Monetary Policy Transmission, Bank Market Power, and Wholesale Funding Reliance

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Abstract

I study the impact of deposit market concentration and wholesale funding reliance on the transmission of monetary policy shocks to mortgage rates. I find empirically that, in the United States, banks with greater reliance on wholesale funding transmit monetary policy more to mortgage rates. However, banks with greater reliance on wholesale funding in concentrated deposit markets transmit monetary policy less to mortgage rates because banks borrow wholesale funding rather than increase their deposit rates. I then build a partial equilibrium banking model with monopolistically competitive banks with a quasi-kinked mortgage and deposit demand curves and costly access to wholesale funding. The model replicates asymmetric and imperfect pass-through to mortgage rates where banks with greater reliance on wholesale funding in concentrated deposit markets transmit monetary policy shocks less to mortgage rates. Lastly, monetary policy transmission to mortgage rates is amplified when banks' wholesale funding reliance in concentrated deposit markets is limited by tighter liquidity requirements.

JEL Codes: E44, E52, G21

Keywords: Monetary policy transmission, market power, wholesale funding reliance

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1 Introduction

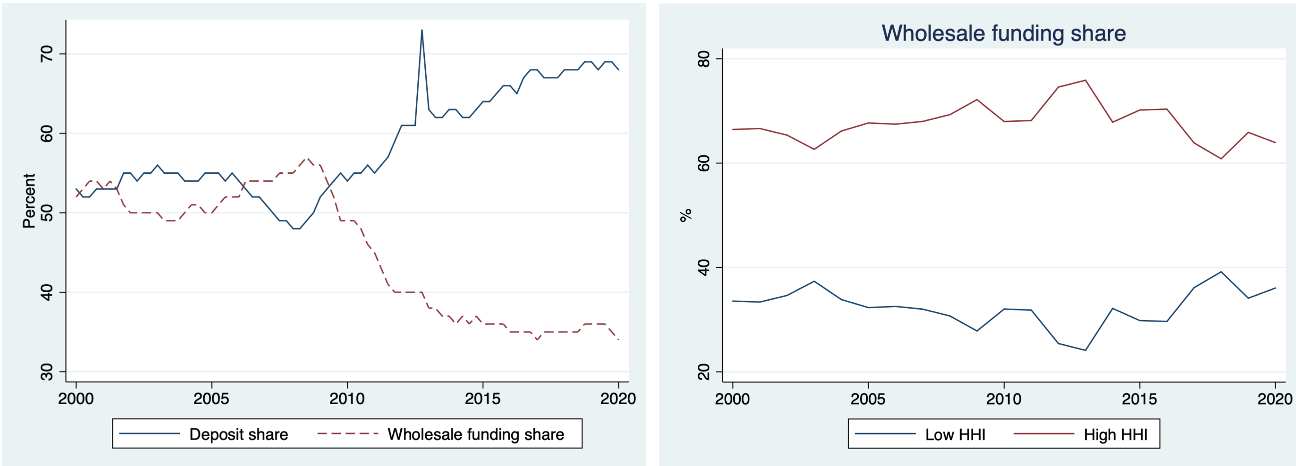
Housing is the largest asset on most homeowners' balance sheets, and mortgages tend to be their dominant source of credit. Central banks influence the state of the economy by changing the policy interest rate, which affects commercial banks' cost of funding. Banks set mortgage rates and the efficacy of monetary policy depends on borrowers' exposure to changes in mortgage rates that have been passed through banking. The effectiveness of monetary policy largely depends on how commercial banks' changes in funding costs, influenced by the policy interest rate, translate into changes in mortgage rates. Commercial banks' funding is mostly composed of retail deposits from households and wholesale funding from institutional investors. Thus, the degree of reliance on wholesale funding—which is measured as the ratio of wholesale funding to retail deposits—may vary by deposit market concentration and influence monetary policy effectiveness.

In this paper, I examine how deposit market concentration and wholesale funding reliance affect the transmission of monetary policy shocks to mortgage rates. To the best of my knowledge, I am the first to show that the interactions between bank market concentration and reliance on wholesale funding are important features for examining the effectiveness of monetary policy changes on mortgage rates. I present new panel regression results using bank- and loan-level microdata across US metropolitan statistical areas (MSAs). I then develop a partial equilibrium model that generates implications comparable to the empirical patterns of imperfect and asymmetric pass-through of monetary policy shocks to mortgage rates. In my model, high-market power banks with greater reliance on wholesale funding only partially respond to policy interest rate changes, which dampens monetary policy transmission to mortgage rates.

To explore the heterogeneous transmission of monetary policy to mortgage rates, I combine loan- and bank-level datasets from the US banking industry for the period from 2000 to 2019. At the loan level, I use the borrower characteristics and geographical variation of mortgage rates from Fannie Mae's Single-Family Loan Performance Data and Freddie Mac's Single-Family Loan-Level Dataset. At the bank level, I utilize the Summary of Deposits to construct a measure of deposit market concentration and obtain wholesale funding information from the Call Reports. I use monetary policy surprises from Bauer and Swanson (2023) as instruments for the policy rate.

I document that the interaction between deposit market concentration and wholesale funding reliance is a critical determinant of the monetary policy pass-through to mortgage rates. Banks in highly concentrated deposit markets rely on wholesale funding to issue loans (Choi and Choi, 2019) and market concentration has been rising (Corbae and D'erasmo, 2011). Figure 1a shows deposit and wholesale funding shares relative to the total liability. Before the Great Recession, both deposit and wholesale funding shares were contributing roughly equally. After the Great Recession, deposit and wholesale funding shares drift away from each other, with the wholesale funding share dropping to around 30%. Figure 1b shows that banks in concentrated markets, shown in a red line, hold a larger fraction of wholesale funding than banks in competitive markets, shown in a blue line.

Figure 1: Deposit share and wholesale funding reliance



(a) Wholesale funding and deposit shares

(b) Wholesale funding share by HHI

Notes: Wholesale funding is the sum of repurchase agreements, time deposits, brokered deposits, foreign deposits, federal funds, and other borrowed funds. Retail deposits consist of checking, savings, and small-time deposits. Wholesale funding reliance (WFR) is defined as wholesale funding over retail deposits. Figure 1b shows wholesale funding share in concentrated (high HHI) and competitive markets (low HHI).

To assess the relative importance of the market power and wholesale funding reliance channels, I estimate how the transmission of monetary policy shocks to mortgage rates is affected by both banks' local market concentration in deposits, measured by the Herfindahl-Hirschman Index (HHI), and its reliance on wholesale funding. My empirical identification comes from variation both across banks within each MSA and over time. I find that when the policy interest rate increases by 100 basis points (bps) banks on average transmit 62 bps of this increase to mortgage rates. I then present new panel regression results: in response to an increase in the policy interest rate of +100 bps, banks in concentrated markets transmit 54 bps less, whereas banks with greater reliance on wholesale funding transmit 16 bps more. However, banks with greater reliance on wholesale funding in concentrated markets transmit 18 bps less.

The analysis shows that market concentration has a more significant effect on mortgage rates than wholesale funding reliance. However, the direction of the transmission to mortgage rates is altered by the interaction between these two factors. Specifically, the transmission of monetary policy shocks to mortgage rates increases for banks with greater reliance on wholesale funding in competitive markets, but it decreases for banks with greater reliance on wholesale funding in concentrated markets. These results suggest that wholesale funding is more costly for banks in competitive markets with enough deposit funding, but it partially alleviates deposit shortfalls and smooths the transmission of monetary policy shocks to mortgage rates in concentrated markets. Banks in concentrated markets borrow wholesale funding at higher rates than they offer on deposits because raising deposit rates on a larger pool of deposits is costlier than borrowing wholesale funding at the margin.

Motivated by this evidence, I develop a partial equilibrium model of heterogenous monetary policy pass-through to mortgage rates where banks are monopolistically competitive and have costly access to wholesale funding. Banks borrow wholesale funding and deposits to finance mortgages. When they need to access more liabilities, they face quadratic adjustment costs on wholesale funding that can be expensive when deposits are scarce. Banks face a quasi-kinked mortgage demand curve where a drop in their relative mortgage rate only stimulates a small increase in mortgage demand, while a rise in their relative mortgage rate generates a large fall in mortgage demand. This introduces strategic complementarity in mortgage rate setting which causes banks to adjust rates less to a given change in marginal cost. Monopolistic competition with quadratic adjustment cost generates imperfect pass-through, while the quasi-kinked mortgage demand curve produces asymmetric monetary policy transmission to mortgage rates.

The mechanism that generates imperfect pass-through of changes in the policy rate to mortgage rates relies on two key features: banks have market power in both deposit and mortgage markets and banks face quadratic costs on wholesale funding. When the central bank increases the policy rate, the cost of short-term funding increases. In response, banks exercise their market power in deposits by partially raising deposit rates, while the rate on wholesale funding increases fully. Two channels affect the aggregate transmission of monetary policy: *market power channel*: a higher concentration in deposit markets leads to a widening wedge between the central bank's policy rate and the commercial banks' mortgage and deposit rates; and *wholesale funding reliance channel*: banks in concentrated markets rely heavily on wholesale funding to mitigate the increased cost of funds by borrowing wholesale funding at the margin rather than increasing deposit rates on all of their deposit holdings. This shift increases banks' marginal cost of funds, which is then passed on to new mortgage rates.

The Great Financial Crisis motivated a significant reform in liquidity management where many banks faced severe liquidity shortages despite appearing solvent. I introduce liquidity regulation where the Basel III Liquidity Coverage Ratio (LCR) rule restricts excessive reliance on wholesale funding. Reliance on wholesale funding increases liquidity risks during times of market disruption because wholesale funding is susceptible to bank runs while bank assets including mortgages are typically illiquid and long-term. I find that banks with high market power that rely excessively on wholesale funding are affected the most by this regulation. During a monetary tightening, banks with high market power cannot borrow wholesale funding due to the LCR rule. As a result, banks switch to deposits by increasing their deposit rates. Lower funding reduces their new issuances of mortgages and amplifies the increase in mortgage rates relative to banks with low market power.

