Bank Capitalization Heterogeneity and Monetary Policy *

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Abstract

This paper shows that heterogeneity in bank capitalization rates plays a crucial role in the transmission of monetary policy to bank lending. First, I offer new empirical evidence on the dependence of bank lending responses to monetary-policy shocks on their capitalization rates. Highly-capitalized banks reduce their lending more after a monetary tightening, even after controlling for bank liquidity, size, and market power in the deposit market. I also document that highly capitalized banks have a riskier portfolio, as measured by loan charge-off rates, and default rates on their loans increase relatively more after a tightening in monetary policy. I then construct a dynamic macroeconomic model that rationalizes the empirical evidence through the interaction of heterogeneous recovery technologies of banks facing a risk-weighted capital constraint. In particular, after an increase in the policy rate, the model predicts that loan rates and default probabilities increase in both sectors. Higher-capitalized banks with a riskier portfolio are more sensitive because the risk-weighted capital constraint affects them more, so they contract lending more. In a counterfactual analysis, I find higher capital requirements amplify the effects of monetary policy.

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1. Introduction

Many economic consequences of the Global Financial Crisis (GFC) are associated with the worsening of banks' balance sheets. This reinvigorated the literature that stresses the central role of financial intermediaries in macroeconomic models. Apart from aggregate implications, the literature has uncovered broad heterogeneity in the responses of financial institutions to changes in economic conditions. This paper contributes to this literature by studying the role of the bank capitalization rate in shaping the pass-through of monetary-policy shocks to bank lending.

This paper is not the first to study the cross-sectional implications of changes in interest rates for banking sector lending. For example, Kashyap and Stein (1994) stress the importance of bank liquidity, whereas Drechsler, Savov, and Schnabl (2017) emphasize the role of bank market power in the deposit market. Closest to this paper in its aim is the work of Van den Heuvel (2012), who also link bank capitalization to the sensitivity of bank lending. These papers study the relationship between the level of interest rates and the cross-sectional implications of bank lending; instead, I revisit these views with better data and careful identification of monetary-policy shocks.

Specifically, I first provide three new empirical facts related to the response of bank lending to monetary-policy shocks across banks with different capitalization rates, the response of default rates on loans with different riskiness to monetary-policy shocks, and the portfolio composition of banks with different capitalization rates. I then rationalize these cross-sectional facts in a dynamic macroeconomic model with heterogeneous banks that face a risk-weighted asset (RWA) constraint. The model emphasizes the role the RWA constraint plays in shaping banks' portfolios and capitalization rates, and their response to the monetary-policy shock.

In the empirical part of the paper, I combine data on monetary shocks, measured using high-frequency event-study approach, as proposed by Gurkaynak (2005) and Gorodnichenko and Weber (2016), with cross-sectional U.S. banking data sets known as "call reports." I also test other factors that previous empirical papers determined to be important for the propagation of monetary policy through the banking sector. Here, I use the Herfindahl index of geographical concentration to measure bank market power in deposits, as explained by Drechsler et al. (2017).

First, I document that banks with higher capitalization rates reduce their lending more than less capitalized banks in response to monetary-policy tightening. In particular, a bank with a capitalization rate one standard deviation above the mean of the capitalization-rate distribution reduces lending by 0.75 percentage points more than a bank that lies at the mean of the capitalization-rate distribution. These results are robust to controlling for size, liquidity, and market power on deposits, and are consistent across all types of loans (Commercial and Industrial (C&I), Real Estate, and Personal loans). The contraction in credit is not substituted with investment in other assets—I show that in response to a monetary tightening, better-capitalized banks reduce their overall balance sheets more than their less-capitalized counterparts.

In addition, I provide two pieces of empirical evidence that play a crucial role in supporting the economic mechanism underlying the above result. Specifically, I show that loan default rates, proxied with delinquency rates and charge-off rates, increase after a monetary-policy shock. This result is also consistent across all types of loans. I also document the heterogeneity in the composition of bank loan portfolios. Portfolios of highly capitalized banks are more oriented toward C&I and personal loans, which are riskier than real estate loans, as measured by charge-off rates.

In the second part of the paper, I propose a theoretical mechanism consistent with the empirical evidence described above. Consider banks that differ in their ability to recover debtors' assets after a loan default and face a RWA constraint whereby the risk weights reflect the default risk but not the bank-specific recovery rates. Banks with better recovery technologies have a comparative advantage in lending to riskier borrowers, and hence hold riskier loan portfolios. The RWA constraint then forces them to hold more capital against this loan risk.

A monetary-policy tightening translates into increases in loan rates across different sectors. Because of this effect on rates, as well as due to other general equilibrium effects, the default rate of each type of loan increases. This effect is stronger for riskier loans, which in the data correspond to C&I lending and personal loans, as opposed to safer real estate loans. Banks will then seek to reduce their exposure to riskier assets. Banks with better recovery technology, which are better capitalized in equilibrium, have their portfolios more heavily tilted toward riskier loans, and the RWA constraint forces them to contract lending more than their counterparts with worse recovery technology.

In the model, I treat the heterogeneity in banks' ability to recover assets from defaulting debtors as a bank-specific technological primitive. The RWA constraint is a policy primitive. In the main text, I present a stripped-down version of the model that highlights the theoretical mechanism, while preserving relevant quantitative aspects. The central bank directly controls the real rate at which deposits are supplied to the banking sector. Two types of banks exist that differ in their recovery technologies, and these banks lend to two types of firms that differ in their riskiness.[1] Banks with the better recovery technology tilt their portfolios toward lending to riskier firms, and endogenously choose a higher capitalization rate due to the presence of the RWA constraint.

The model generates all three empirical relationships that I documented in the first part of the paper. The RWA constraint in the presence of differences in recovery technologies generates the positive association between bank capitalization and riskiness of banks' portfolios. After monetary-policy tightening, loan default rates increase, the better-capitalized banks holding riskier portfolios contract lending more in response. To assess the quantitative performance of the calibrated model, I study the model-implied bank-specific lending responses to a monetary-policy shock as a function of a bank's capitalization rate. In my baseline calibration, I find the model generates sensitivity in the lending response to the capitalization rate that is very close to the data, but not enough cross-sectional differences in capitalization rates. This finding suggests not all the heterogeneity in

[1]A full general equilibrium model that features a riskier corporate sector and a less riskier mortgage sector, as well as a New-Keynesian structure linking a nominal policy rate to the real economy, is in the appendix.

the capitalization rate can be explained by differences in recovery technologies. I only focus one dimension, but I explore other factors that might contribute to the capitalization-rate heterogeneity in ongoing work.

In addition, I use the model to conduct a policy experiment that analyzes the implications of bank regulation for the bank lending channel of monetary policy. The question is: What is the effect of higher capital requirements on the effectiveness of monetary policy? I find that in an economy with higher capital requirements, the monetary-policy shock has more adverse effects. Therefore, a monetary-policy shock generates a higher reaction of the main economic variables.

Literature. This paper adds to three strands of literature. First, I contribute to the literature on how the effect of monetary policy varies across banks, by showing banks with higher capitalization rates contract their lending more than lower-capitalized banks after a monetary-policy tightening. Studies such as Kashyap and Stein (1994), Bernanke and Gertler (1995), and Kashyap and Stein (2000), argue that banks with low liquidity in their balance sheets are more responsive to monetary policy, a mechanism that I denote the "liquidity view." Van den Heuvel (2012) advocates a "bank capital view" of the transmission of monetary policy. He uses state-level data and argues the effect of monetary policy is stronger in states where banks have a low capital-asset ratio. He finds bank liquidity measures are not associated with variation in the impact of monetary policy on output at the state-level monetary policy.[2] However, I finds the opposite association between capitalization rates and the sensitivity of bank lending.

Recent empirical studies focus on how the transmission of monetary policy to households and the real economy depends on banks' market power. A number of papers, including Drechsler et al. (2017), find empirical evidence of market power in the deposit market and show monetary policy has a powerful impact on the price and quantity of deposits supplied by the banking system. Additionally, Scharfstein and Sunderam (2016) find evidence of market power in the loan mar-

[2] This result implies the bank lending channel is not operational; and uses a panel of state-level data to assess the bank capital channel.

ket, where higher market power leads to lower pass-through of secondary market rates to households and lower refinancing activity in response to declining interest rates.

In this paper, I find a key of heterogeneity in capitalization rates. After monetary tightening, better-capitalized banks reduce lending more, in contrast to the results of Van den Heuvel (2012). When I simultaneously allow for different channels, I do not find the market-power view to be statistically significant, and the liquidity channel is substantially weakened, whereas the capitalization rate continues to play an important role.

Second, on the theoretical front, I contribute to the literature on how micro-level heterogeneity affects the understanding of monetary policy relative to traditional representative-agent models in a real model and a New Keynesian model. A growing strand of literature focuses on how household-level heterogeneity affects the consumption channel of monetary policy; see, for example, Auclert (2019), Wong (2019), Kaplan, Moll, and Violante (2018), and McKay, Nakamura, and Steinsson (2016). Another strand of the literature analyzes the role of firm-level heterogeneity in determining the investment channel of monetary policy; see, for example, Ottonello and Winberry (2020), and Jeenas (2019). By contrast, my paper analyzes the role of bank-level heterogeneity in determining the lending channel of monetary policy and explores bank heterogeneity in recovery rates on defaulting loans as a theoretical mechanism that affects the lending channel.

