Appendix A).

[10] DSTI and PD for home mortgage loans are only available from 2018 onward, so the analysis comparing the median values was carried out on a shorter data sample (2018-2021).

Beside the reference rate, we employ several control variables. First, we control for loan characteristics such as loan-to-value (LTV) ratio,[11] maturity, and fixed-rate period. We expect that a higher LTV will increase the riskiness of the loan, the risk premium banks charge, and hence the mortgage rate. We also create a dummy variable (0/1) to control for the possible threshold effect of the LTV regulatory limit (*LTV 80+*). While loans with LTVs below the regulatory limit may have a risk premium close to zero and low elasticity of the mortgage rate to LTV, loans with LTVs above 80% are expected to show greater elasticity of the mortgage rate (risk premium) to increases in LTV. A longer loan maturity should *ceteris paribus* increase the liquidity premium of the loan and hence the mortgage rate. However, a longer loan maturity means spreading the repayments into smaller amounts and lowering DSTI—a risk indicator for mortgage market regulation since 2018. The effect of loan maturity on mortgage rates is thus ambiguous.[12] The length of the fixed-rate period can also affect the mortgage rate. Longer-term fixed-rate loans carry higher interest rates because mortgage lenders assume additional risk without knowing the future market dynamics. Paradoxically, in the Czech Republic, the rates for longer fixed-rate periods have been lower than those for shorter ones in recent years (Figure A8 in Appendix A)—perhaps because the swap market is quite liquid up to 10 years and the interest rate risk (expected loss) for the borrower is lower than the cost of the swap hedging. To separate loans with the commonly offered fixed-rate periods (of up to 10 years) from special arrangements for mortgage loans with fixed-rate periods above 10 years, we also create a dummy variable (*rate fixed for up to 10y=1 otherwise 0*). We expect mortgage rates on loans with a fixed-rate period of up to 10 years to decrease with the length of the fixed-rate period as indicated in Figure A8 in Appendix A, whereas we expect an increased liquidity premium on loans with a fixed-rate period beyond 10 years (Table A3 in Appendix A).

Second, we include control variables that capture borrower characteristics such as income, source of income, age, and size of other debts. We assume that higher net income, employment income (i.e., the client is not self-employed), and lower other debts make clients less risky and are therefore reflected in lower mortgage rates. It turns out that more than 80% of loan applicants have income from employment (Figure A1—top chart—in Appendix A). Banks perceive these applicants to be less risky, with a more reliable and transparent income history. The age of the client shows a non-linear (U-shaped) relationship, with increasing age associated with decreasing rates up to the point where the positive square term starts dominating and reversing the positive relationship to a negative one, because higher (post-productive) age implies higher credit risk (Table A3 in Appendix A).

Third, we control for bank size and mortgage broker involvement in the lending transaction. We divide banks that provide loans into three groups based on their total assets: small (below 2% of total banking sector assets), medium-sized (between 2% and 10% of total banking sector assets), and large (over 10% of total banking sector assets). In addition, we create a dummy for foreign bank branches, which can manage their loan exposures and lending differently. Overall, 16 banks participated in granting new mortgage loans from January 1, 2016 to July 31, 2021. Large banks dominated market activity, providing almost 80% of all new mortgage loans during the period (Figure A1—bottom chart—in Appendix A). As for mortgage broker involvement in loan

[11] The loan volume and loan collateral are highly correlated with the borrower's income. We thus prefer to use the LTV ratio together with the borrower's income.

[12] We do not control directly for DSTI because we already control for both income and loan maturity and loan to value in the regression. DSTI is naturally strongly correlated with these variables, and, as a ratio, provides much less information than the separate indicators we use. In addition, the DSTI variable in the dataset has only been available since 2018.

transactions, most mortgage loans (more than 67%) are negotiated through a mortgage broker (Figure A1—middle chart—in Appendix A).

Fourth, we try to capture and control for the variation in the spatial characteristics of the demand and supply sides of the mortgage market. Specifically, we control for the local unemployment rate (at the district level at monthly frequency), which reflects the local risk of potential mortgage loan default.[13] Spatially, the unemployment rate seems to be systematically higher in border districts (Figure A5). On the supply side, we control for a measure of mortgage market concentration at the level of individual districts. We hypothesize that banks operating in more concentrated markets tend to exert their higher market power on interest rates in order to achieve higher margins. Following the literature (Uchino, 2014; Drechsler et al., 2017; Scharfstein & Sunderam, 2016; Antoniades, 2021), we use the Herfindahl–Hirschman index (HHI) as the baseline measure of concentration in our estimations:

$$HHI_{k,t} = \sum_{l=1}^{n} \left(\frac{volume\ of\ originated\ mortgage\ loans_{k,t,l}}{\sum_{l=1}^{n} volume\ of\ originated\ mortgage\ loans_{k,t,l}} \times 100 \right)^2, \quad (1)$$

where k stands for districts, t for time, and l for lending institution. For a robustness check, we also construct the concentration ratio (CR) of the three largest mortgage lenders in the district, similarly as in Scharfstein & Sunderam (2016):

$$CR_{k,t} = \frac{\sum_{l=top\ 1}^{top\ 3} volume\ of\ originated\ mortgage\ loans_{k,t,l}}{\sum_{l=1}^{n} volume\ of\ originated\ mortgage\ loans_{k,t,l}}. \quad (2)$$

Mortgage market concentration varies over time and space. At the end of 2018, the concentration of local banking markets was decreasing. Favorable economic conditions were stimulating increasing competition. However, as of 2019, and especially after the outbreak of the COVID pandemic, concentration started to increase again—perhaps partly because the population turned more toward large banks (Figure A6). From a spatial perspective, the concentration of the mortgage market is the highest in the south-western part of the Czech Republic, mostly around the city of Pilsen (Figure A7).

5. Methodology

For the estimation, we use a standard OLS with fixed effects (FE) representing the individual districts of the Czech Republic (76 districts and the capital city of Prague). We cluster the standard errors of this OLS regression at the bank level to allow for spillovers across banks because of common lending policy.

The data structure does not allow us to create a dynamic model, because we only have data on the loan origination date for individual borrowers on a daily basis. We do not track the originated loans over time and thus cannot lag the dependent or most explanatory variables in time. A possible alternative solution would be to aggregate mortgage rates at the level of individual districts—similar

[13] We tried to include several district-level variables that are stable over time or available at annual frequency, such as distance to district town, number and density of bank branches, population density, number of housing completions, balance of migration, GDP, GDP per capita, and level of awareness, but these variables were always highly correlated in the final estimation and could not be used.

to Hurst et al. (2016)—and then use a dynamic panel model with the average loan in the district as the unit of observation. However, this estimation strategy would lead to a loss of valuable information and variation in the data at the level of individual loans.

Following the literature, we estimate the interest rate pass-through to individual mortgage rates (i.e., to loan-level interest rates) using 5-year swaps (*5y IRS*) as the reference rate (the 5-year interest rate swap broadly corresponds with the average fixed-rate period of mortgage loans, which is 5.5 years). We assume the 5-year swap rate to be (weakly) exogenous and not affected by changes in individual mortgage loan rates. We further lag the 5-year swap rate by 4 months and use it as a predetermined explanatory (policy) variable. We predetermine the appropriate lag using correlation analysis (Table A4 in Appendix A) and formally validate through a test using the Bayesian Information Criterion based on a conditional regression analysis (Table B1 in Appendix B).[14] The main motivation is the administrative delay in arranging a mortgage loan, where the offer rate that the client receives is not realized until several months later. For this reason, we also lag the two regional variables (the unemployment rate and the HHI) identically (4 months) to reflect the bank's initial conditions in the period when the mortgage offer was made.