Related Literature This paper contributes to four strands of the literature on monetary policy transmission. First, I contribute by studying how the interaction between banking market concentration and reliance on wholesale funding affects monetary policy transmission to mortgage rates. While recent studies focus on bank market power and reliance on wholesale funding (Drechsler, Savov, and Schnabl (2017), Choi and Choi (2019), Scharfstein and Sunderam (2016), Wang, Whited, Wu, and Xiao (2022)), less attention has been paid to the interplay between market concentration and reliance on wholesale funding in the mortgage market. I follow Drechsler, Savov, and Schnabl (2017) and Choi and Choi (2019) in putting deposit concentration and wholesale funding, respectively, at the center stage, but I highlight a complementary mechanism: banks with a greater reliance on wholesale funding in concentrated markets transmit monetary shocks less relative to banks with a greater reliance on wholesale funding in competitive markets. Following a tightening in monetary policy, banks with market power over deposits optimally contract their deposit supply to earn a higher deposit spread (Drechsler, Savov, and Schnabl, 2017). As a result, banks borrow wholesale funding to replace retail deposits to meet their lending requirements and loans may contract if wholesale funding becomes costly (Choi and Choi, 2019). The interaction between wholesale funding reliance and market concentration in my paper is novel and important, suggesting a scope for heterogeneous monetary policy transmission to mortgage rates.

Second, I contribute to the literature on the impact of reserve requirements on bank lending behavior, examining whether this impact is stronger for banks with less liquid balance sheets (Bernanke and Blinder, 1988, 1992; Kashyap and Stein, 1995b). They propose that banks with larger reserves can buffer their lending activity against external finance shocks by drawing on their stock of liquid assets, and their study finds strong evidence of such an effect on small banks. In this paper, I conduct an analogous exercise but focus on analyzing market concentration and the composition of funding rather than bank size, and assess the impact on mortgage rates. These studies, which rely on aggregate data and vector autoregression, have produced ambiguous results partly due to a high level of aggregation. To overcome this limitation, I use micro-data on bank rates, which allows me to highlight market power and wholesale funding reliance channels via the banking sector and to capture the effects of a monetary policy transmission mechanism.

Third, I contribute to the industrial organization literature that documents price dispersion in mortgage markets. Benetton (2021) finds larger banks charge higher loan markups in the UK mortgage market. Allen et al. (2014a,b, 2019) explore that banks charge differentials in mortgage rates due to negotiated-price markets and search frictions. Gödl-Hanisch (2022) finds mortgage rates dispersion within banks and locations in the US. Institutions set prices strategically across locations depending on their local market share and costs to originate loans vary across locations, explaining differences across branches of the same institution. I document dispersion in monetary policy transmission to mortgage rates.

Fourth, I contribute to the literature on how banks' balance sheets can affect monetary policy transmission and aggregate consequences of bank market power. Several studies analyze market power in deposit and credit markets using a macro-banking framework that incorporates stochastic deposit withdrawal shocks, wholesale funding markets, and heterogeneous banking features (Bianchi and Bigio, 2022; Gertler et al., 2016; Jamilov and Monacelli, 2021; Jamilov, 2021; Bellifemine et al., 2022; Gödl-Hanisch, 2022). I contribute to this literature by building a partial equilibrium banking model with market power in deposits and mortgages, a quasi-kinked mortgage demand curve, and costly access to wholesale funding to generate asymmetric imperfect monetary policy transmission to mortgage rates.

Outline The paper is organized as follows. In Section the 2, I describe data. In Section 3, I use the loan- and bank-level data to document heterogeneous monetary policy transmission to mortgage rates. Section 4 describes the partial equilibrium model with a monopolistic banking sector. Section 5 investigates monetary policy transmission to mortgage rates under the Basel III liquidity coverage ratio rule. Section 6 concludes.

2 Data Description

I employ four different datasets: (i) loan-level mortgage rates from Fannie Mae and Freddie Mac, (ii) deposit from the Summary of Deposit to construct market concentration, (iii) wholesale funding reliance from the Call Report, and (iv) monetary policy shocks from Bauer and Swanson (2023). My dataset runs from the first quarter of 2000 to the fourth quarter of 2019. The unit of observation is at the quarter-MSA-bank level.

2.1 Monetary shocks

I use unanticipated monetary shocks from Bauer and Swanson (2023). This dataset contains the changes in financial variables in a 30-minute window around FOMC announcements (from 10 minutes before to 20 minutes after the announcement). Monetary policy surprises focus on interest rate changes in a narrow window of time around FOMC announcements to rule out reverse causality and other endogeneity problems including the FOMC could not have been reacting to changes in financial markets in a sufficiently narrow window of time around the announcement.

2.2 Fannie Mae and Freddie Mac

Loan-level mortgage rates are obtained from publicly available Fannie Mae's Single-Family Loan Performance Data and Freddie Mac's Single-Family Loan-Level Dataset. The sample files are created by selecting a simple random sample that is representative of the population of 30-year, fully amortizing, full documentation, single-family, conventional fixed-rate mortgages acquired by the government-sponsored enterprise (GSEs). The datasets include borrower and loan information at the time of origination and performance of the loan. The origination data includes the borrower's credit (FICO) score, the date of origination, the loan size, the loan size relative to the house value (LTV ratio), whether the loan is originated for purchase or refinancing, the MSA code of the property, and the interest rate on the mortgage.

I pool data from the Fannie Mae and Freddie Mac data sets because the combination of these two datasets covers the majority of conforming loans issued in the US. I include loans associated with both new-purchase mortgages and refinancings. The advantage of Fannie Mae and Freddie Mac datasets is that they identify lenders, thus making it easier to merge with bank balance sheet data. It provides information for the largest 27 commercial banks and excludes investment banks such as Goldman Sachs or Morgan Stanley.

2.3 Summary of Deposit

Deposit information is collected from the Summary of Deposit (SOD) data provided by the Federal Deposit Insurance Corporation (FDIC). The SOD dataset is updated on June 30th of each year and covers all depository institutions insured by the FDIC. The dataset includes branch level information on deposits, location, and bank affiliation. Based on the MSA identifier of each branch, I construct total deposits for each bank in each MSA.

I calculate the local HHI from the Summary of Deposits. I use deposit market concentration for my empirical analysis because deposit and mortgage market concentrations are highly correlated and market power comes from holding deposits. I use the Herfindahl-Hirschman Index (HHI) to measure market concentration by summing deposit market shares squared:

$$\text{HHI}_{mt} = \sum_{b\in\{m\}} \Big(\frac{dep_{bmt}}{\sum_{b\in\{m\}} dep_{bmt}}\Big)^2$$

where dep_{bmt} is deposit of bank b in MSA m in year t, $\sum_{b\in\{m\}} dep_{bmt}$ is total deposit in MSA m in year t, and HHI_{mt} is the sum of squared deposit market shares of all banks b that operate in a given MSA m in a given quarter t. I combine the SOD and mortgage rate datasets using the bank and MSA identifiers. I calculate HHI before merging it with the mortgage rates dataset to capture market concentration from the universe of all US banks. A lower HHI indicates a competitive market, while a higher HHI indicates a concentrated market.

2.4 Call Reports

I obtain bank-level characteristics including liquid assets, repricing maturity, real estate loans, commercial and industrial loans, and number of branches from the Federal Reserve Board's Report on Condition and Income (Call Reports).

Wholesale funding reliance is defined as the ratio of wholesale funding over retail deposits $\text{WFR}_{bt} = \frac{\text{wholesale funding}}{\text{retail deposits}}$ for bank b in quarter t. Wholesale funding is the sum of repurchase agreements, time deposits, brokered deposits, foreign deposits, federal funds, and other borrowed funds. Retail deposits consist of checking, savings, and small-time deposits. Retail deposits that are used to construct wholesale funding reliance are aggregated at the bank level from the Call Reports as opposed to disaggregated deposits that are used to construct market concentration. Wholesale funding is easier to access given its unlimited supply of funds (Huang and Ratnovski (2011)), but reliance on wholesale funding increases liquidity risks during market disruption. In contrast, retail deposits are limited by savers' supply of deposits.

2.5 Home Mortgage Disclosure Act (HMDA)

Mortgage origination comes from the HMDA which covers about 90 percent of the mortgage applications and approved loans in the US. The data provides the loan amount, loan type and purpose, property location, and some borrower characteristics, such as gender, race, and income. The data set contains the originator's identity, which allows for linking with the mortgage rate information present in the Fannie Mae and Freddie Mac. The HMDA also records whether the loan is retained on the originator's balance sheet or sold within the origination year to a third party such as government-sponsored enterprises or private-label securitization identity. I restrict the sample to home mortgages for 30-year fixed mortgages from single-family homes, which corresponds to the majority of the applications.

For robustness, I measure market concentration using the Home Mortgage Disclosure Act (HMDA) for the mortgage market. Figure 4 in Appendix A.1 shows the distribution of HHI in the mortgage and deposit markets. Mortgage market concentration in HMDA has a mean of 0.17 and a standard deviation of 0.15. Deposit market concentration in SOD has a mean of 0.28 and a standard deviation of 0.22. I do not use these datasets as they are annual surveys, while other datasets are at the quarterly level.

2.6 Summary Statistics

My working sample includes micro-level data for the 27 largest banks in the US, with assets over $1 billion. Based on a unique bank-MSA-quarter identifier, I construct panel data for each bank in each MSA and quarter. For example, in a given quarter, the identifier for Bank of America in Philadelphia is different from that of Bank of America in New York, as Philadelphia mortgagors are not taking out their mortgage loans from New York. I construct a panel-level dataset at the bank level by weighting the loan-level interest rates with loan volume. Table 1 presents summary statistics from my working sample. My dataset consists of banks with an average mortgage rate of 5.24%. Borrowers have an average credit score of 737 and an average loan-to-value ratio (LTV) of 73%. Bank funding is composed of 59% retail deposits and 37% wholesale funding. The average HHI is 0.54 with a standard deviation of 0.37. Mortgage loans are 55% of all loans and 40% of assets.