Finally, I contribute to the literature that embeds the banking sector in a general equilibrium macroeconomic model. To date, papers such as Gertler and Kiyotaki (2010), Gertler and Karadi (2011), Wang (2018), and Arce, Nuño, Thaler, and Thomas (2019) assume a representative bank in a standard New Keynesian DSGE to assess unconventional monetary policy. Other papers, such as Balloch and Koby (2019) or Coimbra and Rey (2020), develop a heterogeneous banking sector. Coimbra and Rey (2020) present a flexible-price model that introduces heterogeneity in the value at risk of financial intermediaries and assess monetary and financial stability jointly. Balloch and Koby (2019) focus on how low-nominal-rate environments affect bank credit supply. Their model assumes banks have market power on deposits and that a leverage constraint limits lending. My heterogeneous-bank model is based on the work by Elenev, Landvoigt, and Van Nieuwerburgh (2020), who study the effect of tighter bank capital requirements in response to the GFC. I contribute to this literature in three ways. First, I incorporate heterogeneity in the banking sector, specifically for commercial banks. Second, I incorporate borrower heterogeneity across sectors, with a high-risk and a low-risk sector that differ in their equilibrium default rates due to differences in the volatility of their productivity shocks. Third, I use my framework to study how bank heterogeneity affects the transmission of monetary-policy shocks.

Outline. The remainder of the paper is structured as follows. Section 1 presents data and empirical analysis. Section 2 builds the baseline dynamics equilibrium model. Section 3 lays out the qualitative analysis of the model and counterfactual. The last section concludes and explains ongoing work. Additional details can be found in the Appendix.

2. Empirical work: Data, methodology, and empirical results

In this section, I summarize the main data sources, focusing on the U.S. economy. Detailed descriptions can be found in appendix A.

First, I use bank-level variables from the Consolidated Reports of Condition and Income (known as "Call Reports") filed quarterly by all banks. I use quarterly income and balance-sheet data for all U.S. public commercial banks (only commercial banks are indicated by the SIC Codes 60, 61, and 6712 and charter type equal to 200, which means only commercial banks). The bank-level data is a panel sample for 1990-2007. I end the sample before the GFC, because the latter was followed by a period of unconventional monetary policy and an effective lower bound on interest rates. For example, after 2008, monetary policy is not based on the interest rate, but on unconventional monetary policy such as quantitative easing (QE) and forward guidance. Therefore, using the interaction with Fed-Funds-rate changes could yield misleading or biased results, because it has not been the main monetary-policy tool after 2008. Table 1 shows the cross-sectional average for the top 10% of banks and the bottom 90% in the sample about the components of the balance sheet. The table shows deposits and loans are the most important elements of the balance sheet. In addition, I follow Drechsler et al. (2017) to get a measure of bank market power in the deposit market, measured as the weighted-average HHI across all of a bank's branches, using branch deposits as weights.

Table 1: Bank balance-sheet statistics

Fraction total assets (\%)	All sample: 1990-2007	
	top 10 %	bottom 90%
Cash / Fed funds repo	9	11
Securities	23	28
Loans	63	57.5
Deposits	79	86
Other borrowing, Fed funds repo	12.2	3
Equity	8.8	11

(Top 10 % and botton 90% refers to total assets)

Second, I use a measure of monetary-policy shocks based on high-frequency identification. These monetary-policy shocks must be understood as surprises or unanticipated economic forces uncorrelated with other structural shocks implied by the Fed funds rate. The strategy for measuring monetary-policy shocks based on high-frequency identification builds on the series used by Gurkaynak et al. (2004) and Gorodnichenko and Weber (2016). The idea is to isolate the unexpected (surprise) policy change that can generate market response. These series are constructed by measuring the reaction of the implied Fed funds rate from a current-month Federal funds future contract during the window from 15 minutes before to 45 minutes after the release of the announcement of the Federal Open

Market Committee (FOMC) meetings. Further details can be found in Appendix section A.2.

Given the bank-data characteristics, my empirical strategy is based on panel data regression and a local forecasting method proposed by Jordà (2005) to estimate impulse responses. Second, given the results (i.e., that the response depends on the capitalization rate), I tested the traditional and modern view of the bank lending channel mentioned in the motivation part by including an additional interaction between bank size, liquidity, market power on deposits, and monetary policy. Third, I decompose total loans and analyze the response of different types of loans instead of overall loan growth. I find higher-capitalization banks react more across different types of loans than lower-capitalization banks after a monetary-policy tightening. Fourth, I analyze how loan-portfolio composition and riskiness is conditional on bank capitalization. Fifth, I analyze the relationship between bank capitalization and default rates for different types of loans over the business cycle, and find no evidence of significant differences in cyclicality of customers with different capitalization rates. Finally, I propose a mechanism that explains my findings and is consistent with how the overall components of a bank's balance sheet move after a tightening. The following subsections describe these results.

2.1 Fact 1

2.1.1 Dynamic response: Heterogeneous responses to monetary-policy shock

This section documents the heterogeneity impact of monetary-policy shocks on bank lending. First, I answer my main question with a lineal specification by focusing on the estimation of the interaction coefficient between the capitalization rate and a monetary-policy shock on bank lending. Second, I study the dynamic version of my linear specification in order not only to assess the moment of the policy shock, but also the dynamic behavior of the interaction coefficient at some horizon in the future in response to a change in policy today.

Lineal specification: I begin by estimating the following specification:

$$\Delta log\text{loan}_{i,t} = \alpha_i + \alpha_{st} + \delta_1 \text{MPShock}_t + \delta_2 X_{i,t-1} + \beta(\text{MPShock}_t * X_{i,t-1}) + \Gamma_1' \text{macro}_t + \Gamma_2' Y_{i,t-1} + \epsilon_{i,t} \tag{1}$$

where α_i is a bank's i fixed effect[3], α_{st} is a state s-by-quarter t fixed effect,[4] MPShock_t is the monetary-policy shock, $X_{i,t-1}$ represents a set of explanatory variables under consideration for a given specification, such as bank capitalization, liquidity, and market power. $Y_{i,t-1}$ is a vector of bank-level controls such as age, size, liquidity, capitalization, loan loss, deposit over liabilities, and wholesale funding over liabilities. $\gamma_1, \gamma_2, \Gamma_1$, and Γ_2 are regression coefficients. The main coefficient of interest in the regression (1) is β, which measures the semi-elasticity of loans with respect to a monetary-policy shock depending on a bank's capitalization rate.[5] Note I use the lag of the explanatory and control variables to ensure they are predetermined at the time of the monetary-policy shock.[6] I cluster standard errors at the bank and time level. $\beta < 0$ implies banks with a higher capitalization rate reduce their lending more than banks with a lower capitalization rate after a positive monetary-policy surprise.

Table 2 shows the results from the estimation of equation (1). The four columns in the table show a negative coefficient $\beta < 0$, which implies higher-capitalized banks reduce their lending more than lower-capitalized banks after a positive monetary-policy surprise. Column (1) reflects that banks with one standard deviation of capitalization rate above the mean in the capitalization-rate distribution react, on average, 0.8 percentage points more than a bank located at the mean of the capitalization-rate distribution. Columns (3) and (4) drop the time fixed effect, so I can estimate the average effect of monetary policy. This coefficient in column

[3] Bank-fixed effects capture permanent differences in lending behaviour across banks.

[4] State-by-quarter fixed effects capture differences in how broad states are exposed to aggregate shocks.

[5] Alternately, β measures the importance of variable $X_{i,t}$ on predicting heterogeneity in bank lending response.

[6] Note a positive monetary-policy shock represents a Fed funds rate increase, and a negative δ (interaction coefficient) reflects that banks with a greater explanatory variable (X_i, t) prior to the shock experience smaller loan growth (or a larger contraction) after a contractionary shock.

Table 2: Heterogeneous Effects of Monetary Policy on Bank Lending

	(1)	(2)	(3)	(4)
	Loan Growth			
Capitalization$\times$ MPshock	-0.758***	-0.769***	-0.936***	-0.825***
	(0.27)	(0.26)	(0.26)	(0.26)
MPshock			0.607	0.925**
			(0.46)	(0.39)
Observations	642311	642303	642303	642303
R^2	0.281	0.295	0.275	0.278
Bank controls	no	yes	yes	yes
Time sector FE	yes	yes	no	no
Macro control	no	no	no	yes
Bank,Time clustering	yes	yes	yes	yes

Robust standard errors in parenthesis
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

(4), which is statistically significant, indicates that a 1% increase in the policy rate increases loan growth by around 0.9$\%$.