In the baseline estimation, we define the aggregate interest rate pass-through and run an OLS regression of the following form:

$$mlr_{i,t} = \alpha + \beta\ 5y\ IRS_{t-4} + \gamma X_{i,t} + \delta D_k + \varepsilon_{i,t}, \tag{3}$$

where *mlr* represents the mortgage lending rate, *i* stands for individual loans, and *t* stands for time. $5y\ IRS_{t-4}$ is the variable of primary interest, showing the size of the aggregate (average) interest rate pass-through. The vector X_i contains control variables that can be divided into borrower-level, loan-level, and bank-level controls. The rationale for including these variables is given in the previous section. D_k stands for district-level fixed effects, where *k* stands for districts. The term $\varepsilon_{i,t}$ denotes the estimation error, which we cluster at the bank level and use robust standard error computation for inference.

Further, we expand the baseline specification with district-level controls to examine the district-level variation in the mortgage rate pass-through. Specifically, we use one demand-side variable at the level of districts: the local unemployment rate, and one supply-side variable: local mortgage market concentration. In addition, we allow for variation in the district-level pass-through based on unobservable fixed effects (D_k)—that is, by controlling for interactions with possible time-invariant institutional and other district-specific factors that could compete with the two structural factors which we hypothesize to be important drivers of the district-level variation in the pass-through. We measure local mortgage market concentration (*BC*) using the Herfindahl-Hirschman index (*HHI*). In our robustness checks, we use an alternative measure based on the concentration ratio (*CR*) of the three largest local mortgage lenders.[15] The selection of a mortgage market concentration variable reflects the findings of relevant literature highlighting the importance of local market power for the interest pass-through to local mortgage lending rates (Scharfstein & Sunderam, 2016).[16] To capture

[14] Our results, reported in the next section, are robust to using a lag of 3 or 5 months for IRS. These supplementary results are available from the authors upon request.

[15] The percentage of mortgages captured by the three largest mortgage lenders is 76% on average.

[16] Apart from the two district-level variables (mortgage market concentration and the unemployment rate), we do not use any other district-level control variables. This is because other available district-level data do not show significant variation at the district level. We tried using region-level data at quarterly or annual frequency, but such variables were strongly correlated with district-level fixed effects and had to be dropped from the estimation. Therefore, we assume that the residual systematic variability across regions is sufficiently captured by the district-level fixed effects.

the effect of regional variables (*RV*) on the interest rate pass-through, we thus interact the *5y IRS* regional structural supply and demand RVs as well as district fixed effects (D_k):

$$mlr_{i,t} = \alpha + \beta\ 5y\ IRS_{t-4} + \gamma X_{i,t} + \delta D_k + \theta(D_k \times 5y\ IRS_{t-4}) + \varphi RV_{k,t-4} + \omega\left(RV_{k,t-4} \times 5y\ IRS_{t-4}\right) + \varepsilon_{i,t}. \quad (4)$$

The pass-through, considering the average value of the regional variables in each district and other locally specific factors, can then be calculated as follows:

$$PT_k = \beta + \theta D_k + \sum_{j=1}^{n} \omega_j mean\ RV_{j,k}, \quad (5)$$

where *j* stands for the individual regional variables and mean refers to the average over the sample (January 1, 2016 to July 31, 2021).

6. Estimation Results

The estimation results are reported in Table 2 and indicate (in column (I)) that the average interest rate pass-through in the Czech Republic is quite weak (about 0.5) and lower than most of the pass-throughs estimated in the literature for the Czech Republic (Table 1). Controlling for several loan, borrower, and bank-level characteristics, we find that banks charge higher interest rates on loans with shorter maturity, shorter fixed-rate periods, and LTVs above 80% (the regulatory threshold for risky loans). While longer loan maturities carry a higher liquidity premium, they also reduce monthly repayments and the debt service-to-income (DSTI) ratio—a regulatory indicator of loan riskiness. The credit risk regulation (regulatory recommendation) may have encouraged banks to lower the risk premium and rates on loans the borrowers of which spread repayments over more years (repay a smaller amount each month) and appear less risky based on the DSTI loan-risk indicator. The estimated effect of the fixed-rate period suggests that interest rates on loans with longer fixed-rate periods tend to be lower in the Czech Republic (Figure A8 in Appendix A) and could be partly explained by the period of an inverse yield curve (Figure 2).[17] In addition, anecdotal evidence from market interviews indicates that banks may price in a loyalty discount during the fixed-rate period, when borrowers are much less likely to refinance with a rival mortgage lender. The effect of LTV is non-monotonous, where LTV growth of up to 80% contributes to falling mortgage rates because of economies of scale[18] while LTV growth of above 80% contributes to a rising risk premium charged by banks because collateral coverage declines and the loan breaches the soft regulatory limit.

From the borrower perspective, clients who have other debt obligations at the time of mortgage loan origination receive a higher interest rate. By contrast regular employment status (not self-employed status) and a higher net income help borrowers secure a lower mortgage rate. Furthermore, the mortgage lending rate appears to decline with the age of the borrower, but progressively less so as

[17] However, the negative effect of the fixed-rate period is statistically significant only for loans with commonly available fixed-rate periods of up to 10 years and is insignificant for special loans with fixed-rate periods greater than 10 years (Table A3 in Appendix A).

[18] Loans with very low LTVs are often small loans, which banks price at a higher rate.

the age of the borrower increases beyond the average—as indicated by the positive square term related to age.[19]

Finally, we find that medium-sized banks price mortgage loans at a slightly higher rate than large banks (this was especially true in the period of the inverted yield curve—Figure A9 in Appendix A) and that borrowers who obtain their mortgage loan through a broker tend to contract loans with a higher mortgage rate.[20]

Overall, the effects of the length of the fixed-rate period (negative until 10 years), LTV (negative from economies of scale versus positive risk pricing above the soft regulatory limit), loan maturity (helping borrowers to lower their DSTI), and net income (indicating the borrower's capacity to repay and withstand shocks) are the four most economically significant factors explaining the pricing margin of mortgage loan lenders in the Czech Republic.

Next, we proceed with the estimation of equation (4) to investigate possible heterogenous pass-through across districts in the Czech Republic. We first estimate the model only with fixed effects interacted with the 5y IRS to highlight the contribution of the regional structural variables (Table 2, column II). Then we estimate the full model and test the significance of the local concentration of the mortgage loan market and the unemployment rate in explaining district-level variation in the pass-through using a specification with interactive fixed effects as a competitor (Table 2, column III).

The estimation results in columns (II) and (III) suggest that neither the direction nor the significance of the control variables changes when we include interactions with district-level fixed effects and regional variables. However, the interpretation of the pass-through does change. While in the first column of Table 2 the 5y IRS coefficient (β) reflects the average level of pass-through for the whole country, in the second column of Table 2 the coefficient indicates the size of the pass-through in Prague (our baseline category when using district fixed effects in interaction with the 5y IRS). In the third column of Table 2, the coefficient shows the strength of the pass-through in Prague as well, but is additionally conditional on the level of the unemployment rate and the size of bank concentration in the districts. A simple comparison of these coefficients shows that the pass-through in Prague is slightly stronger than the national average (column (III) estimate of β).