Table 1: Summary statistics

Variable	Mean	Std. Dev.	P25	P50	P75
Mortgage rates	5.24	1.25	4.25	5	6.13
Wholesale funding/retail deposit	1.17	2.01	.41	.68	1.42
HHI	.54	.37	.21	.47	.7
MBS/asset	.09	.08	0	.08	.13
Credit score	737.39	54.48	701	747	782
LTV	73.29	17.93	65	78	80
Mortgage loans/asset	.4	.31	.25	.36	.49
Commercial and industrial loans/asset	.14	.13	.05	.11	.17
Equity/asset	.1	.05	.08	.1	.12
Number of branch	49122	161025	2	4992	26659

Summary statistics are based on the Consolidated Reports of Condition and Income (Call Reports) from 2000Q1 to 2019Q4 for US banks with size greater than $1B. All variables are quarterly. Wholesale funding includes brokered deposits, federal funds purchased, deposits held in foreign offices, time deposits, and other borrowed funds. The interest rate liability is the ratio of total interest expenses to total liability.

3 Empirical Approach

In this section, I first discuss my empirical strategy and then discuss results. I find that banks in concentrated markets transmit 54 bps less than banks in competitive markets in response to a contractionary monetary policy shock. Banks with greater reliance on wholesale funding transmit monetary policy by 21 bps more than banks with less reliance on wholesale funding. Lastly, banks with greater reliance on wholesale funding in concentrated markets transmit monetary policy by 18 bps less than banks in competitive markets.

3.1 Identification

Empirical identification comes from the variation across banks after controlling for the MSA and the interaction between bank and MSA fixed effects. Deposits can be transferred across MSAs within a bank, whereas mortgage loans are location-specific. I incorporate MSA fixed effects to control for time-invariant geographical differences such as mortgage rate trends across MSAs. I also use bank fixed effects to control supply and time-invariant differences between banks. Then I test the interaction between bank and MSA fixed effects to control for macroeconomic conditions that affect banking decisions in different locations. I use exogenous unanticipated monetary policy shocks to analyze the transmission of monetary shocks to changes in mortgage rates for banks in concentrated markets. I cluster standard errors at the bank level for correlation within banks.

3.2 Heterogeneity in Monetary Policy Transmission

I estimate whether the composition of bank funding and local market concentration affect the transmission of monetary policy shocks:

$$\begin{aligned}\Delta r_{mbt} = \alpha_b + \alpha_m + \beta_1 \Delta i_t + \beta_2 WFR_{bt-1} + \beta_3 HHI_{mt-1} + \beta_4 WFR_{bt-1} \times HHI_{mt-1} \\ + \beta_5 WFR_{bt-1} \times \Delta i_t + \beta_6 \Delta i_t \times HHI_{mt-1} + \beta_7 WFR_{bt-1} \times HHI_{mt-1} \times \Delta i_t \\ + \Gamma \text{HH Controls}_{bmt-1} + X \text{Bank Controls}_{bmt-1} + \Phi \text{Bank Controls}_{bmt-1} \times \Delta i_t + \epsilon_{mbt}\end{aligned} \quad (1)$$

where Δr_{mbt} is changes in loan-level mortgage rate at MSA m by bank b at quarter t, α_b is bank fixed effect, α_m is MSA fixed effect, and Δr_{mbt} is the change in the mortgage rate for bank b in MSA m at quarter t. The term Δi_t is the monetary shock from Bauer and Swanson (2023) normalized to have a +100 bps impact. The term WFR_{bt-1} is the wholesale funding reliance for bank b at quarter $t-1$, and HHI_{mt-1} is the local deposit concentration in MSA m at quarter $t-1$. The term HH Controls$_{bmt-1}$ includes the credit score, LTV ratio, and debt to income ratio; BankControls$_{bmt-1}$ includes the number of branches, liquidity asset ratio, duration mismatch, liability interest rate, real estate loans ratio, commercial and industrial loans ratio, equity to asset ratio, and mortgage-backed securities (MBS) to assets ratio.

I use the number of branches to control for bank size because interest rate pass-through to mortgage rates may fall with bank size. I include a liquid asset ratio to control for the liquidity of a bank's assets. I use data on repricing maturity from the US Call Reports to proxy for the duration because it distinguishes between long-term fixed-rate assets and short-term floating-rate assets. I control for equity to asset ratio to capture differences in bank capital. The liability interest rate is the ratio of total interest expenses to total liability, capturing a difference in funding costs across banks. The real estate loan ratio is the fraction of real estate loans to total loans, and the commercial and industrial loans ratio is the fraction of commercial and industrial loans to total loans, which controls for differences in bank business models. I include the MBS to asset ratio to control for a bank's ability to securitize mortgages.

We can see that banks operating in concentrated markets increase their mortgage rates by 54 bps less than those in competitive markets when the policy rate increases by 100 bps. This is because banks in concentrated markets are trying to offset the negative impact of a fall in loan demand (Scharfstein and Sunderam (2016), Wang, Whited, Wu, and Xiao (2022)). On the other hand, banks that rely more heavily on wholesale funding tend to increase their mortgage rates by 16 bps more than banks with lower reliance on wholesale funding in response to the same increase in the policy rate. Even though wholesale funding is more expensive (Choi and Choi (2019)), it helps stabilize loan supply shocks in concentrated markets. Interestingly, the triple interaction term reveals a negative effect of 18 bps on the mortgage rate. Banks with greater reliance on wholesale funding in concentrated markets have smaller rate pass-through.

Table 2: Heterogeneous Monetary Policy Transmission

	(1)	(2)	(3)	(4)
			Δr_{mbt}	
Δi_t	62.46***	60.33***	67.58***	67.10***
	(0.338)	(0.338)	(0.351)	(0.350)
HHI_{mt-1}	0.791***	0.752***	-0.623***	-0.527**
	(0.0137)	(0.0138)	(0.0228)	(0.0228)
WFR_{bt-1}	-0.0670	-0.00536	0.0693	0.0412
	(0.00434)	(0.00437)	(0.00624)	(0.00623)
$HHI_{mt-1} \times WFR_{bt-1}$	0.00573	-0.0419	-0.106*	-0.0787
	(0.00415)	(0.00418)	(0.00616)	(0.00614)
$\Delta i_t \times WFR_{bt-1}$	16.92***	16.74***	17.98***	17.84***
	(0.0943)	(0.0942)	(0.0954)	(0.0951)
$\Delta i_t \times HHI_{mt-1}$	-53.84***	-51.66***	-63.51***	-63.12***
	(0.364)	(0.364)	(0.379)	(0.377)
$\Delta i_t \times HHI_{mt-1} \times WFR_{bt-1}$	-18.15***	-18.00***	-18.55***	-18.39***
	(0.0985)	(0.0984)	(0.0990)	(0.0987)
Bank FE	No	No	Yes	Yes
MSA FE	No	Yes	No	Yes
Controls	Yes	Yes	Yes	Yes
R^2	0.018	0.030	0.086	0.099
F	90.28	92.69	101.6	98.91
N	70037	70035	70036	70034

Notes: Results from estimating

$$\begin{aligned}\Delta r_{mbt} = \alpha_b + \alpha_m + \beta_1 \Delta i_t + \beta_2 WFR_{bt-1} + \beta_3 HHI_{mt-1} + \beta_4 WFR_{bt-1} \times HHI_{mt-1} \\ + \beta_5 WFR_{bt-1} \times \Delta i_t + \beta_6 \Delta i_t \times HHI_{mt-1} + \beta_7 WFR_{bt-1} \times HHI_{mt-1} \times \Delta i_t \\ + \Gamma \text{HH Controls}_{bmt-1} + X \text{Bank Controls}_{bmt-1} + \epsilon_{mbt}\end{aligned}$$

where Δr_{mbt} is changes in a loan-level mortgage rate at MSA m by bank b at quarter t, α_b is bank fixed effects, α_m is MSA fixed effects, WFR_{bt-1} is wholesale funding reliance, HHI_{mt-1} is the HHI in the deposit market, Δi_t is a +100 bps monetary policy shock, HH controls include borrower's credit score, LTV, and debt to income ratio, and bank controls include the number of branches, liquidity asset ratio, duration mismatch, equity asset ratio, liability interest rate, real estate loans ratio, commercial and industrial loans ratio, and MBS-to-asset ratio. Standard errors are clustered at the bank level. $*p < 0.1, **p < 0.05, ***p < 0.01$.

When monetary policy tightens, banks in concentrated markets face deposit outflows due to partial pass-through to deposit rates and become more dependent on wholesale funding. However, reliance on wholesale funding enables these banks to maintain lending stability, which results in a lower transmission rate compared to banks in competitive markets that do not observe deposit outflow due to perfect transmission of monetary policy to deposit rates (Drechsler, Savov, and Schnabl (2017)).

3.2.1 Total Effect

To interpret Table 2, I plug in different percentiles of market concentration and wholesale funding reliance. The main variable of interest is the total effect of the response of changes in mortgage rates to changes in monetary policy shocks:

$$\frac{\partial \Delta r_{mbt}}{\partial \Delta i_t} = (\beta_1 + \beta_5 WFR_{bt-1} + \beta_6 HHI_{mt-1} + \beta_7 WFR_{bt-1} \times HHI_{mt-1}),$$

which is the sum of the coefficients that interact with monetary policy surprises Δi_t from (1). This empirical design allows us to test how the transmission of monetary shocks to mortgage rates changes for banks with a greater reliance on wholesale funding in concentrated markets.