To estimate the **dynamic** response across banks, I estimate the Jordà (2005) local projection specification:

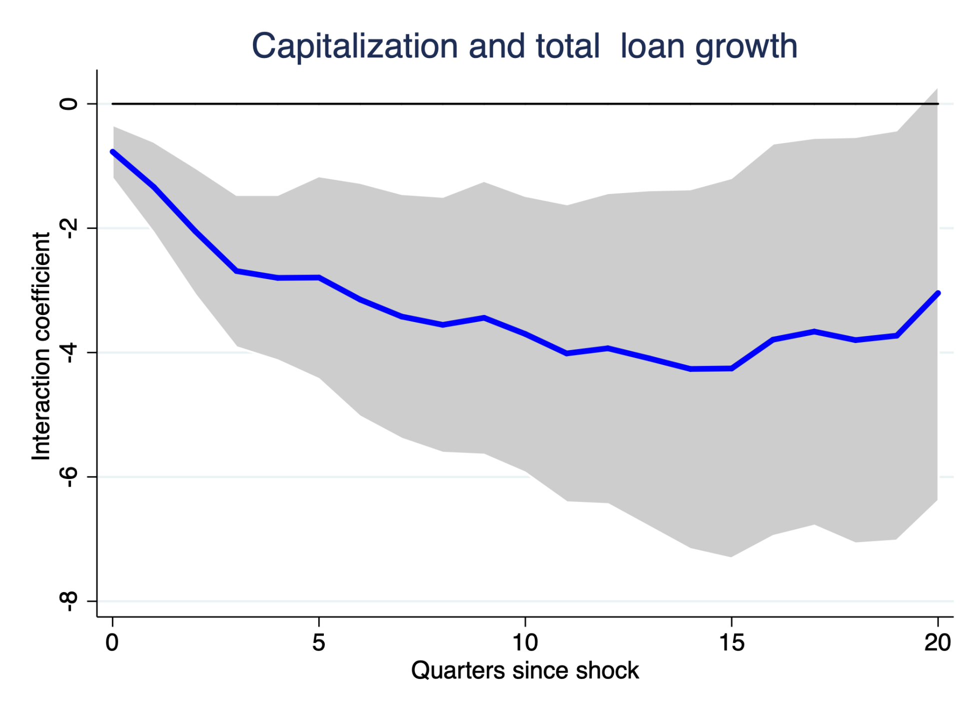
$$\Delta log \text{loan}_{i,t+h} = \alpha_i^h + \alpha_{st}^h + \delta_1^h \text{MPShock}_t + \delta_2^h X_{i,t-1} + \beta^h (X_{i,t-1} \cdot \text{MPShock}_t) + \Gamma'^h Y_{i,t-1} + \Gamma_2^h \text{macro}_{t-1} + \epsilon_{i,t+h} \tag{2}$$

where $h \geq 0$ is the forecast horizon. Now β^h indicates the cumulative response of lending in quarter $t+h$ to a monetary-policy shock in quarter t, which depends on the bank capitalization rate.

Figure 1 shows the dynamic response. The estimated interaction coefficient $\beta^h < 0$ implies higher-capitalized banks are more responsive to monetary-policy shocks at the time of a contractionary monetary-policy shock over horizon h. The point estimate is negative and statistically significant over the horizon until quarter 20.[7] This result is in contrast the capital approach proposed by Van den Heuvel

[7]This result is robust if we use the tier1 capital-to-asset ratio or the tier 1 capital to risk-weighted-assets ratio.

Figure 1: Dynamics of Differential Response to Monetary Shocks: Capitalization



Note: Dynamics of the interaction coefficient between the capitalization rate and monetary shocks over time. The figure reports the coefficient β^h from 2. Also, the grey shadow means 90% of confidence interval. Confidence interval constructed based on two-way clustered standard errors at bank and time levels.

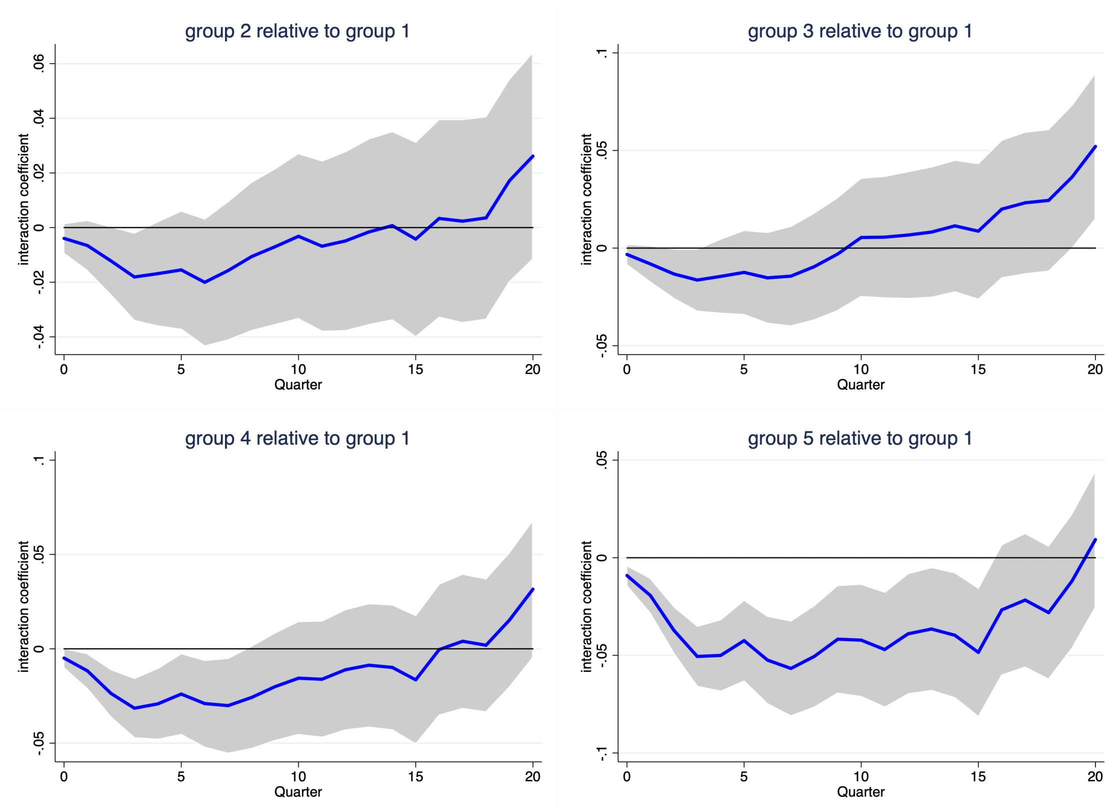
et al. (2002) in the sense that lower-capitalized banks are more responsive to a monetary-policy shock.

Non-linear model specification: As a robustness check, I use a non-linear specification as follows:

$$X_{i,t+h} - X_{i,t-1} = \alpha_i^h + \alpha_t^h + \sum_{g=1}^{G-1} \alpha_g^h \times D_g^h{}_{i,t} + \sum_{g=1}^{G-1} \beta_g^h \times D_g^h{}_{i,t} \times \text{MPshock} + \delta^h \text{MPshock} + \Gamma'^h Y_{i,t-1} + \epsilon_{i,t+h} \tag{3}$$

where X is the endogenous variable of interest, bank total lending, α_i^h, and α_t^h banks fixed effects and time fixed effects, and D_g is a dummy for a group of capitalization rates in the previous quarter. I divide the sample into quintiles where banks are ranked by capitalization rate and each group represents 20% of total assets in the sample. $Y_{i,t-1}$ is the banks' control, which are the same in the previous specification. MPshock is the monetary-policy shock at time t. Again, the coefficient of interest is β_g^h, which is the impulse response for a group g at forecast horizon h. Finally, the standard errors are clustered by banks. Figure 2 shows the results of the non-linear specification. The first group, the lowest-capitalization-rate quantile, is omitted. Therefore, the coefficient of interest, β_g^h, is interpreted as the response relative to group 1. Figure 2 shows the response of group 5 (higher capitalization rate) relative to group 1 (lower capitalization) is negative and statistically significant on impact and over some horizon going forward.

Figure 2: Non-linear Response



2.1.2 Testing different channels

In this section, I tested the other approaches found in the empirical literature about the response of bank lending to monetary policy. So far, the literature has two main channels, namely, the traditional and modern approaches to the bank lending channel mentioned in the motivation part. The idea is to include an additional interaction between bank size, liquidity, market power on deposits, and monetary policy in my main specification. The specification is as follows:

$$\Delta log\text{loan}_{i,t+h} = \alpha_i^h + \alpha_{st}^h + \delta_1^h \text{MPShock}_t + \delta_2^h X_{i,t-1} + \beta^h (X_{i,t-1} \cdot \text{MPShock}_t) + \Gamma'^h Y_{i,t-1} + \epsilon_{i,t+h} \tag{4}$$

where $X^1 = \{\text{capitalization}, \text{size}\}$, $X^2 = \{\text{capitalization}, \text{liquidty}\}$, and $X^3 = \{\text{capitalization}, \text{Market Power}\}$.