[19] The positive effect breaks even at around 45 years. Overall, it appears that banks assess clients who are too young (under 26 years) and too old (over 65 years) as riskier and charge them a higher mortgage rate. However, the overall differences in the rates are rather small.

[20] The broker may be reward driven, looking for the highest reward from a lender instead of representing the client's best interests and helping secure the lowest lending rate for the client. As suggested by Woodward & Hall (2010), the incentives faced by mortgage brokers likely differ from those of loan officers. Traditionally, loan officers are paid in salaries, plus some bonus for volume. But the mortgage broker's compensation is either the difference between the terms agreed by the borrower and the terms offered by the wholesale lender or a percentage of the agreed loan amount. This finding may also suggest that borrowers who choose not to engage a mortgage broker are very well informed about the mortgage market and are able to negotiate better terms with the bank or have directly negotiated better terms as bank employees or special customers of the bank.

Table 2: Estimation Results

	(I)		(II)		(III)	
	Estimate	**Std. Error**	**Estimate**	**Std. Error**	**Estimate**	**Std. Error**
(Intercept)	3.4208***	(0.1875)	3.3912***	(0.1857)	3.2465***	(0.1710)
5y IRS_{t-4}	0.4987***	(0.0102)	0.5257***	(0.0125)	0.6342***	(0.0143)
loan maturity	-0.0008***	(0.0001)	-0.0008***	(0.0001)	-0.0008***	(0.0001)
fixed-rate period	0.0027	(0.0018)	0.0027	(0.0018)	0.0027	(0.0018)
rate fixed for up to 10y	-0.0048***	(0.0014)	-0.0048***	(0.0014)	-0.0048***	(0.0014)
LTV	-0.1154***	(0.0382)	-0.1149***	(0.0382)	-0.1136***	(0.0383)
LTV 80+	0.2182***	(0.0262)	0.218***	(0.0263)	0.2064***	(0.022)
log(net income)	-0.0986***	(0.0122)	-0.0987***	(0.0122)	-0.0941***	(0.0115)
employment income: yes	-0.0349***	(0.0126)	-0.0346***	(0.0125)	-0.0341***	(0.0123)
log(other debt)	0.009***	(0.0017)	0.009***	(0.0017)	0.0087***	(0.0017)
Age	-0.0055*	(0.0029)	-0.0055*	(0.0028)	-0.0056**	(0.0028)
age squared	0.0001*	(0.0000)	0.0001*	(0.0000)	0.0001*	(0.0000)
broker	0.0716***	(0.0184)	0.0717***	(0.0184)	0.0724***	(0.0181)
bank size: small	0.1256	(0.0940)	0.1253	(0.0941)	0.1233	(0.0944)
bank size: foreign branch	-0.0157	(0.0480)	-0.0157	(0.0480)	-0.0142	(0.0476)
bank size: medium	0.0756*	(0.0445)	0.0757*	(0.0445)	0.0783*	(0.0452)
unemployment $rate_{t-4}$					0.2894*	(0.1682)
unempl. $rate_{t-4}$ × 5y IRS_{t-4}					-0.3839**	(0.1506)
HHI_{t-4}					0.2707***	(0.0725)
HHI_{t-4} × 5y IRS_{t-4}					-0.4318***	(0.0639)
Districts FE	YES		YES		YES	
Districts FE × 5y IRS_{t-4}	NO		YES		YES	
No. of obs.	346,902		346,902		346,902	
R-sq.	0.329		0.329		0.332	

Note: ***, **, * statistical significance at 1, 5, and 10% significance level. We cluster standard errors by individual banks.

As for the regional variables, we find that the unemployment rate significantly affects both mortgage rates and the pass-through to those rates. In districts with higher unemployment rates, mortgage rates are higher on average than in districts with lower unemployment rates. At the same time, the pass-through to mortgage rates appears to be significantly higher in districts with lower unemployment rates, suggesting that mortgage rates in these districts respond more elastically to changes in the 5y IRS. Thus, in districts with higher unemployment rates, banks price mortgage loans at a higher risk premium and the lending rates in these districts tend to be more inelastic (stable) over time, whereas in districts with lower unemployment rates, banks react more strongly to changes in the 5y IRS—that is, they lower their rates for clients faster when the 5y IRS falls but also raise them significantly faster when the 5y IRS rises relative to other districts.

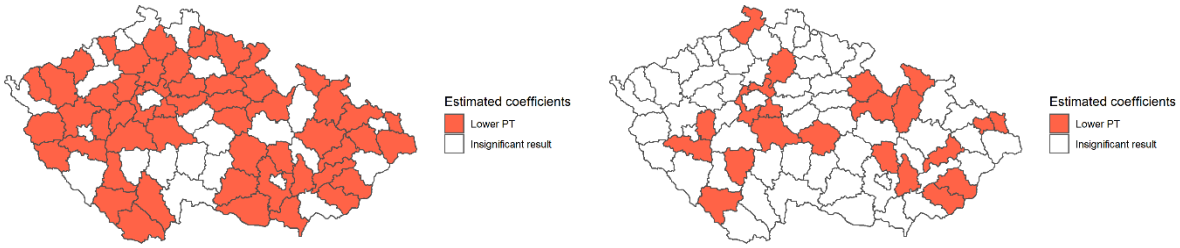
From the supply-side perspective, banks in more concentrated markets benefit from their market power and price loans at a higher mortgage rate than in less concentrated markets. At the same time, the pass-through to mortgage rates appears to be significantly weaker in districts with higher bank concentration, consistent with the empirical literature (Gambacorta, 2008; Scharfstein & Sunderam, 2016).

While we present our estimation results using standard regression tables, we also display them in district-level maps for better visualization. The mapping reflects the direction and strength of the district-level pass-through using a color scheme explained in the legends to the maps. The strength and direction of the pass-through is expressed relative to our base district—Prague. Red indicates a significantly lower pass-through compared with Prague and green a significantly

higher one. The white color indicates that there are no statistically significant differences in the interest rate pass-through compared with Prague.

Figure 5: Variation in the Interest Rate Pass-Through at the District Level

(a) Table 2 Column (II) Results ***(b) Table 2 Column (III) Results***

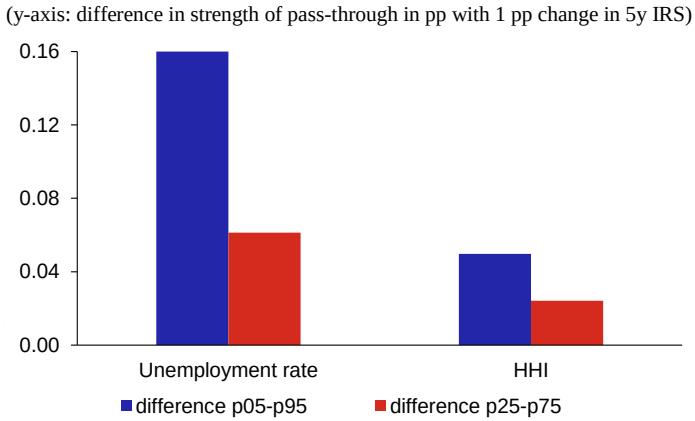


Note: The maps represent the effects on the interest rate pass-through after the 5y IRS change. Non-white areas show statistically significant results (p-value < 0.05).