The coefficient magnitudes of market concentration (β_6) are bigger than the coefficient magnitudes of wholesale funding (β_5) and the triple interaction term (β_7). Reading Table 3 from top to bottom, monetary policy transmission to mortgage rates falls as the market becomes more concentrated because banks are reducing markups to mitigate the impact of contractionary monetary policy transmission on loan demand. I find that the difference in pass-through between low-concentration vs high-concentration banks is 24 bps when the policy rate increases by 100 bps. Even though market concentration (β_6) has a larger effect than wholesale funding (β_5) and the triple interaction term (β_7), the direction of monetary policy transmission switches when we read Table 3 from left to right. In addition, the total effect of wholesale funding reliance is as large as the total effect of market concentration on pass-through to mortgage rates. The difference in pass-through between banks with fewer reliance on wholesale funding vs greater reliance on wholesale funding is 24 bps, similarly, the difference in pass-through between banks in competitive vs concentrated markets is 24 bps when the policy rate increases by 100 bps. Monetary policy transmission *rises* as banks rely more heavily on wholesale funding in competitive markets because wholesale funding is an expensive form of funding. Banks in competitive markets have enough deposits to issue loans and they transmit additional costs of borrowing wholesale funding to mortgage rates. However, monetary policy transmission to mortgage rates *falls* for banks in concentrated markets as they rely more on wholesale funding. Banks in concentrated markets observe deposit outflow due to partial pass-through to deposit rates. To mitigate the impact of a deposit outflow on mortgages, banks borrow wholesale funding.

It is important to note that although market concentration has a larger effect than wholesale funding and the triple interaction term, the direction of monetary policy transmission changes depending on the market structure. I find that monetary policy is more powerful when banks have greater reliance on wholesale funding in a competitive market. These findings suggest that there is a scope for heterogeneous monetary policy transmission to mortgage rates and policymakers need to consider the interaction between market concentration and wholesale funding reliance when designing and implementing monetary policy tools to stimulate the economy.

Table 3: Heterogeneous Monetary Policy Transmission in Percentiles (new)

	Wholesale funding reliance					
Market Concentration	P10	P25	P50	P75	P90	P90-P10
P10	0.617	0.631	0.67	0.77	0.83	0.21
P25	0.546	0.558	0.592	0.682	0.728	0.18
P50	0.376	0.384	0.402	0.454	0.481	0.105
P75	0.259	0.263	0.272	0.297	0.310	0.051
P90	0.084	0.081	0.076	0.0616	0.054	-0.03
P90-P10	-0.533	-0.55	-0.594	-0.7084	-0.776	

Notes: To understand the transmission of increase of a +100 bps shock in monetary policy on mortgage rates, I plug in different percentiles of market concentration and wholesale funding reliance into $\beta_1 + \beta_5 WFR_{bmt} + \beta_6 HHI_{mt} + \beta_7 WFR_{bmt} \times HHI_{mt}$.

3.3 Regression demeaned variables

I use regression demeaned variables to minimize the risk of estimated interaction terms spuriously capturing other features of the data. I estimate whether the composition of bank funding and local market concentration affect the transmission of monetary policy shocks:

$$\begin{aligned} \Delta r_{mbt} = \alpha_m + \beta_1 \Delta i_t + \beta_2 WFR_{bt-1} + \beta_3 HHI_{mt-1} + \\ \beta_4 (WFR_{bt-1} - \overline{WFR}) \times (HHI_{mt-1} - \overline{HHI}) + \beta_5 \Delta i_t \times (WFR_{bt-1} - \overline{WFR}) + \\ \beta_6 \Delta i_t \times (HHI_{mt-1} - \overline{HHI}) + \beta_7 \Delta i_t \times (WFR_{bt-1} - \overline{WFR}) \times (HHI_{mt-1} - \overline{HHI}) \\ + \Gamma \text{HH Controls}_{bmt-1} + X \text{Bank Controls}_{bmt-1} + \epsilon_{mbt} \end{aligned} \tag{2}$$

where Δr_{mbt} is changes in loan-level mortgage rate at MSA m by bank b at quarter t, α_m is MSA fixed effects, and Δr_{mbt} is the change in the mortgage rate for bank b in MSA m at quarter t. The term Δi_t is the monetary shock from Bauer and Swanson (2023) normalized to have a +100 bps impact. The term WFR_{bt-1} is the wholesale funding reliance for bank b at quarter $t-1$, $\overline{WFR}$ is the average level of wholesale funding reliance, HHI_{mt-1} is the local deposit concentration in MSA m at quarter $t-1$, and $\overline{HHI}$ is the average level of local deposit concentration. The term HH Controls$_{bmt-1}$ includes the credit score, LTV, and debt to income ratio; BankControls$_{bmt-1}$ includes the number of branches, liquid asset ratio, liability interest rate, real estate loans ratio, commercial and industrial loans ratio, equity asset ratio, and mortgage-backed securities (MBS) to assets ratio.

I demean market concentration and wholesale funding reliance in the regression. This ensures that the un-interacted market concentration and wholesale funding therefore correspond to estimates of the responses for an average mortgage rate. The results are one magnitude smaller than the main regression without demeaned variables. Banks that rely more heavily on wholesale funding tend to increase their mortgage rates by 1.1 bps in response to the same increase in the policy rate shown in Table 4. The triple interaction term reveals a negative effect of 3 bps on the mortgage rate. Banks with greater reliance on wholesale funding in concentrated markets have smaller rate pass-through. However, banks in concentrated deposit markets tend to increase their mortgage rates by 10 bps more than those in competitive markets when the policy rate increases by 100 bps.

Banks operating in concentrated deposit markets cannot further increase their competitiveness to attract more deposits from competitors by raising deposit rates further because they already control the market and they do not need to worry that keeping deposit rates constant despite higher monetary policy rates would lead to large deposit outflows to competitors, since no competitors are trying to steal the deposit base in concentrated markets. Thus, it is costly to raise deposits with higher deposit rates because it would come from household savings and they cannot steal deposits from competitors. The benefit of raising deposit rates is low since the bank has market power, and depositors engage in very little switching (Kiser, 2003; Carbo-Valverde et al., 2011; Brunetti et al., 2016), i.e., are captive by their home banks. As a result, wholesale funding covers any fluctuations in lending or decrease in deposits.

Table 4: Heterogeneous Monetary Policy Transmission

	(1)	(2)
		Δr_{mbt}
Δi_t	-3.307***	-2.949***
	(0.229)	(0.232)
HHI_{mt-1}	0.0381	0.0369
	(0.0286)	(0.0289)
WFR_{bt-1}	0.0104*	-0.00855
	(0.00581)	(0.00710)
$(HHI_{mt-1} - \overline{HHI}) \times (WFR_{bt-1} - \overline{WFR})$	-0.0480***	-0.0211
	(0.0117)	(0.0138)
$\Delta i_t \times (WFR_{bt-1} - \overline{WFR})$	1.135***	1.206***
	(0.368)	(0.373)
$\Delta i_t \times (HHI_{mt-1} - \overline{HHI})$	10.40***	9.514***
	(0.602)	(0.608)
$\Delta i_t \times (HHI_{mt-1} - \overline{HHI}) \times (WFR_{bt-1} - \overline{WFR})$	-3.007***	-3.220***
	(0.935)	(0.947)
Bank FE	No	No
MSA FE	No	Yes
Controls	Yes	Yes
R^2	0.057	0.076
F	96.81	89.84
N	70037	70035

Notes: Results from estimating

$$\begin{aligned}\Delta r_{mbt} = \alpha_b + \alpha_m + \beta_1 \Delta i_t + \beta_2 WFR_{bt-1} + \beta_3 HHI_{mt-1} + \\ \beta_4 (WFR_{bt-1} - \overline{WFR}) \times (HHI_{mt-1} - \overline{HHI}) + \beta_5 (WFR_{bt-1} - \overline{WFR}) \times \Delta i_t + \\ \beta_6 \Delta i_t \times (HHI_{mt-1} - \overline{HHI}) + \beta_7 (WFR_{bt-1} - \overline{WFR}) \times (HHI_{mt-1} - \overline{HHI}) \times \Delta i_t \\ + \Gamma \text{HH Controls}_{bmt} + X \text{Bank Controls}_{bmt} + \epsilon_{mbt}\end{aligned}$$

where Δr_{mbt} is changes in loan-level mortgage rate at MSA m by bank b at quarter t, α_b is bank fixed effects, α_m is MSA fixed effects, and Δr_{mbt} is the change in the mortgage rate for bank b in MSA m at quarter t. The term Δi_t is the monetary shock from Bauer and Swanson (2023) normalized to have a +100 bps impact. The term WFR_{bt-1} is the wholesale funding reliance for bank b at quarter $t-1$, $\overline{WFR}$ is the average level of wholesale funding reliance, HHI_{mt-1} is the local deposit concentration in MSA m at quarter $t-1$, and $\overline{HHI}$ is the average level of local deposit concentration. The term HH Controls$_{bmt}$ includes the credit score, LTV and debt to income ratio; BankControls$_{bmt}$ includes the number of branches, liquid asset ratio, liability interest rate, real estate loans ratio, commercial and industrial loans ratio, equity asset ratio, and mortgage-backed securities (MBS) to assets ratio. $*p < 0.1, **p < 0.05, ***p < 0.01$.