This specification will allow me to answer a sub-question: Does my result survive controlling for the interaction between bank size (or liquidity or market power) and monetary policy shock? I find the capitalization rate is still significant when I test the other channel at the same time.

First, the traditional channel of bank lending proposed by Kashyap and Stein (2000) suggests a tightening of monetary policy reduces lending more in less liquid banks, because they cannot sell assets to meet reserve requirements. Additionally, they claim the sensitivity of the contraction to liquidity is stronger for small banks. Figure 3 shows the results of the dynamic response by controlling the double interaction with the size of banks. Figure 4 shows the result by controlling the double interaction with liquidity. Both figures show the effect of the capitalization rate is negative and statistically significant. The figures show the effect of liquidity as well, but it becomes less important going forward.

Second, the modern bank lending channel proposed by Drechsler et al. (2017) suggests banks with more market power are more responsive to a monetary-policy tightening. They can keep interest rates on deposits low when monetary policy tightens, thus increasing spreads. Figure 2.1.2 shows the result by controlling the double interaction with bank market power on deposits and a monetary-policy shock.

Table 8 summarizes the main differences concerning the main empirical literature on the heterogeneous response across banks with different capitalization rates, market power on deposits, and liquidity in the U.S. economy (see appendix B for more details). I view these findings as reflecting that once I also allow for these different channels jointly, I do not find the market-power view to be statistically significant, and liquidity channel is there, but is less important. Therefore, heterogeneity in bank capitalization rates plays a crucial role in the transmission of monetary policy to bank lending.

Figure 3: Dynamics: Joint regression capitalization rate and real size

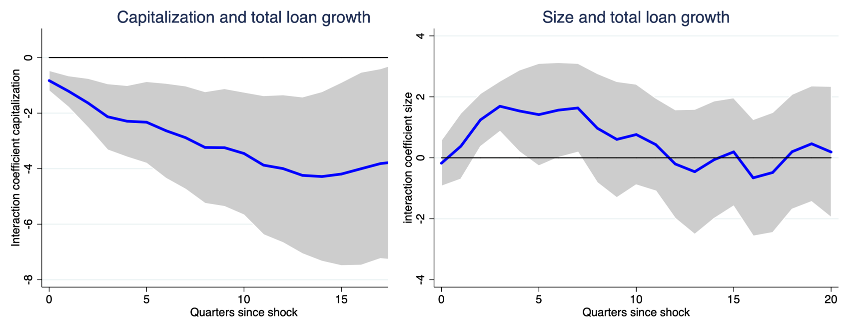


Figure 4: Dynamics: Joint regression capitalization and liquidity

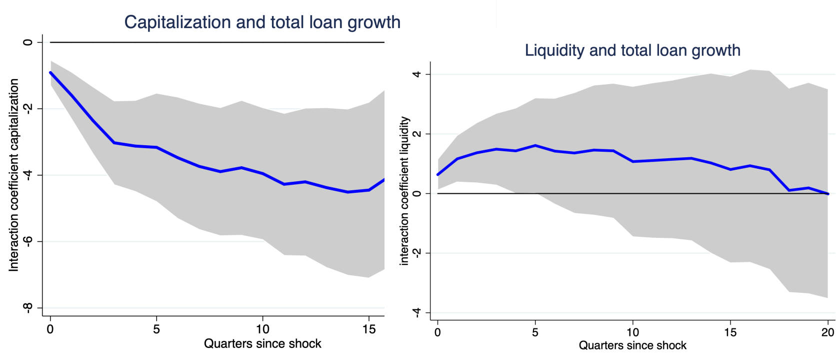


Figure 5: Dynamics: Joint regression capitalization and market power

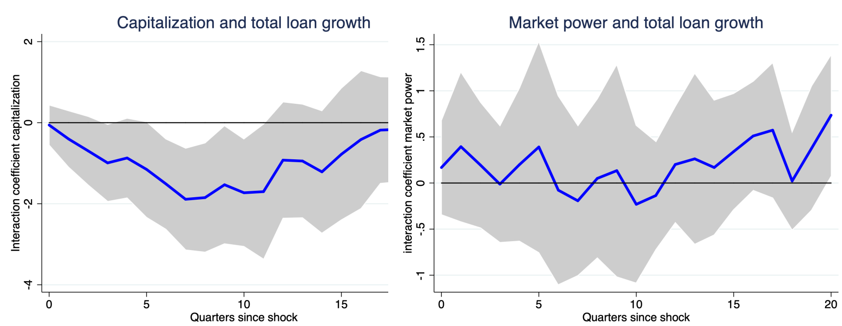


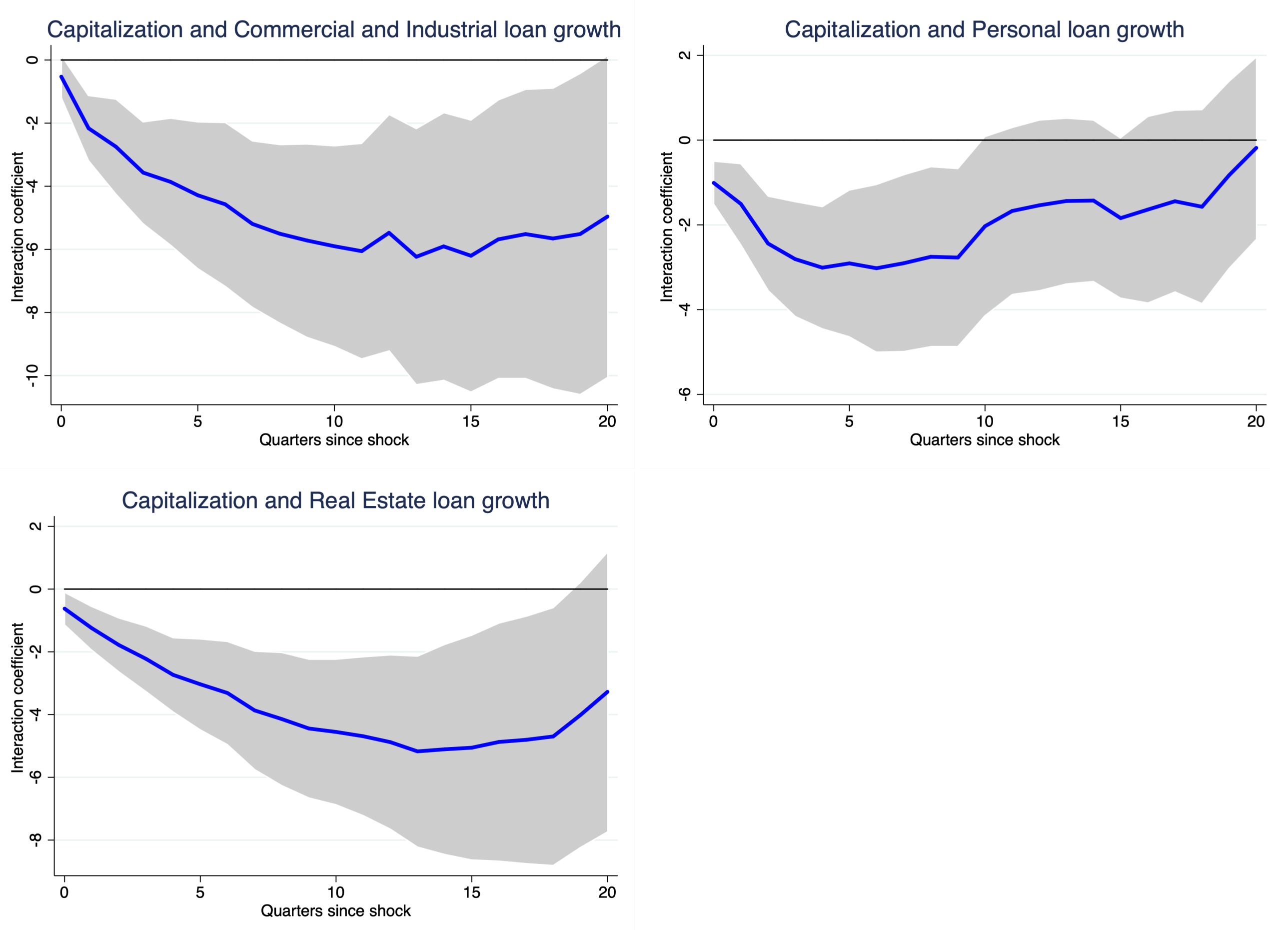
Table 3: Comparison with main existing empirical literature

	Monetary-Policy Measure	**Sample Period** and **frequency**	**Individual Analysis**	**Econometric Specification**
Paz (2020)	High-frequency identification	1990-2007 quarterly	Bank Level	-Linear regression with bank controls, interaction term, bank fixed effect, state X times fixed effects. Standard errors are clustered at bank and time level, macro controls. -Dynamic: Local projection Method -Robustness: Non-linear regression
Drechsler, I., Savov, A., and Schnabl, P. (2017, QJE)	Change in Fed funds	1994-2013 quarterly	Bank Level	Linear regression with interaction term, bank fixed effect, and quarter fixed effects. Standard error are clustered by bank.
Van den Heuvel, (2012,BEJM)	Change in Fed funds, Bernanke-Mihov indicator	1969-1995 annual	State Level	Linear regression with interaction term, with state fixed effects.
Kashyap, A. K. and Stein, J. C. (2000, AER)	Change in Fed funds, Bernanke-Mihov indicator	1973-1996 quarterly	Bank Level	Two-Step regression for different size class.