When we compare the visualizations of the district-level results in the maps (Figure 5), we can conclude that regional variables can help explain much of the spatial variation in the district-level pass-throughs. Figure 5(a) shows numerous districts with a significantly lower pass-through than in Prague and none with a significantly higher one—marking it possibly as one of the most elastic districts in terms of adjustment to aggregate changes in interest rates. However, when the structural regional variables (RVs) are added to the regression in levels and in interaction with the 5y IRS, the picture of significant district-level variation in the pass-through changes substantially (Figure 5(b)). The pass-through appears significantly different from that in Prague in much fewer districts when we control for the local level of mortgage loan market concentration and the local unemployment rate. Local structural factors on both the supply and demand side are thus important drivers of the district-level pass-through in the Czech Republic. This is important information for the CNB as the monetary authority, the prudential authority, and also the agency responsible for promoting competition in financial markets. A question remains as to whether the supply-side factors dominate over the demand-side ones and whether the CNB should be putting a greater emphasis on promoting local competition in mortgage loan markets to ensure fairer impacts of changes in monetary policy on households and their access to housing finance across Czech districts. We shed some light on this question next.

Figure 6 shows the relative average contributions of the local HHI index (market concentration) and the local unemployment rate to the variation in the district-level pass-through. Overall, it seems that the differences in the district-level pass-through are not negligible. With a 1 percentage point change in the 5y IRS, the differences between districts could rise to 0.16 percentage points, assuming the same level of bank concentration and the same fixed effects across all districts. The contribution of the unemployment rate to the district-level variation in the pass-through is, on average, about three times larger than that of market concentration. These relative contributions suggest that, in the Czech Republic, demand-side factors could be more important than supply-side factors in driving the local pass-through to mortgage rates.

Figure 6: Contributions of the Unemployment Rate and the HHI to the Variation in the Pass-Through Across Districts



Note: The difference in pass-through is calculated as the difference between the pass-through values in districts with an unemployment rate (HHI) at the 5th and 25th percentile and the 95th and 75th percentile, assuming that the other factors (the value of the second regional variable and the FE of the district) are the same for all districts. The last column reports the real maximum difference in pass-through between two districts (Prague and Sokolov) when the assumption of constant other factors is removed.

7. Robustness

To test the robustness of our results, we re-estimate our interest rate pass-through model with the concentration ratio (*CR*) instead of the *HHI* (Table B2 in Appendix B, column I). The estimation results with the concentration ratio confirm the baseline results with the *HHI*. The mean pass-through is the same for the Czech Republic, and also locally for Prague and most other districts. The direction and significance of all the control variables remain similar to the baseline model. The estimation also confirms a statistically significant effect of the unemployment rate and the concentration ratio on the pass-through but not on mortgage lending rates.

Next, we test the robustness of our results to spillovers within districts that could arise due to common housing or urban planning policies. To that end, we change the clustering of the errors from bank-level to district-level and re-estimate our baseline model. The results are reported in Table B2 in Appendix B (column II) and confirm that our baseline results are robust to this type of possible spillover. The clustering of the standard errors at the district level appears less strict than the clustering at the bank level for the significance of some control variables that determine the mortgage rate risk premium and its variation over time and across districts. All the control variables become significant in this robustness test, including the dummies for exceptionally long fixed-rate period (over 10 years), age, and bank-size.

Lastly, we estimate the model with a combination of clustered standard errors at the district and bank levels. The results are similar to the ones for the district clustering and are reported in Table B2 in Appendix B (column III).

8. Conclusions

This paper studied the pass-through from the market rate—the five-year swap rate (*5y IRS*)—to local mortgage rates at the district level using unique supervisory data on all new residential mortgage loans originated in the Czech Republic. The pass-through estimations and analysis control for key borrower, loan, and bank characteristics, as well as structural and time-invariant factors at the district level, while allowing for possible spillovers among loans of similar banks. The paper found that, at about 0.5, the pass-through estimated at the level of individual loans using high-frequency data could be at the lower end of the range of pass-throughs previously estimated for the Czech Republic. The most economically significant determinants of the mortgage lending rate are longer fixed-rate periods up to the general 10-year mark, which reduce mortgage rates; increasing loan-to-value (LTV) ratios, which decrease mortgage rates thanks to economies of scale up to the 80% soft prudential limit, after which LTV increases loan risk and pricing; longer loan maturity, which helps borrowers lower their DSTI; and greater net income, which indicates the borrower's capacity to repay the loan and withstand shocks.

We found significant heterogeneity in the pass-through at the district level, driven by both demand-side and supply-side structural factors, while controlling for unobservable district-level fixed effects. We found the pass-through to mortgage rates to be significantly weaker in districts with higher bank concentration, consistent with the empirical literature (Gambacorta, 2008; Scharfstein & Sunderam, 2016). The local unemployment rate appears to be an important demand-side driver of the pass-through heterogeneity across districts. Specifically, the unemployment rate contributes about three times more strongly to the district-level variation in the pass-through than loan market concentration does. Therefore, in the Czech Republic, demand-side factors—which tend to be out of the control of the central bank—could be more important in driving the local pass-through to mortgage rates than the main supply-side factors.

Our results have important policy implications. The Czech National Bank and probably other EU central banks, particularly the ECB, cannot count on complete (one for one) pass-through to mortgage rates when trying to manage mortgage loan markets and may need to lean forward in their setting of monetary policy rates. The central bank needs to bear in mind that the effect of monetary policy rates on local mortgage rates could be significantly different across districts based on local demand-side factors—notably the structural (prevailing) unemployment rate—and supply-side factors—notably the level of competition in the local mortgage loan market. So far, it seems that demand-side factors, which may be out of the control or the area of responsibility of the central bank, dominate in explaining the variance in the district-level pass-through. Therefore, making the pass-through more homogeneous could be dependent on real sector policies—especially those that can improve the structural unemployment rate in worse performing districts.

References

ANDRIES, N. AND S. BILLON (2016): "Retail Bank Interest Rate Pass-Through in the Euro Area: An Empirical Survey." *Economic Systems*, 40(1): 170-194.

ANTONIADES, A. (2021): "Monetary Easing and the Lending Concentration Channel of Monetary Policy Transmission." *Journal of Banking & Finance*, 133: 1-22.

APERGIS, N. AND A. COORAY (2015): "Asymmetric Interest Rate Pass-Through in the U.S., the U.K. and Australia: New Evidence From Selected Individual Banks." *Journal of Macroeconomics*, 45: 155-172.

ARISTEI, D. AND M. GALLO (2014): "Interest Rate Pass-Through in the Euro Area During the Financial Crisis: A Multivariate Regime-Switching Approach." *Journal of Policy Modeling*, 36(2): 273-295.

BAERISWYL, R., L. FUHRER, P. GERLACH-KRISTEN, AND J. TENHOFEN (2021): "The Dynamics of Bank Rates in a Negative-Rate Environment-The Swiss Case." SNB Working Papers 5/2021, Swiss National Bank.