3.4 Dynamics of mortgage rate and mortgage loans

I estimate quarterly local projection regressions to understand the role of wholesale funding and mortgage market concentration on mortgage volumes and mortgage rates following a contractionary monetary policy shock:

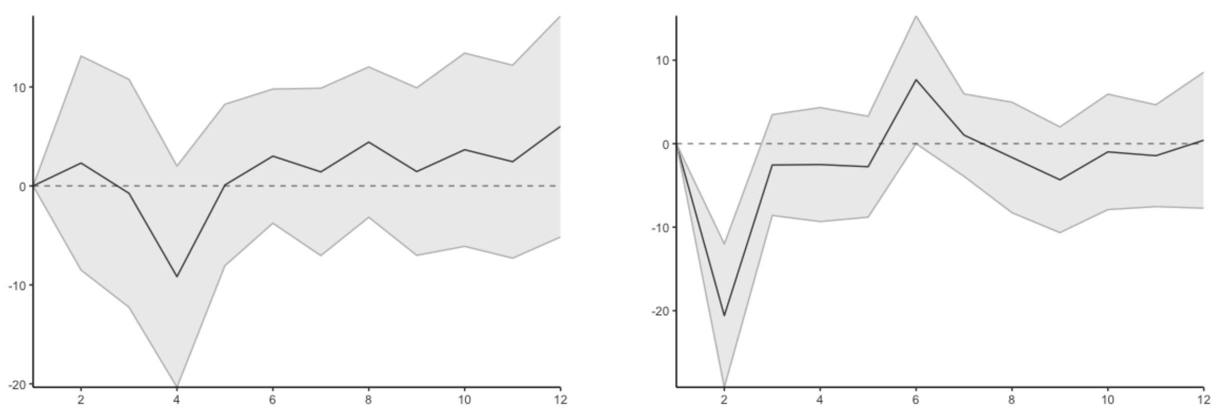
$$
\begin{aligned}
y_{b,t+h} - y_{b,t-1} = \alpha_{b,h} + \alpha_{m,h} + \beta_{1h}\Delta i_t + \beta_{2h} WFR_{bt-1} + \beta_{3h} HHI_{mt-1} + \beta_{4h} WFR_{bt-1} \times HHI_{mt-1} \\
+\beta_{5h} WFR_{bt-1} \times \Delta i_t + \beta_{6h}\Delta i_t \times HHI_{mt-1} + \beta_{7h} WFR_{bt-1} \times HHI_{mt-1} \times \Delta i_t \\
\gamma_h \text{controls}_{bmt-1} + \Phi_h \text{controls}_{bmt-1} \times \Delta i_t + \epsilon_{bmt+h}
\end{aligned}
\tag{3}
$$

Dependent variable y_b is the mortgage volume or mortgage rate, and Δ_t is monetary policy shock from Bauer and Swanson (2023). Other regressors include bank fixed effects $\alpha_{b,h}$ and MSA fixed effects $\alpha_{m,h}$ for each horizon. X_{bt-1} includes a set of bank and household characteristics mentioned previously in 3.2. I use lagged terms to mitigate concerns about reverse causality.

Figure 2 shows the full impulse responses for $h = 12$ representing the estimated response of the dependent variable to a monetary policy shock of +100 bps at quarter h after impact. The initial drop in mortgage rates encourages households to borrow more for the first two quarters. However, as mortgage rates begin to rise and continue to do so until the sixth quarter, the volume of mortgages starts to decrease, with this trend persisting until the fifth quarter.

Figure 2: Heterogenous monetary policy transmission

(a) Log(mortgage volume) (b) Δ mortgage rate



Notes: Results from estimating

$$
\begin{aligned}
y_{b,t+h} - y_{b,t-1} = \alpha_{b,h} + \alpha_{m,h} + \beta_{1h}\Delta i_t + \beta_{2h} WFR_{bt-1} + \beta_{3h} HHI_{mt-1} + \beta_{4h} WFR_{bt-1} \times HHI_{mt-1} \\
+\beta_{5h} WFR_{bt-1} \times \Delta i_t + \beta_{6h}\Delta i_t \times HHI_{mt-1} + \beta_{7h} WFR_{bt-1} \times HHI_{mt-1} \times \Delta i_t \\
\gamma_h \text{controls}_{bmt-1} + \Phi_h \text{controls}_{bmt-1} \times \Delta i_t + \epsilon_{bmt+h},
\end{aligned}
$$

where y_b is the mortgage volume or mortgage rate for bank b in MSA m for every quarter t, and Δ_t is monetary policy shock from Bauer and Swanson (2023) as described in Equation 3. I plot β_7 to show how each lender in highly concentrated markets with greater reliance on wholesale funding transmits monetary policy to mortgage rates. Results are shown in black solid lines with confidence intervals in the grey area.

3.5 Empirical Analysis Takeaway

After monetary policy tightening, there is a shortfall of deposits in concentrated markets (Drechsler, Savov, and Schnabl (2017)). It is costlier for banks in concentrated markets to raise deposit rates for all deposit holdings than to access wholesale funding to mitigate the shortfall in liabilities. Although the policy rate, which is the rate where banks borrow wholesale funding, is higher than deposit rates, banks are constrained in raising deposits due to a limited supply of deposits from households. When banks in concentrated markets observe deposit outflow, they access wholesale funding because it is cheaper at the margin.

The interaction between market concentration and reliance on wholesale funding plays an important role when driving the heterogeneities in monetary policy transmission. Banks operating in competitive markets and relying more heavily on wholesale funding exhibit greater transmission, while those operating in concentrated markets exhibit lower transmission to mitigate the negative impact on loan demand. Despite being a relatively expensive source of funding, wholesale funding effectively mitigates loan supply shocks in concentrated markets and facilitates smooth pass-through to mortgage rates. This empirical analysis informs policymakers that the effectiveness of monetary policy tools to stimulate the economy depends on the interaction effect between market concentration and reliance on wholesale funding.

Reliance on wholesale funding is an endogenous choice; therefore, a model that interlinks market concentration and reliance on wholesale funding is needed to quantify the importance of imperfect monetary policy transmission to mortgage rates. In my model, banks optimally choose between deposits and wholesale funding and exercise market power in both mortgage and deposit markets. Further rationalization of empirical findings will be in the modelling section.

4 Banking problem

This section contains a partial equilibrium model of the banking sector that illustrates how banks transmit the policy rate to the mortgage rate. The objects of interest in this section are the exogenous policy rate, and endogenous deposit and mortgage rates. The amount lent and the amount of deposits received by each bank are endogenous, but the aggregate amounts are exogenous. Before going into the banking problem, I describe the demand for deposit and mortgage markets. I then show how the interaction between market concentration and wholesale funding reliance replicates asymmetric imperfect monetary policy transmission to mortgage rates.

4.1 Deposit market

There are $j = 1, ..., n$ banks. Depositors want to maximize total repayment from deposits across all banks subject to total deposits as aggregated through a Dixit and Stiglitz (1977) aggregator:

$$\max_{D_j} \sum_{j=1}^{n} (1 + i_j^D) D_j$$

s.t

$$\sum_{j=1}^{n} \Upsilon\Big(\frac{D_j}{D}\Big) = 1$$

where $\Upsilon(\cdot)$ is an increasing, strictly concave function. When $\Upsilon(1) = 1$ all banks produce the same amount of deposit implying constant returns to scale. Dotsey and King (2005) and Levin et al. (2007) use the Kimball aggregator that takes the following form:

$$\Upsilon\Big(\frac{D_j}{D}\Big) = \frac{\omega}{1+\psi}\left[(1+\psi)\frac{D_j}{D} - \psi\right]^{\frac{1}{\omega}} - \frac{\omega}{1+\psi} + 1$$

where $\omega = \frac{\phi(1+\psi)}{1+\phi\psi}$ and $\phi = 1 + \theta^M$. Net markup, θ^M, is greater than equal to zero, gross markup, ϕ, is greater than equal to one, and the Kimball parameter, ψ, that controls the degree of complementarities in the bank's mortgage rate decisions is less than or equal to zero. When the Kimball parameter $\psi = 0$ is equal to zero, there is a linear relationship between relative demand and relative prices which is the constant elasticity of substitution. Constant elasticity of substitution is a special case of the Kimball aggregator. Banks face a quasi-kinked demand curve when the Kimball parameter, ψ, is less than zero.

The first order condition with respect to D_j yields deposit demand:

$$D_j = \frac{D}{1+\psi}\left[\psi + \Big(\frac{1+i_j^D}{1+i^D}\Big)^{\frac{\omega}{1-\omega}}\right] \tag{4}$$

where the aggregate deposit rate is

$$1 + i^D = \sum_{j=1}^{n}(1+i_j^D)\frac{D_j}{D}. \tag{5}$$

The elasticity of substitution for deposits across banks, θ^D, is less than -1 which means that savers put more deposits in a particular bank the higher that bank's deposit rate is.

4.2 Mortgage market

The elasticity of demand depends upon the bank's relative sales. It is easier to lose customers by increasing its relative mortgage rate than to gain customers by lowering its relative mortgage rate. Borrowers minimize the total mortgage payment:

$$\min_{M_j} \sum_{j=1}^{n}(1+i_j^M)M_j$$

s.t

$$\sum_{j=1}^{n} \Upsilon\Big(\frac{M_j}{M}\Big) = 1$$

where $\Upsilon(\cdot)$ is an increasing, strictly concave function. When $\Upsilon(1) = 1$ all banks produce the same amount of mortgage loans implying constant returns to scale. Dotsey and King (2005) and Levin et al. (2007) use the Kimball aggregator that takes the following form:

$$\Upsilon\Big(\frac{M_j}{M}\Big) = \frac{\omega}{1+\psi}\left[(1+\psi)\frac{M_j}{M} - \psi\right]^{\frac{1}{\omega}} - \frac{\omega}{1+\psi} + 1$$

where $\omega = \frac{\phi(1+\psi)}{1+\phi\psi}$ and $\phi = 1 + \theta^M$. Net markup, θ^M, is greater than equal to zero, gross markup, ϕ, is greater than equal to one, and the Kimball parameter, ψ, that controls the degree of complementarities in the bank's mortgage rate decisions is less than or equal to zero. Banks face a quasi-kinked demand curve when the Kimball parameter, ψ, is less than zero. A drop in its relative mortgage rate only stimulates a small increase in mortgage demand, whereas a rise in its relative mortgage rate generates a large fall in mortgage demand. This introduces strategic complementarity in mortgage rate setting which causes banks to adjust mortgage rates less to a given change in marginal cost.