2.1.3 Dynamic response for types of lending

This section documents the lending response across different types of loans instead of overall loan growth. The specification is the same as in equation (2), but the dependent or endogenous variables are loan growth rates for different types of loans: commercial and industrial (C&I), real estate, and personal loans. I find higher-capitalization banks react more in reducing their loans across different types of loans than lower-capitalization banks after a monetary shock. The effect is negative, statistically significant, and lasts several quarters after the shock. Figure 6 shows the results for each type of loan. I find the C&I loans are more sensitive on average than real estate loans to monetary shocks. Therefore, my main result holds for all types of loans. These results allow me to conclude no sectoral-driven or sectoral-risk history exists; that is is not the type of loan that matters, because my results hold across different types of loans.

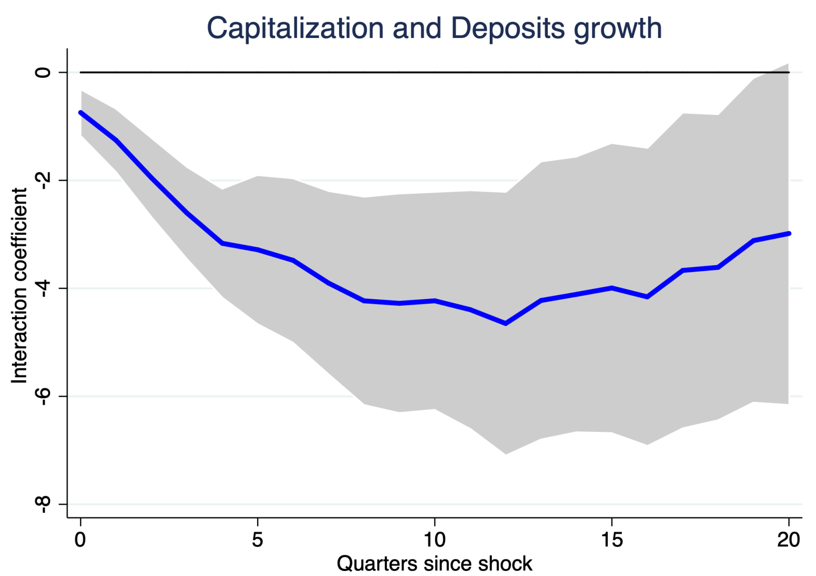
Figure 6: Dynamic responds on banks' loan portfolio by type

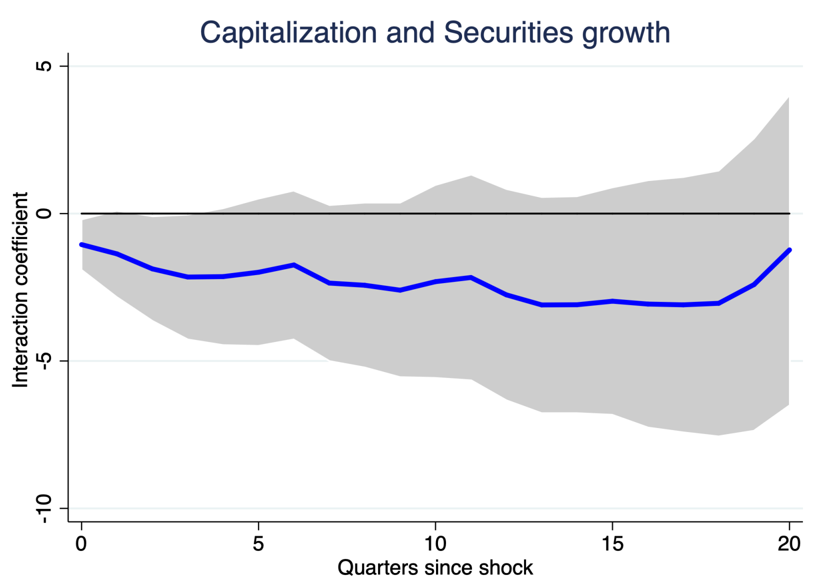


2.1.4 Bank balance sheets and monetary policy: Deposits and securities

This section documents the response of other banks' balance-sheet variables, such as deposits and securities, after a monetary shock. First, the top part of Figure 7 shows bank deposits' response to a monetary shock. I find higher-capitalized banks reduce their deposits more than lower-capitalized bank. Second, the bottom part of Figure 7 shows bank securities' response to a monetary shock. I find securities' response, on average (blue line), is systematically below zero and the gray band is wide, meaning highly capitalized banks also reduce security holdings. In sum, highly capitalized banks reduce deposits, securities, and loans; that is, the overall balance sheet shrinks.

Figure 7: Bank balance sheets and monetary policy: Deposits and securities



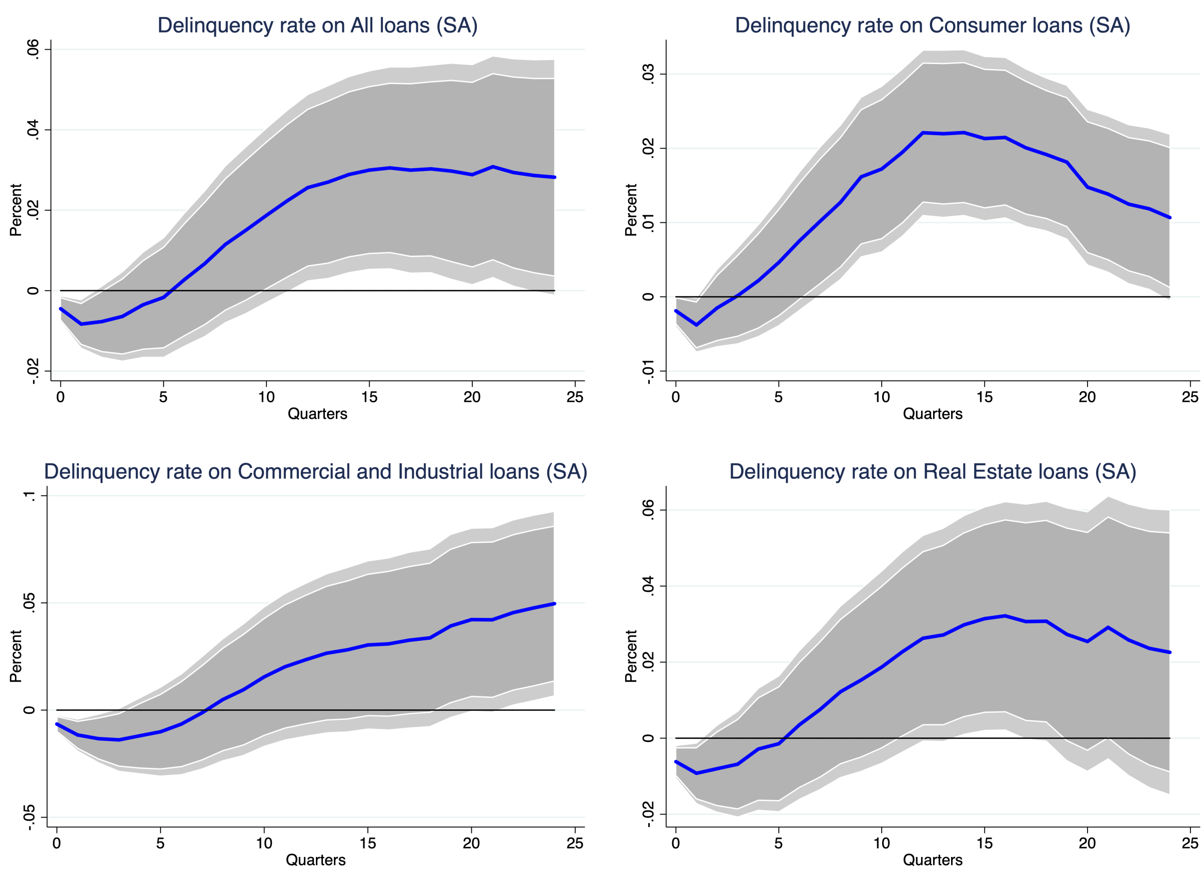


2.2 Fact 2

2.2.1 Default rates, bank capitalization rate, and monetary policy

This section documents the relation between default rates and a monetary shock. Given the aggregate data in delinquency rates (charge-off rates for each category of loans), I document the response of a proxy of default rates to a monetary shock. Figure 8 shows the response of delinquency rates to a monetary shock for each type of loan (main fact 2). I find delinquency (proxy of default) goes up for all types of loans. In particular, default rates increase over two years after a monetary tightening (see Appendix C for the charge-off responses).