BELKE, A., J. BECKMANN AND F. VERHEYEN (2013): "Interest Rate Pass-Through in the EMU-New Evidence From Nonlinear Cointegration Techniques for Fully Harmonized Data." *Journal of International Money And Finance*, 37: 1-24.

BENNOUNA, H. (2019): "Interest Rate Pass-Through in Morocco: Evidence From Bank-Level Survey Data." *Economic Modelling*, 80: 142-157.

BIS (2019): "Triennial Central Bank Survey of Foreign Exchange and Over-The-Counter (OTC) Derivatives Markets In 2019." Bank for International Settlements, Dec/2019.

CHILESHE, P. M. AND O.A. AKANBI (2016): "The Effect of Bank Competition on the Effectiveness of The Interest Rate Channel of Monetary Policy Transmission." *International Journal of Economic Sciences*, 5(3): 10-32.

DOW, S. C. AND A. MONTAGNOLI (2007): "The Regional Transmission of UK Monetary Policy." *Regional Studies*, 41(6): 797-808.

DRECHSLER, I., A. SAVOV AND P. SCHNABL (2017): "The Deposits Channel of Monetary Policy." *Quarterly Journal of Economics*, November, 132(4): 1819-1876.

ECB (2013): "Assessing the Retail Bank Interest Rate Pass-Through in the Euro Area at Times of Financial Fragmentation." *Monthly Bulletin*: 75-92.

EGERT, B., J. CRESPO-CUARESMA AND T. REININGER (2007): "Interest Rate Pass-Through in Central and Eastern Europe: Reborn from Ashes Merely to Pass Away?" *Journal of Policy Modeling*, 29(2): 209-225.

EHRENBERGEROVÁ, D., M. HODULA AND Z. RAKOVSKÁ (2022): "Does Capital-Based Regulation Affect Bank Pricing Policy?".*Journal of Regulatory Economics*, 61(2): 135-167.

GAMBACORTA, L. (2008): "How Do Banks Set Interest Rates?" *European Economic Review*, 52(5): 792-819.

GAMBACORTA, L. AND S. IANNOTTI (2007): "Are There Asymmetries in the Response of Bank Interest Rates to Monetary Shocks?" *Applied Economics*, 39(19): 2503-2517.

GAMBACORTA, L., A. ILLES AND M. J. LOMBARDI (2015): "Has the Transmission of Policy Rates to Lending Rates Changed in the Wake of the Global Financial Crisis?" *International Finance*, 18(3): 263-280.

GREGOR, J., A. MELECKÝ AND M. MELECKÝ (2021): "Interest Rate Pass-Through: A Meta-Analysis of the Literature." *Journal of Economic Surveys*, 35(1): 141-191.

GREGOR, J. AND M. MELECKÝ (2018): "The Pass-Through of Monetary Policy Rate to Lending Rates: The Role of Macro-Financial Factors." *Economic Modelling*, 73(1): 71-88.

GRIGOLI, F. AND J. M. MOTA (2017): "Interest Rate Pass-Through in the Dominican Republic." *Latin American Economic Review*, 26(1):1-25.

HAUPTMEIER, S., F. HOLM-HADULLA AND K. NIKALEXI (2020): "Monetary Policy and Regional Inequality." ECB Working Paper Series, No 2385, European Central Bank.

HAVRANEK, T., Z. IRSOVA AND J. LESANOVSKA (2016): "Bank Efficiency and Interest Rate Pass-Through: Evidence from Czech Loan Products." *Economic Modelling*, 54: 153-169.

HOLTON, S. AND C. R. D'ACRI (2018): "Interest Rate Pass-Through Since the Euro Area Crisis." *Journal of Banking & Finance*, 96(1): 277-291.

HOLTON, S. AND C.R. D'ACRI (2015): "Jagged Cliffs and Stumbling Blocks: Interest Rate Pass-Through Fragmentation During the Euro Area Crisis." ECB Working Paper Series, No 1850, European Central Bank.

HORVATH, R., J. KOTLEBOVA AND M. SIRANOVA (2018): "Interest Rate Pass-Through in the Euro Area: Financial Fragmentation, Balance Sheet Policies and Negative Rates." *Journal of Financial Stability*, 36(1): 12-21.

HORVATH, R. AND A. M. PODPIERA (2012): "Heterogeneity in Bank Pricing Policies: The Czech Evidence." *Economic Systems*, 36(1): 87-108.

HRISTOV, N., O. HÜLSEWIG AND T. WOLLMERSHÄUSER (2014): "The Interest Rate Pass-Through in the Euro Area During the Global Financial Crisis." *Journal of Banking & Finance*, 48(1): 104-119.

HURST, E., B. J. KEYS, A. SERU AND J. VAVRA (2016): "Regional Redistribution Through the US Mortgage Market." *American Economic Review*, 106(10): 2982-3028.

ILLES, A. AND M. J. LOMBARDI (2013): "Interest Rate Pass-Through Since the Financial Crisis." BIS Quarterly Review, Sep/2013, Bank for International Settlements.

LEROY, A. AND Y. LUCOTTE (2015): "Heterogeneous Monetary Transmission Process in the Eurozone: Does Banking Competition Matter?" *International Economics*, 141(1): 115-134.

LI, J. AND M. H. LIU (2019): "Interest Rate Liberalization and Pass-Through of Monetary Policy Rate to Bank Lending Rates in China." *Frontiers of Business Research in China*, 13(8):1-19.

LIM, G. C. (2001): "Bank Interest Rate Adjustments: Are They Asymmetric?" *The Economic Record* , 77(237): 135-147.

LIU, M.-H., D. MARGARITIS AND A. TOURANI-RAD (2008): "Monetary Policy Transparency and Pass-Through of Retail Interest Rates." *Journal of Banking & Finance*, 32(1): 501-511.

MAECHLER, A. M. (2020): "Introductory Remarks by Andrea M. Maechler." News Conference of The Swiss National Bank. Swiss National Bank, June 2020.

MOAZZAMI, B. (1999): "Lending Rate Stickiness and Monetary Transmission Mechanism: The Case of Canada and the United States." *Applied Financial Economics*, 9(6): 533-538.

MOJON, B. (2000): "Financial Structure and the Interest Rate Channel Of ECB Monetary Policy." ECB Working Paper Series, No. 40, European Central Bank.

MONTAGNOLI, A., O. NAPOLITANO AND B. SILIVERSTOVS (2016): "Regional Interest Rate Pass-Through in Italy." *Regional Studies*, 50(8): 1404-1419.

NGUYEN, C. V., K. D. PHAN AND M. WILLIAMS (2017): "The Transmission Mechanism of Russian Central Banks Countercyclical Monetary Policy Since 2011: Evidence from the Interest Rate Pass-Through." *Journal of Eastern European and Central Asian Research*, December, 4(2):1-13.

PANAGOPOULOS, Y., I. REZITI AND A. SPILIOTIS (2010): "Monetary and Banking Policy Transmission Through Interest Rates: An Empirical Application to the USA, Canada, the UK and the Eurozone." *International Review of Applied Economics*, 24(2): 119-136.

PAYNE, J. E. AND G. A. WATERS (2008): "Interest Rate Pass Through and Asymmetric Adjustment: Evidence from the Federal Funds Rate Operating Target Period." *Applied Economics*, 40(1): 1355-1362.