The first order condition gives mortgage demand that takes the following equation:

$$M_j = \frac{M}{1+\psi}\left[\psi + \Big(\frac{1+i_j^M}{1+i^M}\Big)^{\frac{\omega}{1-\omega}}\right] \tag{6}$$

where the aggregate mortgage rate can be rewritten as:

$$1 + i^M = \sum_{j=1}^{n}(1+i_j^M)\frac{M_j}{M}. \tag{7}$$

4.3 Banking problem: wholesale funding reliance

Banks face downward-sloping loan demand and an upward-sloping deposit supply even though aggregate loan demand and deposit supply are constant. Banks choose the interest rate they charge on loans i_j^M, the amount they lend M_j, the interest rate they pay on deposits i_j^D, the amount of deposits they take D_j subject to balance sheet constraints. Their balance sheet constraints determine the amount of wholesale funding B_j where banks pay the policy rate i. Banks have market power over mortgages and deposits and are heterogeneous in their markups under the Kimball (1995) aggregator. Larger banks charge higher loan markups than smaller banks.

Banks are subject to the cost of deviating from a target level of deposit-to-wholesale funding ratio. To compensate for any deposit shortfalls, banks pay a quadratic cost parameterized by coefficient ϕ^B whenever the wholesale funding ratio deviates from the target value ν. The quadratic cost is motivated by the fact that regulators discourage high levels of wholesale funding reliance. If there was no quadratic cost, banks could always borrow wholesale funding at the policy rate. As a result, partial transmission to deposit rates would have no impact on banks borrowing wholesale funding (Jermann and Quadrini, 2012; Begenau, 2020; Wang et al., 2022). Thus, monopolistic competition and quadratic adjustment costs generate imperfect monetary policy pass-through to mortgage rates and deposit rates. In addition, the quasi-kinked demand curve from the Kimball aggregator in the mortgage market results in asymmetric monetary transmission to mortgage rates.

The maximization problem that the individual bank j faces is therefore the following:

$$\max_{M_j, D_j, i_j^M, i_j^D} (1+i_j^M)M_j - (1+i_j^D)D_j - \left[1 + i + \frac{\phi^B}{2}\Big(\frac{B_j}{D_j} - \nu\Big)^2\right]B_j \tag{8}$$

s.t balance sheet constraint where mortgages equal to the sum of deposits and wholesale funding:

$$M_j = D_j + B_j. \tag{9}$$

Banks have market power over mortgages and deposits:

$$M_j = \frac{M}{1+\psi}\left[\psi + \Big(\frac{1+i_j^M}{1+i^M}\Big)^{\frac{\omega}{1-\omega}}\right], \tag{10}$$

$$D_j = \frac{D}{1+\psi}\left[\psi + \Big(\frac{1+i_j^D}{1+i^D}\Big)^{\frac{\omega}{1-\omega}}\right] \tag{11}$$

where $\omega = \frac{\phi(1+\psi)}{1+\phi\psi}$ and gross markup $\phi = 1 + \theta^M$ consists of the elasticity of substitution for mortgages between banks θ^M, M is the aggregate mortgage in the economy, and i^M is the aggregate mortgage rate index. The term θ^D is the elasticity of substitution for deposits between banks, D is the aggregate deposit in the economy, and i^D is the aggregate deposit rate index.

After taking first order conditions with respect to deposits, the optimality condition for the deposit rate is

$$\begin{aligned}(1+i_j^D)\left[1 - \frac{\psi\theta^D}{1+(1+\theta^D)\psi}(1+i_j^D)^{\frac{(1+\theta^D)(1+\psi)}{\theta^D}}\right] = \\ \frac{(1+\theta^D)(1+\psi)}{1+(1+\theta^D)\psi}\left[\Big(1 + i - \frac{\phi^B}{2}\Big[\Big(\frac{B_j}{D_j}\Big)^2 - \nu^2\Big]\Big)\right].\end{aligned} \tag{12}$$

The deposit rate depends on the quadratic adjustment cost of accessing wholesale funding amplified by deposit markdown. Under the *market power channel*, a rise in markdown increases the transmission to deposit rates. The markdown depends on the supply elasticities of deposit θ^D where the lower the elasticity, the lower the markdown linking to a higher concentration. Under the *wholesale funding channel*, an increase in wholesale funding reliance decreases monetary policy transmission to deposit rates because banks shift towards wholesale funding and rely less on deposits. On the contrary, higher marginal cost increases transmission to deposit rates. Moreover, a decrease in quadratic cost parameterized by ϕ^B and an increase in the target value of wholesale funding reliance ν increase transmission to deposit rates.

After taking first order conditions with respect to mortgages, the optimality condition for mortgage rate is

$$
\begin{aligned}
(1+i_j^M)\left[1-\frac{\psi\theta^M}{1+(1+\theta^M)\psi}(1+i_j^M)^{\frac{(1+\theta^M)(1+\psi)}{\theta^M}}\right] = \\
\frac{(1+\theta^M)(1+\psi)}{1+(1+\theta^M)\psi}\left[1+i+\frac{\phi^B}{2}\Big(\frac{B_j}{D_j}-\nu\Big)^2-\phi^B\Big(\frac{B_j}{D_j}-\nu\Big)\frac{M_j}{D_j}\right].
\end{aligned}
\tag{13}
$$

Under the *market power channel*, there is an interaction between markup and the degree of complementarities in the bank's pricing decisions ψ generating variation in market power. The markup is a function of mortgage loan demand θ^M where the lower the elasticity, the higher the markup, and the higher the concentration. Under the *wholesale funding channel*, marginal costs include policy rate and how wholesale funding reliance deviates from the target value. The interaction between the elasticity of substitution θ^M and the quadratic adjustment cost of deviating from the wholesale funding target generates imperfect monetary policy transmission, while the interaction of markup and the degree of complementarities with the quadratic adjustment cost generates asymmetric mortgage rate response.

After substituting the optimality condition for the deposit rate into the optimality condition for the mortgage rate, I get a mortgage rate that depends on wholesale funding reliance and deposit market concentration:

$$
\begin{aligned}
(1+i_j^M)\left[1-\frac{\psi\theta^M}{1+(1+\theta^M)\psi}(1+i_j^M)^{\frac{(1+\theta^M)(1+\psi)}{\theta^M}}\right] = \\
\frac{(1+\theta^M)(1+\psi)}{1+(1+\theta^M)\psi}\left[1+i-\frac{\frac{\theta^D-1}{\theta^D}(1+i_j^D)-1-i}{\Big(\frac{B_j}{D_j}\Big)^2-\nu^2}\Big(\frac{B_j}{D_j}-\nu\Big)^2-\phi^B\Big(\frac{B_j}{D_j}-\nu\Big)\frac{M_j}{D_j}\right].
\end{aligned}
\tag{14}
$$

As shown in equation (14), marginal costs for mortgages vary across banks due to differences in deviation from the wholesale funding reliance target, deposit rate, deposit markdown, and mortgage markups. Demand elasticity falls when the relative mortgage rates of banks fall. At the margin, banks' abilities to increase their demand by cutting their mortgage rates is limited. Large mortgage rate cuts result in lower profits because demand rises slightly while revenues fall heavily. As a result, banks have little incentive to cut mortgage rates a lot. The incentive to cut mortgage rates becomes weaker the larger the fall in marginal cost since the lower relative mortgage rate of banks reduces the demand elasticity. There is an asymmetric mortgage rate response because banks change their mortgage rates less the lower the change in marginal cost, while they change their mortgage rates by more the larger the change in marginal cost.

4.4 Calibration

This section describes the calibration procedure. Time is quarterly. The calibrated parameter values are presented in Table 5. Parameters $(\theta^M, \theta^D, \phi^B)$ are specific to my model. I take half of the average non-interest expenditures excluding expenditures on-premises or rent per dollar of assets of banks in the Call Report from 2000Q1 to 2019Q4. I set $\nu = 0.435\%$ to match the average share of principal paid on existing loans. The wholesale funding adjustment cost ϕ_b is calculated from the no-arbitrage condition for deposits.

The values θ^M and θ^D are calibrated from the deposit and mortgage pricing equations for a given ν, ϕ^B, and distribution of wholesale funding reliance from the data. I use distributions of mortgage and deposit rates and wholesale funding share shown in Figure 3 to generate distributions of θ^M and θ^D.