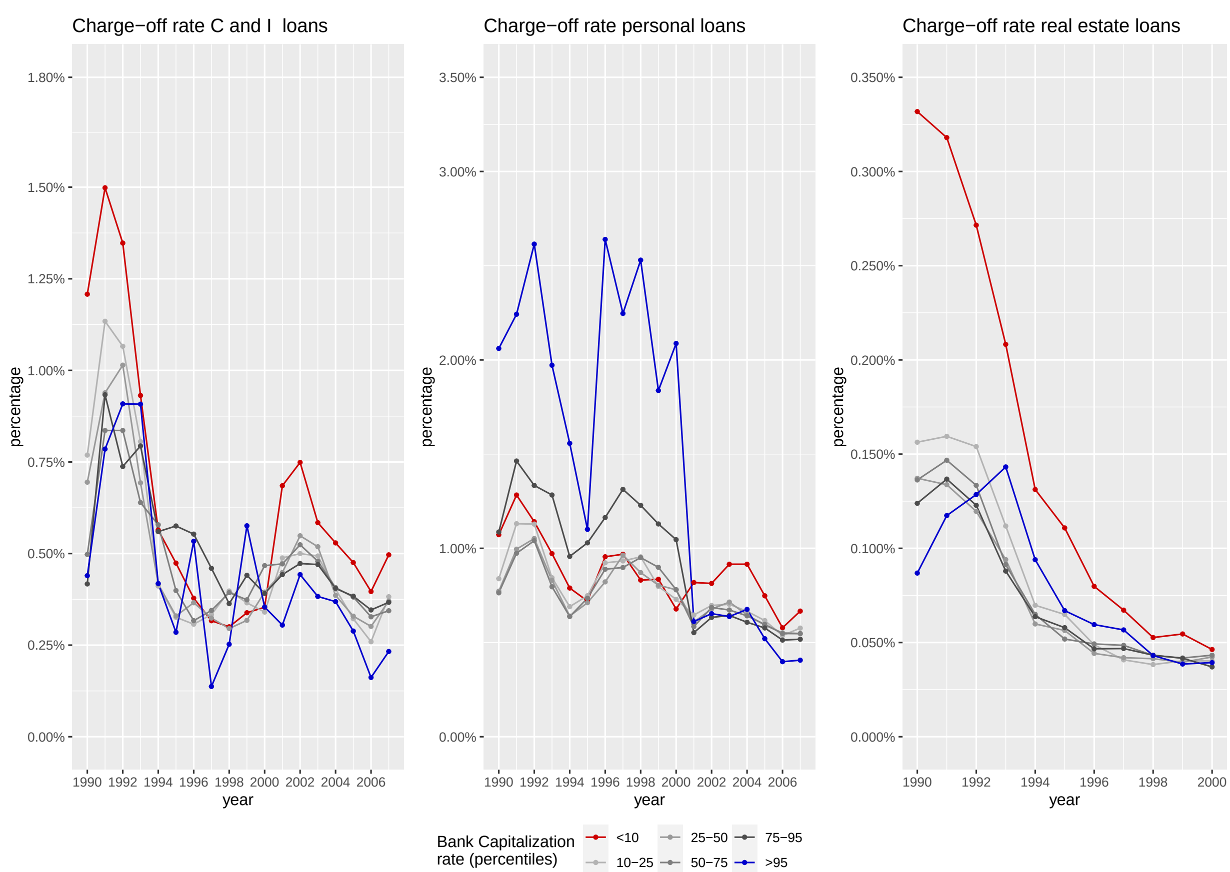
Figure 8: Aggregate: Delinquency responses to monetary-policy shock



This evidence suggests that loans are intrinsically riskier. It is not the case loans becomes riskier after a monetary-policy shock. In addition, note that central banks tighten monetary conditions when the economy is doing well (a context that should have few defaults). However, after tightening occurs, more defaults will occur, so the effect of tightening on the cost of financing these types of sectors matters. Therefore, a first-order effect arises that leads to an increase in default rates from the monetary tightening.

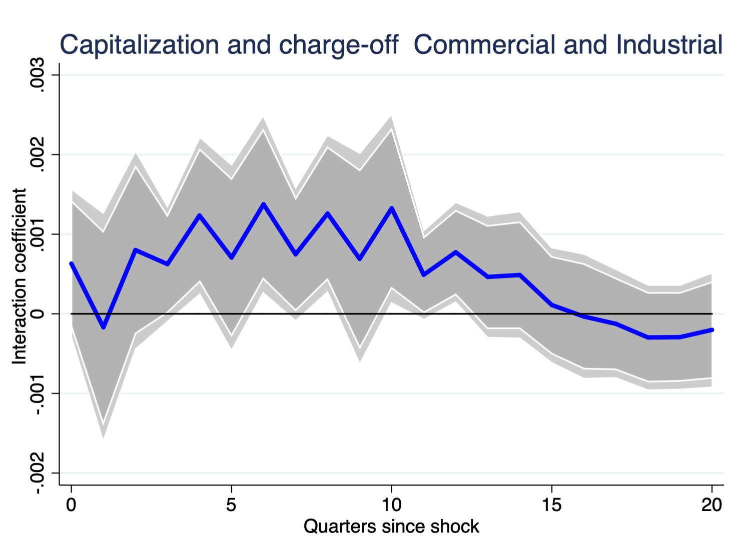
In addition, I use cross-sectional bank-level data to show the charge-off rate for each category of loans across percentiles of bank capitalization. Figure 9 shows no clear pattern in default rates exists across capitalization rates.

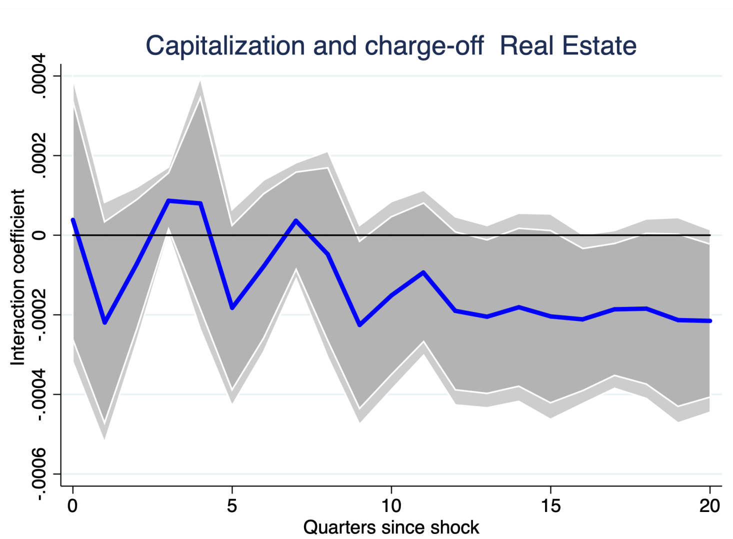
Figure 9: Cross-Sectional: Charge-off rates for loan types across bank capitalization rates



I analyze (conditional on loan types) whether the response of default rates to a monetary shock depends on capitalization rates. Figure 10 shows that within a given sector (e.g., real estate), high- and low-capitalized banks have the same defaults rates. A likely interpretation is that high- and low-capitalized banks tend

Figure 10: Cross-sectional: Charge-off responses to a monetary shock across capitalization rates





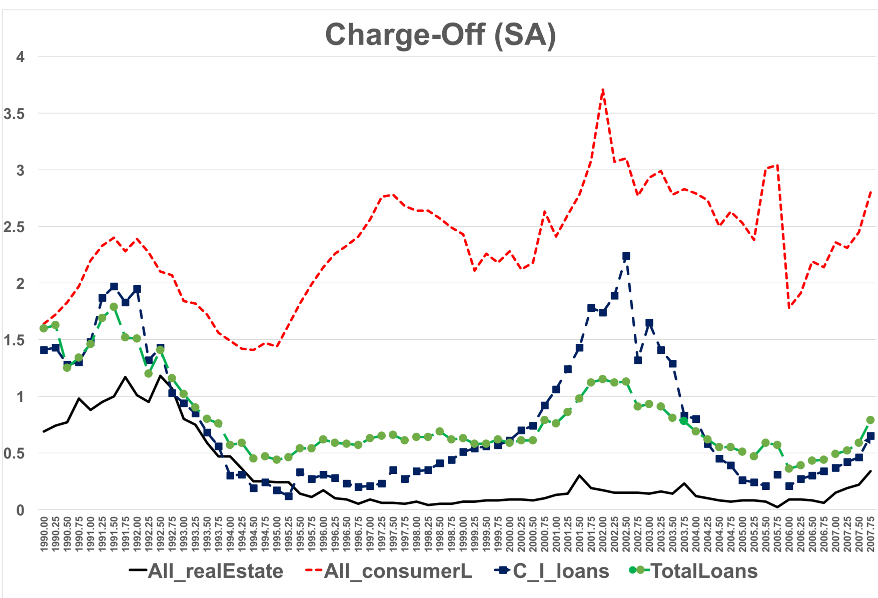
to have similar borrowers; that is, credit risk is similar for both. In addition, appendix D documents the relationship between bank capitalization rates, default rates, and business cycles. I find a negative relation between default rates and GDP growth, but the effect across banks for each type of loan is not statistically different. Therefore, I could rule out the demand-driven history whereby one bank type lends more cyclically than the other.