PONTINES, V. AND R. Y. SIREGAR (2019): "Non-Core Liabilities and Interest Rate Pass-Through: Bank-Level Evidence from Indonesia." *Applied Economics*, 51(25): 2703-2714.

SANDER, H. AND S. KLEIMEIER (2006): "Convergence of Interest Rate Pass-Through in a Wider Euro Zone?" *Economic Systems*, 30(1): 405-423.

SCHARFSTEIN, D. S. AND A. SUNDERAM (2016): "Market Power in Mortgage Lending and the Transmission of Monetary Policy." Mimeo, Aug/2016.

SORENSEN, C. K. AND T. WERNER (2006): "Bank Interest Rate Pass-Through in the Euro Area: A Cross Country Comparison." ECB Working Paper Series, No. 580, European Central Bank.

UCHINO, T. (2014): "Bank Deposit Interest Rate Pass-Through and Geographical Segmentation in Japanese Banking Markets." *Japan and the World Economy*, 30(1): 37-51.

van LEUVENSTEIJN, M., C. K. SORENSEN, J. A. BIKKER AND A. A. van RIXTEL (2013): "Impact of Bank Competition on the Interest Rate Pass-Through in the Euro Area." *Applied Economics*, 45(11): 1359-1380.

von BORSTEL, J., S. EICKMEIER AND L. KRIPPNER (2016): "The Interest Rate Pass-Through in the Euro Area During the Sovereign Debt Crisis." *Journal of International Money and Finance*, 68(1): 386-402.

WOODWARD, S. E. AND E. R. HALL (2010): "Consumer Confusion in the Mortgage Market: Evidence of Less Than a Perfectly Transparent and Competitive Market." *American Economic Review*, 100(2): 511-515.

Appendix A: Descriptive Tables and Figures

Table A1: Data Description

Variable	Description	Source
Mortgage rate (%)	Interest rate set by bank when obtaining loan.	CNB Survey
5y IRS (%)	5-year interest rate swap.	Refinitiv
Loan maturity (No. of months)	Maturity of mortgage loan determined at time of acquisition.	CNB Survey
Fixed-rate period (No. of months)	Length of first fixed-rate period in months.	CNB Survey
LTV (%)	Ratio of amount of mortgage loan to total mortgage collateral.	CNB Survey
Net income (CZK thousands)	Net annual income of mortgage applicant(s).	CNB Survey
Employment income: yes/no	Dummy variable that captures applicant's source of income: employment (YES = 1)/ self-employment (NO = 0).	CNB Survey
Other debt (CZK thousands)	Amount of applicant's other debt outside mortgage loan.	CNB Survey
Age of applicant (No. of years)	Age of main applicant.	CNB Survey
Bank size	Dummy variable that captures size of bank: small, medium, large, and foreign bank branches.	CNB Survey
Mortgage broker: yes/no	Dummy variable that captures whether loan was arranged by mortgage broker: (YES = 1)/ (NO = 0).	CNB Survey
Herfindahl–Hirschman index	Herfindahl-Hirschman index for given district at monthly frequency.	CNB Survey
Concentration ratio	Concentration ratio of three largest mortgage lenders for given district at monthly frequency.	CNB Survey
Unemployment rate	Unemployment rate in given district at monthly frequency	CZSO

Table A2: Summary Statistics

Variable	Mean	Sd	Min	p25	Median	p75	Max
Mortgage rate (%)	2.30	0.56	0.35	1.90	2.19	2.59	9.99
5y IRS (%)	1.27	0.66	0.24	0.64	1.36	1.79	2.66
Loan maturity (No. of months)	312	80	36	263	358	364	600
Fixed-rate period (No. of months)	73	26	12	59	60	96	360
LTV (%)	65	23	1	50	72	80	149
Net income (CZK thousands)	627	801	144	340	482	698	71,594
Other debt (CZK thousands)	738	2,432	0	0	30	581	204,557
Age of applicant (No. of years)	36	9	18	29	35	42	70
Herfindahl–Hirschman index	2,400	500	1,300	2,100	2,400	2,700	8,400
Concentration ratio (%)	76	8	47	71	77	81	100
Unemployment rate (%)	3.7	1.7	1	2.5	3.4	4.5	11.7

Note: Data covers period from January 1, 2016 to July 31, 2021. Each variable contains 346,902 observations.
Source: CNB, CZSO.

Table A3: Median and Mean Mortgage Interest Rates by Categories of Explanatory Variables

Loan maturity		up to 5 years	5–10 years	10–15 years	15–20 years	20–25 years	over 25 years
	Median (%)	2.29	2.19	2.19	2.29	2.19	2.19
	Mean (%)	2.37	2.37	2.35	2.42	2.32	2.27
Fixed-rate period		up to 1 years	1–3 years	3–5 years	5–7 years	7–10 years	over 10 years
	Median (%)	2.40	2.19	2.19	2.22	2.24	2.69
	Mean (%)	2.64	2.34	2.30	2.27	2.28	3.04
LTV		up to 60%	60–70%	70–80%	80–90%	90–100%	over 100%
	Median (%)	2.22	2.19	2.24	1.99	2.61	2.79
	Mean (%)	2.34	2.30	2.30	2.22	2.51	2.49
Net income		up to 240K	240–360K	360–480K	480–600K	600–720K	over 720K
	Median (%)	2.17	2.19	2.19	2.21	2.19	2.19
	Mean (%)	2.29	2.33	2.32	2.31	2.30	2.26
Source of income		employee	self-employed				
	Median (%)	2.19	2.23				
	Mean (%)	2.3	2.33				
Other debt		0	up to 50K	50–100K	100–250K	250–500K	over 500K
	Median (%)	2.19	2.19	2.19	2.21	2.29	2.29
	Mean (%)	2.26	2.28	2.28	2.33	2.36	2.35
Age of applicant		up to 30	30–35	35–40	40–45	45–50	over 50
	Median (%)	2.19	2.19	2.19	2.19	2.19	2.24
	Mean (%)	2.30	2.27	2.28	2.32	2.34	2.38
Mortgage broker		YES	NO				
	Median (%)	2.19	2.19				
	Mean (%)	2.32	2.27				
Bank size		small	medium-sized	large	foreign branch		
	Median (%)	2.34	2.29	2.19	2.15		
	Mean (%)	2.46	2.41	2.27	2.29		

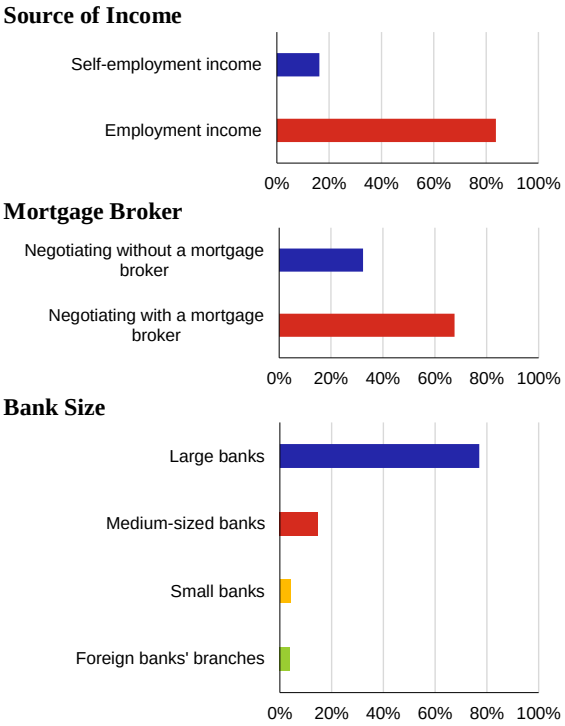
Note: Data covers period from January 1, 2016 to July 31, 2021. Each variable contains 346,902 observations.
Source: CNB.