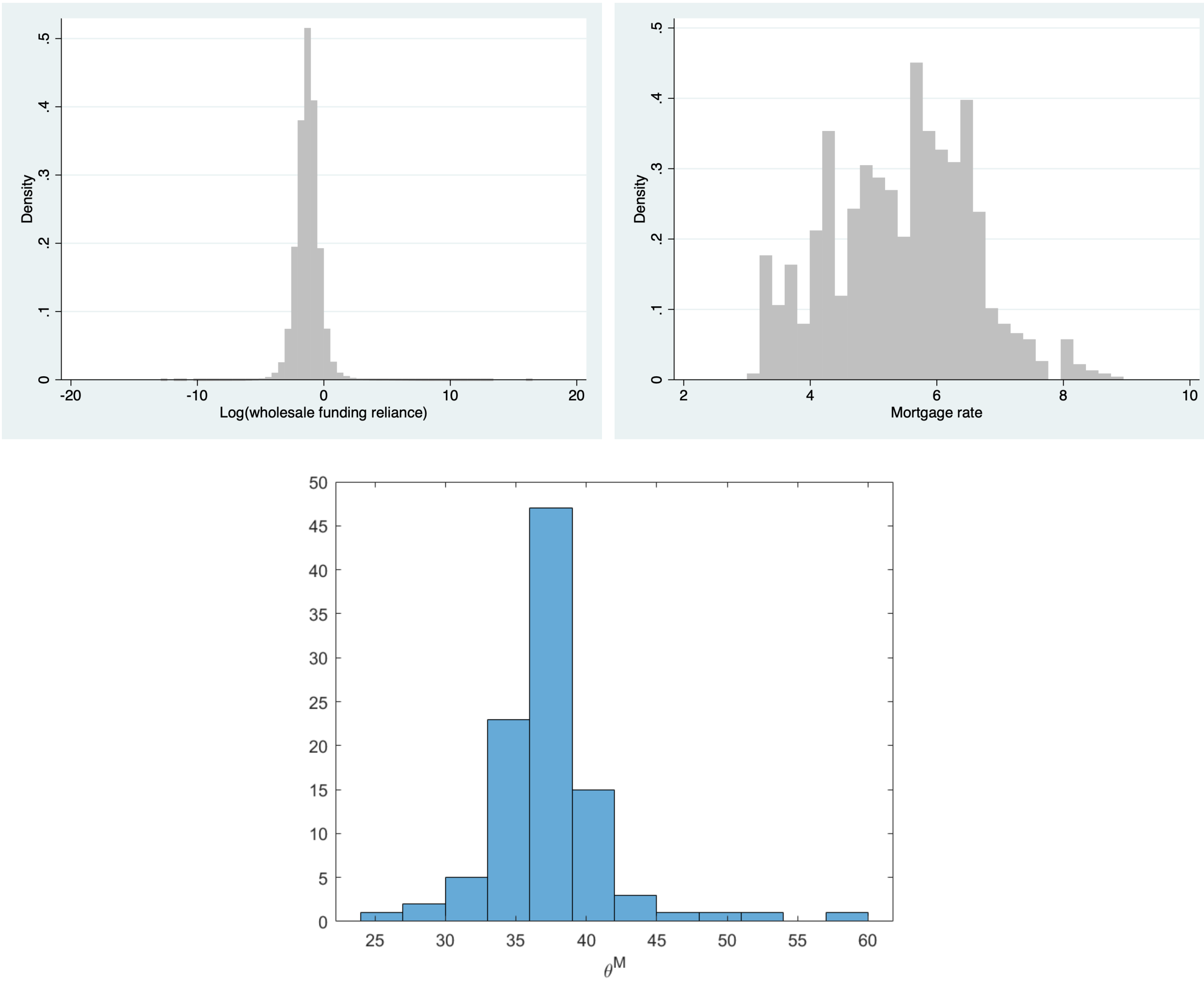
$$(1+i_j^D)\left[1-\frac{\psi\theta^D}{1+(1+\theta^D)\psi}(1+i_j^D)^{\frac{(1+\theta^D)(1+\psi)}{\theta^D}}\right]=$$
$$\frac{(1+\theta^D)(1+\psi)}{1+(1+\theta^D)\psi}\left[\left(1+i-\frac{\phi^B}{2}\left[\left(\frac{B_j}{D_j}\right)^2-\nu^2\right]\right)\right]$$

and

$$(1+i_j^M)\left[1-\frac{\psi\theta^M}{1+(1+\theta^M)\psi}(1+i_j^M)^{\frac{(1+\theta^M)(1+\psi)}{\theta^M}}\right]=$$
$$\frac{(1+\theta^M)(1+\psi)}{1+(1+\theta^M)\psi}\left[1+i+\frac{\phi^B}{2}\left(\frac{B_j}{D_j}-\nu\right)^2-\phi^B\left(\frac{B_j}{D_j}-\nu\right)\frac{M_j}{D_j}\right].$$

In the literature, Ulate (2019) uses θ^M of 203 for annual lending rate of 6% and θ^D of -268 for annual policy rate of 3%. Mark-up is measured by $\frac{\theta^M}{\theta^M-1}$. The cross-section of deposit markups ranges from 1.4 to 1.8, while credit markups range from 1.15 to 1.55 in Bellifemine, Jamilov, and Monacelli (2022).

Figure 3: Distribution of wholesale funding reliance and mortgage rates



Notes: This figure shows distribution of wholesale funding reliance and mortgage rates that are used to calibrate distribution of θ^M.

Two parameters α and γ are used for the counterfactuals section when analyzing the impact of liquidity regulation on wholesale funding. The Basel III LCR rule is defined as $\alpha D_j \leq \gamma S_j$ where α is greater than or equal to γ. The parameter, α, which captures deposit outflow is empirically estimated from Drechsler, Savov, and Schnabl (2017) where a 100 basis point increase in the Fed funds rate leads to a 0.86% lower deposit growth. The parameter, γ, measures how much securities to hold for every deposit outflow and is calibrated according to the Basel III LCR rule. The LCR requires that for every dollar of unused credit facility be backed with 10 cents of high quality liquid assets for nonfinancial firms and 40 cents for nonbank financial firms (Yankov, 2020). I take the average of these two values for calibration.

Table 5: Parameter Values

Parameter	Name	Value	Source
Degree of curvature of bank's demand curve	ψ	[0,-2,-4,-6]	Kimball (1995)
Mortgage amortization	ν	0.435%	Greenwald (2018)
EOS for mortgage	θ^M	35	Mortgage rate of 5.7%
EOS for deposit	θ^D	-34	Deposit rate of 0.028%
Wholesale funding cost	ϕ^B	0.00852	No arbitrage condition for deposits
Deposit outflow	α	0.8	Drechsler, Savov, and Schnabl (2017)
Securities to hold for every deposit outflow	γ	0.25	Yankov (2020)

Notes: This table shows the parameters that are used in the calibration.

4.5 Results

Table 6 shows that the model replicates empirical facts of asymmetric monetary transmission to mortgage rates that vary by market power and wholesale funding reliance. A quasi-kinked mortgage demand curve generates various market powers where banks pass through policy rates differently to mortgage rates. Low-market power banks transmit 85 bps while high-market power banks pass through around 30 bps to mortgage rates. Banks in concentrated markets decrease monetary policy transmission to mortgage rates from 50 to 30 bps as they rely more on wholesale funding. On the contrary, banks in competitive markets increase monetary policy transmission to mortgage rates from 85 bps to 110 bps as they rely more on wholesale funding.

Table 6: Monetary transmission to mortgage rates

	Wholesale funding reliance			
Market Concentration	P10	P50	P75	P90
P10	0.86	0.62	0.77	1.02
P50	0.77	0.74	0.81	0.89
P75	0.62	0.55	0.62	0.69
P90	0.41	0.26	0.31	0.36

Notes: This table depicts how monetary policy is transmitted to mortgage rates across market concentration and wholesale funding reliance. Kimball aggregator with quadratic adjustment costs on wholesale funding reliance captures empirical facts from Table 3.

Monetary policy transmission *rises* as banks rely more heavily on wholesale funding in competitive markets because wholesale funding is an expensive form of funding. Banks in competitive markets have enough deposits to issue loans and they transmit additional costs of borrowing wholesale funding to mortgage rates. However, monetary policy transmission to mortgage rates *falls* for banks in concentrated markets as they rely more on wholesale funding. Banks in concentrated markets observe deposit outflow due to partial pass-through to deposit rates. To mitigate the impact of a deposit outflow on mortgages banks borrow wholesale funding.

Banks with greater reliance on wholesale funding in concentrated markets have smaller rate pass-through. When monetary policy tightens, banks in concentrated markets face deposit outflows due to partial pass-through to deposit rates and become more dependent on wholesale funding. However, reliance on wholesale funding enables these banks to maintain lending stability, which results in a lower transmission rate compared to banks in competitive markets that do not observe deposit outflow due to perfect transmission of monetary policy to deposit rates (Drechsler, Savov, and Schnabl (2017)). It shows that the interaction between market power, a quasi-kinked mortgage demand curve, and quadratic wholesale funding cost would replicate asymmetric empirical facts.[1]

5 Counterfactuals

In this section, I study monetary policy transmission to mortgage rates under the Basel III Liquidity Coverage Ratio (LCR) rule. Banks transmit less to mortgage rates when the LCR rule is stricter because they hold a larger share of liquidity on their balance sheet. Even if central bankers can influence mortgage loan pricing, they have few tools to influence the distribution of debt in the economy. In contrast, macroprudential policymakers possess the ability to shape the distribution of debt through targeted policies aimed at lenders. My findings highlight a consequential interplay between monetary and macroprudential policies, suggesting a potential avenue for coordination among policy committees.

5.1 Basel III Liquidity Coverage Ratio

Reliance on wholesale funding increases liquidity risks during times of market disruptions. Basel III LCR introduced a new liquidity regulation to contain excessive reliance on wholesale funding in the banking sector. Liquidity requirements force banks to hold safe, liquid assets against deposits, limiting their liquidity transformation by restricting the asset side of their balance sheet. The Basel III LCR is defined as:

$$LCR = \frac{\text{High Quality Liquid Assets}}{\text{Cash Outflow}} \geq 1.$$

Bank chooses deposit rate i_j^D and mortgage rate i_j^M

$$\max_{M_j, D_j, i_j^M, i_j^D} (1 + i_j^M) M_j + (1 + i) S_j - (1 + i_j^D) D_j - \left[1 + i + \frac{\phi^B}{2}\left(\frac{B_j}{D_j} - \nu\right)^2\right] B_j \tag{15}$$

s.t balance sheet constraint, mortgage demand, deposit supply, and the Basel III LCR rule.

To study LCR, I introduce securities S_j. The balance sheet constraint now takes the following equation:

$$M_j + S_j = D_j + B_j. \tag{16}$$

The Basel III LCR rule is

$$\alpha D_j \leq \gamma S_j \tag{17}$$

[1] General equilibrium is interesting, however, partial equilibrium is tractable. Kimball vanishes everything out in general equilibrium (Jamilov, 2021). In the trade literature as well, Kimball is notorious for reversing frictions/results in general equilibrium (Boar and Midrigan, 2019; Errico and Lashkari, 2022; Edmond et al., 2023; Aruoba et al., 2024; Baqaee et al., 2020; Lisack et al., 2022).

where α measures deposit outflow and γ captures how much securities to hold for every deposit outflow.

The first order condition with respect to deposit rates is

$$1 + i_j^D = \frac{\theta^D}{\theta^D - 1}\left[1 + i - \left(1 - \frac{\alpha}{\gamma}\right)\frac{\phi^B}{2}\left[\left(\frac{B_j}{D_j}\right)^2 - \nu^2\right]\right]. \tag{18}$$

The LCR term $(1 - \frac{\alpha}{\gamma})$ amplifies the marginal cost leading to higher deposit rates. After stricter liquidity requirements, banks cannot borrow wholesale funding. The pass-through to deposit rates is higher because banks need to rely on deposits.