2.3 Fact 3

2.3.1 Riskiness of types of loan:

This section analyzes which types of loans are riskier. I define riskiness as a higher frequency of default. I consider charge-off rates for each loan category a proxy for default rates. Figure 11 shows the evolution of the aggregate data for charge-off and delinquency rates (proxy of default) for total loans and each loan category in all U.S. commercial banks. I show that, in the period of analysis, the charge-off rates are lower for real estate loans.

Figure 11: Aggregate charge-Off rates



Second, I use cross-sectional data to study the relative effect of risk between loan types using a charge-off rate for each category. The empirical strategy is regressing the charge-off rate for each bank against a charge-off indicator:

$$y_{ikt} = \alpha_i + \beta^p \times \mathbb{1}_{\{k=p\}} + \beta^{ci} \times \mathbb{1}_{\{k=ci\}} + \beta^{ag} \times \mathbb{1}_{\{k=ag\}} + \gamma' x_{i,t} + \epsilon_{i,t} \tag{5}$$

where y_{ikt} is the charge-off rate (proxy for default) of bank i with loan type k at time t, $x_{i,t}$ are bank control variables, $\mathbb{1}_{\{k=\tau\}}$ is an indicator for the charge-off rate, $\tau = \{p, ci, ag\}$, where $\mathbb{1}_{\{k=re\}}$ serves as the omitted category, and β^k represent the riskiness of loan type k relative to real estate loans. Table 4 shows the result of the regression. The coefficient β reflects how risky loan type k is relative to real estate loans, where $k = \{\text{C\&I}, \text{personal}\}$. I find personal and C&I loans are riskier than real estate loans.

Table 4

VARIABLES	(1) Charge-off rate	(2) Charge-off rate
β^{ci}	0.341***	0.346***
	[0.006]	[0.006]
β^{p}	0.530***	0.535***
	[0.006]	[0.006]
β^{ag}	0.014**	0.012**
	[0.006]	[0.006]
constant	0.105***	0.022*
	[0.004]	[0.013]
Bank fe	Y	Y
Bank controls	N	Y
Obs	1,205,998	1,205,998
R^2	0.0874	0.091

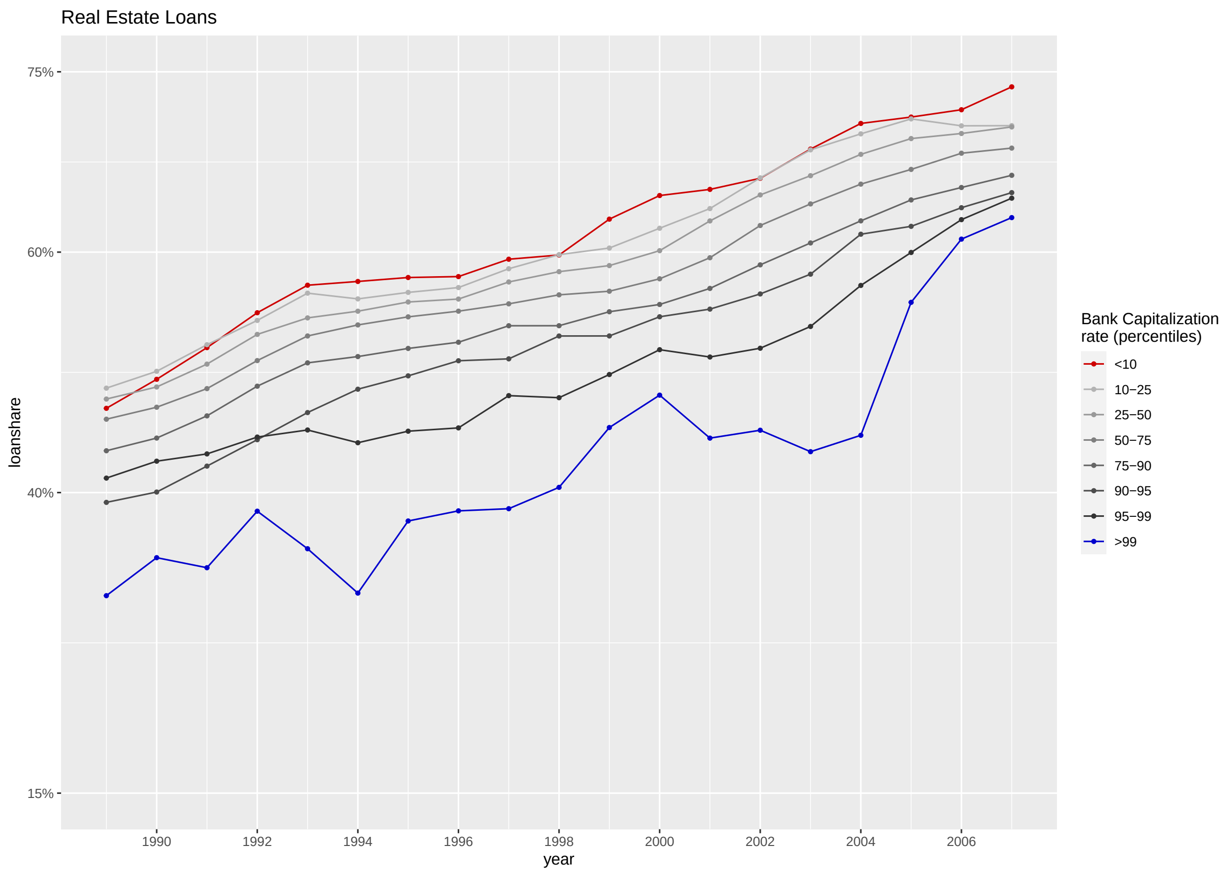
SE in brackets

2.3.2 Banks' loan-portfolio composition:

In this section, given that the response is different across loan types, I document the loan-portfolio composition for banks with different capitalization rates. First,

Figure 32 shows the average loan portfolio across bank-capitalization-rate percentiles for real estate loans. I find higher-capitalized banks have a lower share of real estate loans than lower-capitalized banks.

Figure 12: Average portfolio share for real estate loan across bank-capitalization percentiles



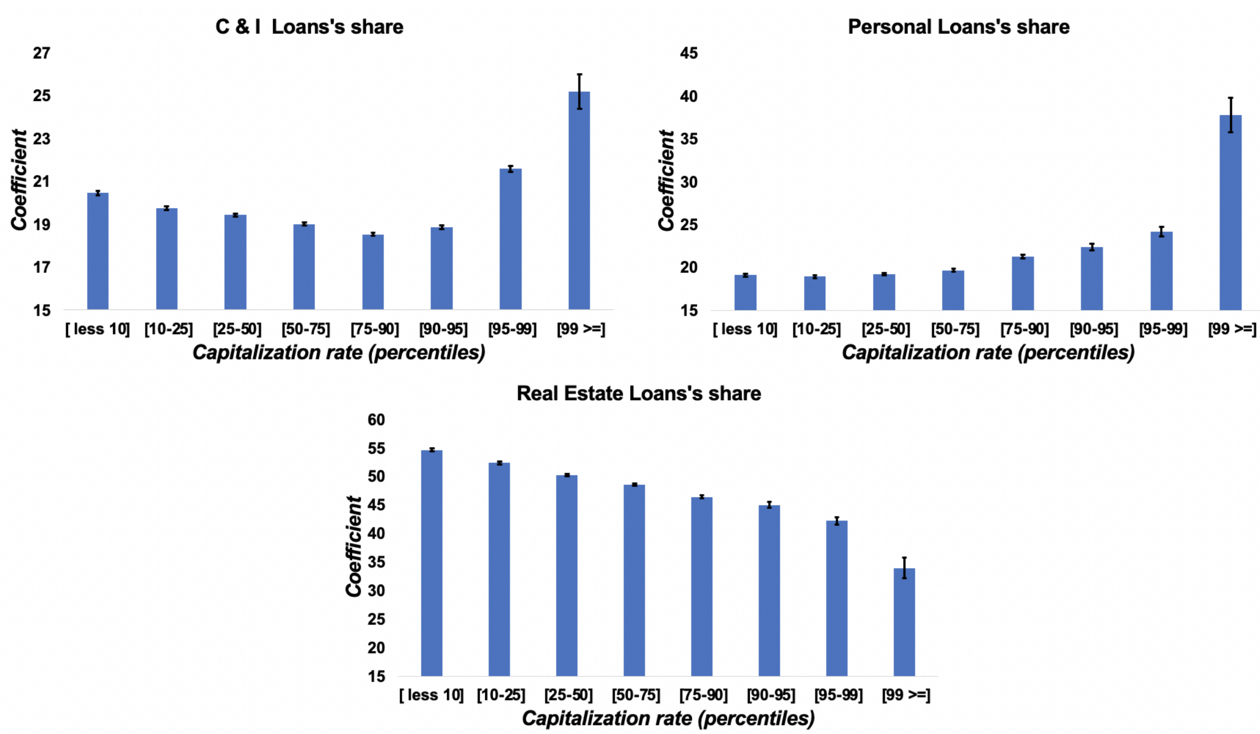
Second, whereas the evidence of Figure 32 suggests that the portfolio composition of banks with higher-capitalization rates is less oriented toward real estate loans, see appendix E for other types of loans. Bank size, or the state-fixed effects, may be the driving force. I calculate the trend in average bank capitalization after controlling for bank size, state, and size-state interactions. The empirical strategy is regressing the portfolio share associated with each category against different percentiles of bank capitalization rates:

$$y_{jbt} = \sum_{i \in I} \beta_i^j \mathbb{1}_{\{bt \in i\}} + \Gamma^j Z_t + \delta_t + \delta_{\text{state}} + \epsilon_{jbt}, \tag{6}$$

where y_{jt} is the bank's loan-type share, j is loan type {C&I, personal, real estate}, $I$is percentiles groups i , $Z_t$are bank size, as a control variable. Therefore, the coefficient of interest is β_{cap}. I find that, on average, higher-capitalized banks have a higher average share of C&I and personal loans, and lower-capitalized banks have more real estate loans.