Table A4: Correlation Between the Mortgage Lending Rate and the 5y IRS at Different Lags

	t0	t-1	t-2	t-3	t-4	t-5	t-6	t-7	t-8	t-9	t-10	t-11	t-12
mlr	0.409	0.455	0.488	0.507	0.512	0.504	0.487	0.464	0.436	0.398	0.368	0.329	0.291

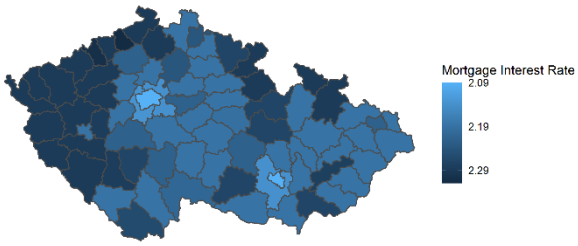
Note: *t* denotes months.

Figure A1: Percentage of Loans by Dummy Variables



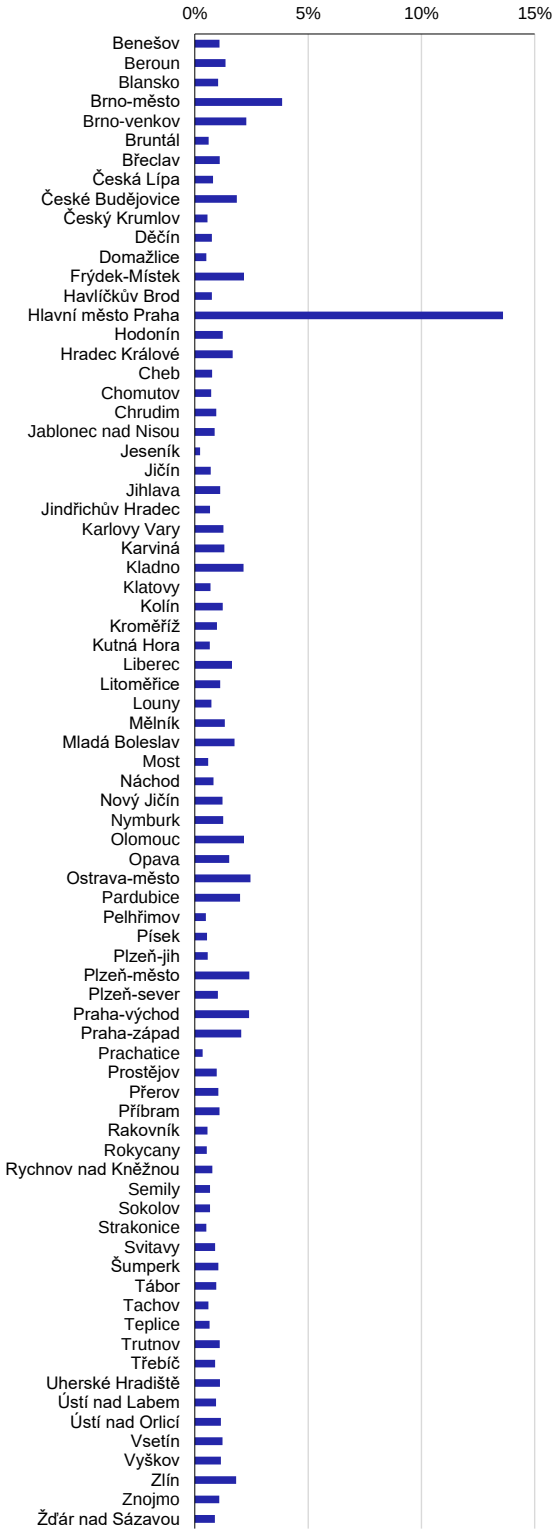
Note: The figure shows the total share of the number of loans granted between January 2016 and the end of July 2021 based on the three categorical variables.
Source: CNB.

Figure A3: Median Mortgage Interest Rate



Note: The figure shows the median level of the mortgage interest rate in each district between January 2016 and the end of July 2021.
Source: CNB.

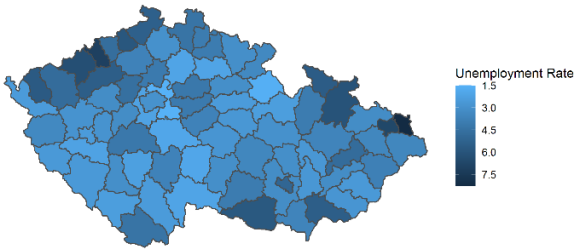
Figure A2: Percentage of Loans by Districts



Note: The figure shows the total share of the number of loans granted between January 2016 and the end of July 2021.
Source: CNB.

Figure A4: Map of the Czech Republic at the District and Regional Level

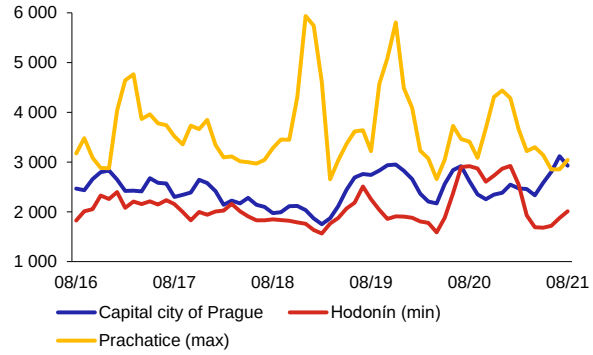
Figure A5: Median Unemployment Rate



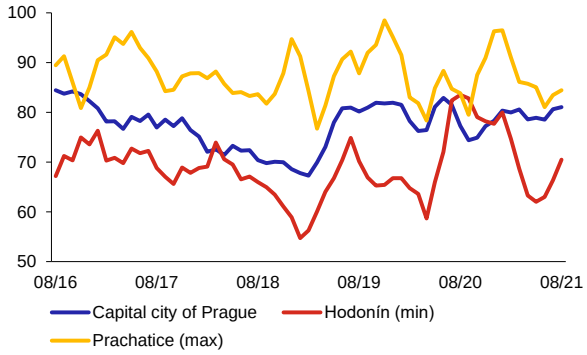
Source: CNB.

Figure A6: Market Concentration in Districts With the Lowest and Highest Average Values Compared With the Capital City of Prague

HHI

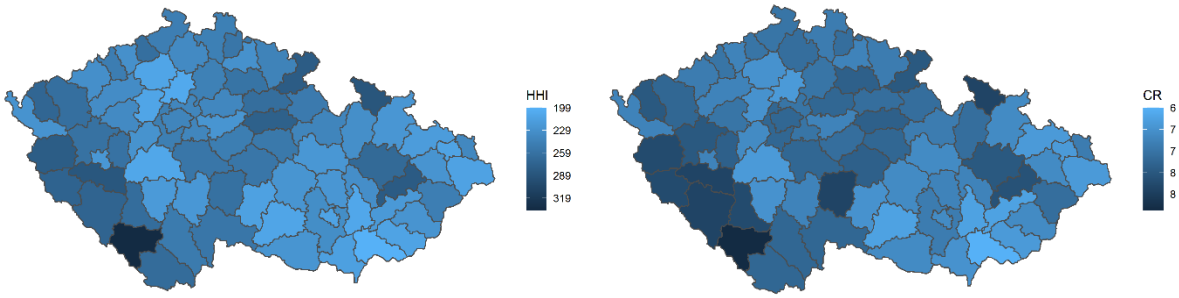


CR



Source: CNB.