I substitute $\frac{\phi^B}{2}$ from the deposit rate into the mortgage rate equation:

$$(1 + i_j^M)\left[1 - \frac{\psi\theta^M}{1 + (1 + \theta^M)\psi}(1 + i_j^M)^{\frac{(1+\theta^M)(1+\psi)}{\theta^M}}\right] =$$

$$\frac{(1 + \theta^M)(1 + \psi)}{1 + (1 + \theta^M)\psi}\left[1 + i - \frac{\frac{\theta^D - 1}{\theta^D}(1 + i_j^D) - 1 - i}{\left(1 - \frac{\alpha}{\gamma}\right)\left[\left(\frac{B_j}{D_j}\right)^2 - \nu^2\right]}\left(\frac{B_j}{D_j} - \nu\right)^2 - \phi^B\left(\frac{B_j}{D_j} - \nu\right)\frac{M_j}{D_j}\right]. \tag{19}$$

Banks that rely heavily on wholesale funding are more affected by the Basel III LCR rule. Table 7 shows that banks with higher market power engage in wholesale funding substitution more during monetary tightening, but because of the Basel III regulation, they would need to rely on retail deposits. Their lending is more affected by monetary tightening, and thus mortgage rates are amplified by the new regulatory constraint. Monetary policy transmission to mortgage rate falls when banks hold fewer securities on their balance sheet and observe more deposit outflow.

Table 7: Basel III Liquidity Coverage Ratio

	Wholesale funding reliance			
Market Concentration	P10	P50	P75	P90
P10	0.263	0.19	0.237	0.284
P50	0.326	0.327	0.39	0.472
P75	0.371	0.399	0.48	0.561
P90	0.399	0.441	0.527	0.612

Notes: This table depicts how monetary policy is transmitted to mortgage rates across market concentration and wholesale funding reliance under Basel III Liquidity Coverage Ratio.

I then analyze stricter LCR requirements by increasing the fraction of securities to hold to replicate stricter Basel III LCR requirements in Table 8. Under stricter liquidity requirements, monetary policy transmission to mortgage rates is dampened. By requiring banks to hold more securities for every deposit outflow, banks are more liquid in issuing mortgages.

Table 8: Stricter Basel III LCR

	Wholesale funding reliance			
Market Concentration	P10	P50	P75	P90
P10	0.221	0.16	0.215	0.262
P50	0.242	0.262	0.335	0.408
P75	0.257	0.302	0.384	0.465
P90	0.266	0.324	0.41	0.496

Notes: Notes: This table depicts how monetary policy is transmitted to mortgage rates across market concentration and wholesale funding reliance under Basel III LCR. I analyze monetary policy transmission to mortgage rates with stricter LCR requirements by increasing the fraction of securities to hold γ.

6 Conclusion

My paper studies the quantitative importance of bank market power and wholesale funding reliance for monetary policy transmission to mortgage rates. I contribute to the literature by empirically documenting that monetary policy transmission to mortgage rates varies across bank market concentration and wholesale funding. To further explore these findings, I build a partial equilibrium model with a quasi-kinked mortgage demand curve and monopolistically competitive banks that have costly access to wholesale funding. My model replicates the asymmetric and imperfect pass-through to mortgage rates.

Using bank- and loan-level datasets, I find that, in response to a 100 bps increase in the policy rate, banks in concentrated markets transmit 54 bps less, whereas banks with greater reliance on wholesale funding transmit 17 bps more. Banks in concentrated markets increase monetary policy transmission to mortgage rates less, while banks in competitive markets increase monetary policy transmission to mortgage rates more as they rely substantially on wholesale funding. My paper adds value to policymakers' decisions by increasing awareness about the fact that the transmission of monetary policy shocks to mortgage rates is asymmetric and imperfect and that the degree of this imperfect pass-through varies across banks by their composition of funding and market power. I focus on the mortgage market due to its significant share of household debt, but future research could extend the analysis to other credit markets.

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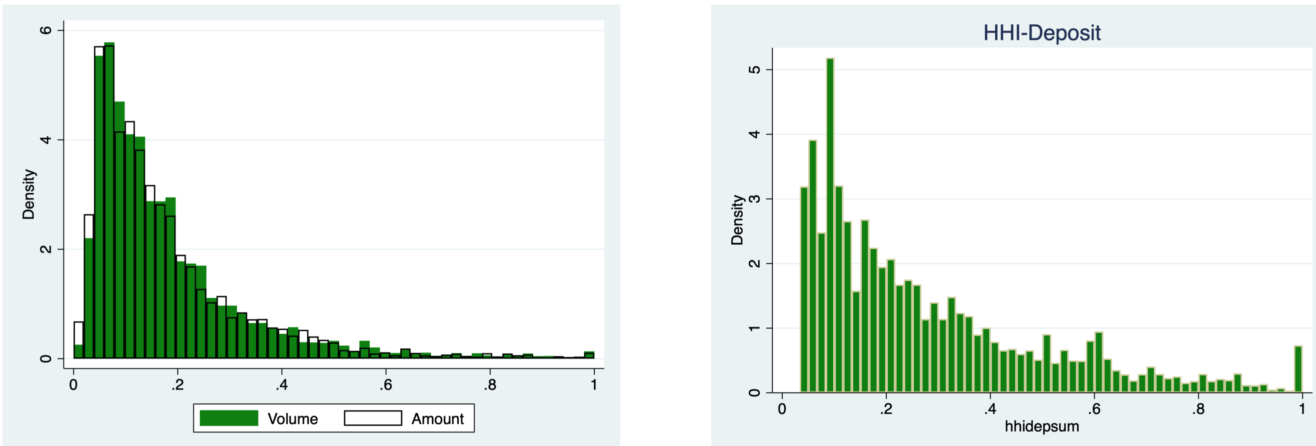
A Appendix

A.1 Empirics

Figure 4: HHI



(a) HHI-Mortgage (HMDA)

(b) HHI-Deposit (SOD)

Notes: Mortgage market concentration is constructed from the Home Mortgage Disclosure Act for loans originated in volume and amount. HHI in the mortgage market has a mean of 0.17 and a standard deviation of 0.15. Deposit HHI is constructed from the Summary of Deposits and has a mean of 0.28 and a standard deviation of 0.22.

A.2 Microfoundation of Bank CES

It may be an inaccurate representation of reality where households borrow from all banks. Ulate (2019) presents how a model where each consumer chooses to borrow from a single bank and is subject to a stochastic utility of borrowing from each bank can deliver the same demand for loans as the CES approach. The different stochastic utilities across individuals borrowing from specific banks can be due to proximity, switching costs, tastes, or asymmetric information.

Assume there is a borrower that lives for two periods, denoted 1 and 2. The borrower has a total income of $\bar{Y}$ in the second period and consumes in both periods. To consume in period 1, this borrower must borrow against their future income $\bar{Y}$ through one of a continuum of banks between zero and one. The decision process happens in two stages. In the first stage, the borrower decides which bank they want to borrow from and in the second stage, they choose the amount they want to borrow. The direct utility function of the borrower conditional on their choice of bank j is

$$U(C_{0j}, C_1) = ln(C_{0j}) + \beta ln(C_1)$$

The first period, second period, and aggregate budget constraints of the borrower are:

$$C_{0j} = B_j$$

$$C_1 = \bar{Y} - (1 + i_j^m)B_j$$

$$(1 + i_j^m)C_{0j} + C_1 = \bar{Y}$$

where $1 + i_j^m$ is the mortgage rate charged between periods 1 and 2 by bank j. The solution to this problem is:

$$C_{0j} = \frac{\bar{Y}}{(1+\beta)(1+i_j^m)}$$

$$C_1 = \frac{\beta\bar{Y}}{1+\beta}$$

and indirect utility is

$$v(1 + i_j^m) = (1 + \beta)(ln(\bar{Y}) - ln(1 + \beta)) + \beta ln(\beta) - ln(1 + i_j^m).$$

As in Anderson and de Palma (1989), assume that the first stage is described by a stochastic utility approach

$$V_i = v(1 + i_j^m) + \mu\epsilon_j$$

where μ is a positive constant and ϵ_j is random variable with zero mean and unit variance. ϵ_j is iid with type-1 extreme value distribution, then the probability of a borrower choosing bank j is:

$$Pr(j) = Pr\left(V_j = \max_r V_r\right) = \frac{e^{v\left(1+i_j^m\right)/\mu}}{\int_0^1 e^{v(1+i_r^m)/\mu}dr} = \frac{\left(1+i_j^m\right)^{-\frac{1}{\mu}}}{\int_0^1 \left(1+i_r^m\right)^{-\frac{1}{\mu}} dr}$$

as in McFadden et al. (1973). Substituting $1/\mu$ for $\theta^m - 1$ gives

$$Pr(j) = \frac{\left(1+i_j^m\right)^{1-\theta^m}}{\int_0^1 \left(1+i_r^m\right)^{1-\theta^m dr}} = \left(\frac{1+i_j^m}{1+i^m}\right)^{1-\theta^m}$$

where i^m is the aggregate loan rate. Multiplying C_{0j} by this probability gives:

$$C_{0j}Pr(j) = \frac{\bar{Y}}{(1+\beta)(1+i^m)}\left(\frac{1+i_j^m}{1+i^m}\right)^{-\theta^m}.$$

If we interpret $C_{0j}Pr(j)$ as the amount borrowed from bank j once the whole population of consumers is taken into account and denote this by M_j then

$$M_j = \left(\frac{1+i_j^m}{1+i^m}\right)^{-\theta^m} M$$

which is the same expression we get directly from the CES aggregator. This shows that a heterogeneous borrower approach with stochastic utility and extreme value shocks works as a microfoundation for the CES aggregator in the case of a homogeneous borrower.