Figure A7: Median Levels of the Two Measures of Bank Concentration



Source: CNB.

Figure A8: Average Mortgage Lending Rates by Fixed-Rate Period

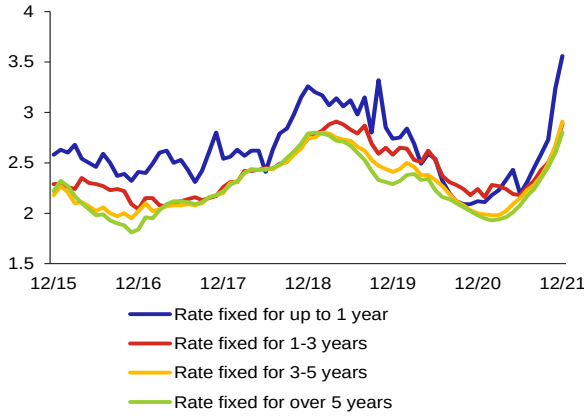
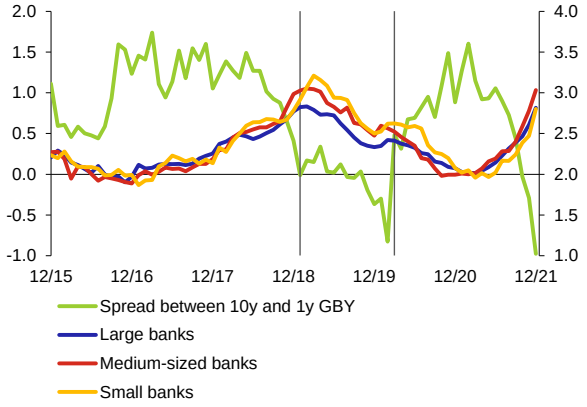


Figure A9: Average Mortgage Lending Rates by Bank Size



Note: The vertical lines in Figure A9 delimit the first inverse yield curve period. The second period occurs from the end of 2021 onward. However, this is outside our data sample for estimation.

Source: CNB.

Appendix B: Robustness Checks

Table B1: Estimation Results for the Full Sample With Different Lags of the 5y IRS

	0	**-1m**	**-2m**	**-3m**	**-4m**	**-5m**	**-6m**	**-7m**	**-8m**	**-9m**
	Est. (Std. Er.)	**Est. (Std. Er.)**	**Est. (Std. Er.)**	**Est. (Std. Er.)**	**Est. (Std. Er.)**	**Est. (Std. Er.)**	**Est. (Std. Er.)**	**Est. (Std. Er.)**	**Est. (Std. Er.)**	**Est. (Std. Er.)**
(Intercept)	3.383***	3.43***	3.458***	3.456***	3.421***	3.371***	3.36***	3.362***	3.363***	3.413***
	(0.184)	(0.189)	(0.193)	(0.195)	(0.188)	(0.178)	(0.173)	(0.168)	(0.161)	(0.157)
5y IRS	0.385***	0.436***	0.476***	0.499***	0.499***	0.487***	0.466***	0.44***	0.41***	0.373***
	(0.019)	(0.019)	(0.018)	(0.015)	(0.01)	(0.008)	(0.01)	(0.013)	(0.016)	(0.017)
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
R-sq.	0.204	0.244	0.277	0.296	0.302	0.292	0.275	0.253	0.227	0.195
BIC	-1.363	-1.416	-1.46	-1.487	-1.495	-1.481	-1.457	-1.427	-1.394	-1.353

Note: ***, **, * statistical significance at 1, 5, and 10% significance level. Clustered standard errors by individual banks are in parentheses.

Table B2: Estimation Results With the Concentration Ratio and Different Cluster SE

	(I)		**(II)**		**(III)**	
	Estimate	**Std. Error**	**Estimate**	**Std. Error**	**Estimate**	**Std. Error**
(Intercept)	3.2797***	(0.1696)	3.2465***	(0.0578)	3.2465***	(0.0269)
5y IRS_{t-4}	0.6538***	(0.0150)	0.6342***	(0.0101)	0.6342***	(0.0052)
loan maturity	-0.0008***	(0.0001)	-0.0008***	(0.0000)	-0.0008***	(0.0000)
fixed-rate period	0.0027	(0.0018)	0.0027***	(0.0002)	0.0027***	(0.0002)
rate fixed for up to 10y	-0.0047***	(0.0014)	-0.0048***	(0.0003)	-0.0048***	(0.0002)
LTV	-0.1146***	(0.0385)	-0.1136***	(0.0141)	-0.1136***	(0.0046)
LTV 80+	0.2062***	(0.0219)	0.2064***	(0.0089)	0.2064***	(0.0028)
log(net income)	-0.0932***	(0.0115)	-0.0941***	(0.0052)	-0.0941***	(0.0017)
employment income: yes	-0.0341***	(0.0123)	-0.0341***	(0.0059)	-0.0341***	(0.0021)
log(other debt)	0.0087***	(0.0017)	0.0087***	(0.0007)	0.0087***	(0.0002)
age	-0.0056**	(0.0028)	-0.0056***	(0.0008)	-0.0056***	(0.0008)
age squared	0.0001*	(0.0000)	0.0001***	(0.0000)	0.0001***	(0.0000)
broker	0.0725***	(0.0180)	0.0724***	(0.0055)	0.0724***	(0.0018)
bank size: small	0.1234	(0.0942)	0.1233***	(0.0054)	0.1233***	(0.0050)
bank size: foreign branch	-0.0137	(0.0475)	-0.0142*	(0.0074)	-0.0142***	(0.0043)
bank size: medium	0.0788*	(0.0453)	0.0783***	(0.0043)	0.0783***	(0.0025)
unemployment $rate_{t-4}$	0.258	(0.1726)	0.2894***	(0.0383)	0.2894***	(0.0190)
unempl. $rate_{t-4} \times$ 5y IRS_{t-4}	-0.3554**	(0.1555)	-0.3839***	(0.0578)	-0.3839***	(0.0176)
CR_{t-4}	0.021	(0.0406)				
$CR_{t-4} \times$ 5y IRS_{t-4}	-0.1771***	(0.0360)				
HHI_{t-4}			0.2707***	(0.0633)	0.2707***	(0.0275)
$HHI_{t-4} \times$ 5y IRS_{t-4}			-0.4318***	(0.0813)	-0.4318***	(0.0195)
Districts FE	YES		YES		YES	
Districts FE × 5y IRS_{t-4}	YES		YES		YES	
Cluster SE	Bank level		District level		Bank & District level	
No. of obs.	346,902		346,902		346,902	
R-sq.	0.333		0.332		0.332	

Note: ***, **, * statistical significance at 1, 5, and 10% significance level.

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