Table 13 shows the results for personal and real estate loans on the left-and right- hand side, respectively. I find higher-capitalization banks have a higher portfolio of personal loans (the same for C&I loans). By contrast, lower-capitalization banks have a higher portfolio of real estate loans.

Figure 13: Estimation: Average-portfolio-share Parameters β_{cap}



2.4 Inspecting the mechanism:

Against this backdrop, I set out to explore the mechanisms underpinning my findings. A framework intending to study the heterogeneous transmission of monetary policy to the economy through the banking sector should include several features absent in conventional macro-finance models. The main facts about banks' loan portfolios and the response of bank lending to a contractionary monetary shock (positive-monetary policy surprise) are the following:

1. Portfolio composition and loan risk: Higher-capitalized banks have a higher share of C&I and personal loans. These types of loans are riskier than real estate loans, as measured by charge-off rates.

2. Response to monetary tightening: default rates increase.

3. Response to monetary tightening: higher-capitalized banks reduce lending more. This response holds across all types of loans (C&I, personal, and real estate). In addition, they contract their balance sheet more (i.e., deposits and securities fall).

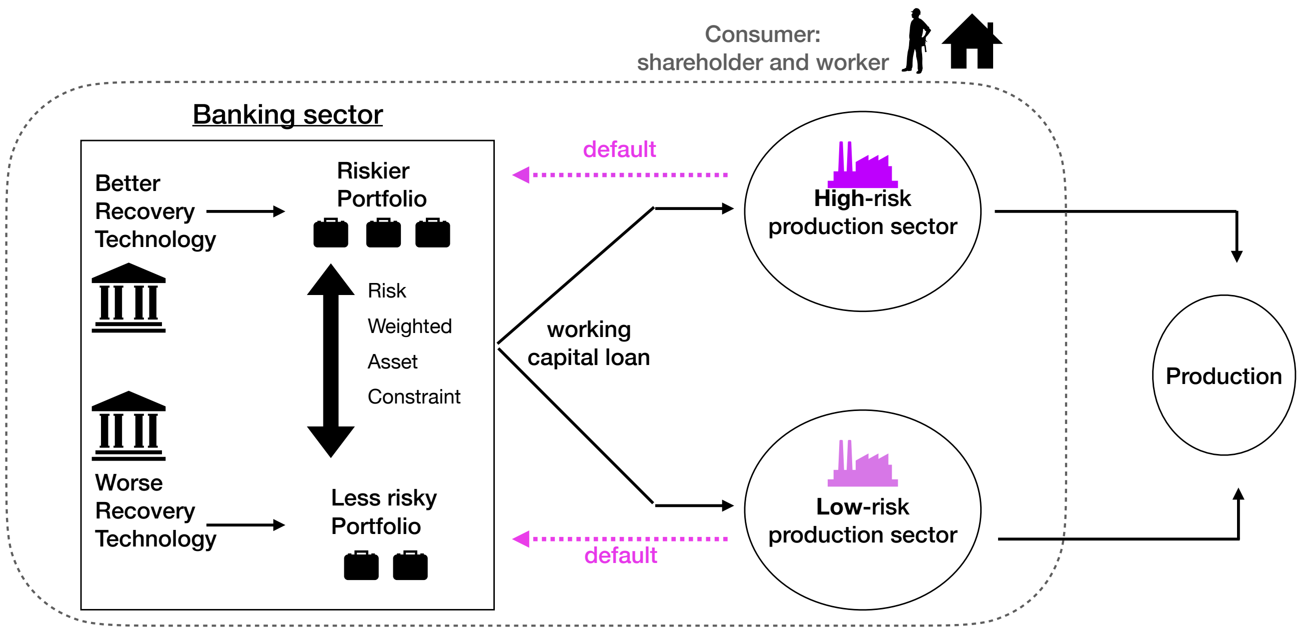
A possible mechanism is than an unanticipated increase in the Fed funds rate increases the probability of loan default. Therefore, banks reduce their exposure to all risky assets. In particular, in terms of portfolio composition and riskiness, higher-capitalized banks have a higher share of risky loans than lower-capitalized banks, and because they have a risk-sensitive capital requirement, they reduce loans even more than lower-capitalized banks. Thus, higher-capitalized banks reduce their overall loans more than lower-capitalized banks. This effect on lending will have a negative impact on economic activity.

3. Baseline model

In the second half of the paper, I develop a heterogeneous-bank model that considers risk-sensitive capital requirements to rationalize the empirical facts. This dynamic stochastic general equilibrium model is based on the Elenev et al. (2020) framework. The proposed model has three key elements. First, it has two banks that are heterogeneous in the recovery rates on defaulting loans and face capital regulation with a risk-weighted asset constraint. This assumption implies an endogenous difference in capitalization rates and portfolio composition. Second, it has two risky production sectors, with heterogeneous volatility in idiosyncratic productivity shocks on each sector. Additionally, these firms have a CES demand for loans, which implies differences in steady-state default rates and in lending responses to monetary shocks. Third, the aggregate fluctuations are driven by the monetary shock, where the deposit rate is given and follows a standard order-1 autoregressive process.

Figure 14 provides an overview of the model. The banking sector is composed by two banks. Additionally, Two productive sectors exists. One of them has higher idiosyncratic volatility than the other (high- and low-risk sectors). Banks are heterogeneous in the ability to recover losses from loans, face a regulatory constraint (a Basel I capital requirement with risk-weighted assets), and maximize the present-value dividends paid to their shareholders. They take the interest rate as given and can issue equity from consumers and extend loans to both production (non-financial) sectors. Banks cannot default. Importantly, banks extend high-risk lending to the firms in the high-risk productive sector and less risky lending to the firms in the low-risk sector. The bank lending is mostly in the form of working-capital loans. Both productive sectors can default their loans to the banks. Producers maximize profits and operate a production technology using labor and capital. They are funded by working-capital loans from banks. They also buy capital from consumers. Finally, consumers maximize inter-temporal expected utility, work for the firms (the labor supply is inelastic), and own firms and banks.

Figure 14: Overview of the model



3.1 Environment

The model is formulated in discrete time over an infinite horizon and has three agents: consumers, firms, and banks. I develop a heterogeneous-bank model in order to interpret the cross-sectional empirical evidence and understand monetary-policy transmission to bank lending considering the heterogeneity in bank capitalization rates. I describe the model in three blocks: (1) sectorial firm block, which captures the difference in default rates; (2) banking block, which generates the differences in capitalization rates, portfolio composition, and lending responses to a monetary shock; and (3) a representative consumer or household, which closes the model.

Two risky production sector block

Two types of firms $j \in \{H, L\}$ exist with heterogeneous risk. Each sector contains a continuum of firms facing an idiosyncratic productivity shock. I assume there is perfect risk-sharing. This assumption implies a representative firm exists in each sector with a default rate in equilibrium. Each risky productive sector uses a Cobb-Douglas production function with capital and labor $\boldsymbol{\ell}$:

$$Y_{t,j} = \omega_{t,j} K_{t,j}^{1-\alpha} \boldsymbol{\ell}_j^{\alpha}$$

where $\omega_{t,j}$ is drawn i.i.d. from c.d.f. gamma distribution , $E[\omega_{t,j}] = 1$, and $\sigma_{\omega_H} > \sigma_{\omega_L}$. Firm j issues debt to finance working capital to bank i, at interest rate $R^i_{t,j} = 1/q^i_{t,j}$. The firm's problem in each sector can be explained in two stages.

Stage I: Given the interest rates, firms determine what fraction of loans to borrow from each bank. I assume the representative firm has a preference for a variety for loans (multiple relationship). This assumption has an empirical counterpart; for example, for emerging markets, Khwaja and Mian (2008) present empirical evidence in the case of Pakistan that 60% of firms borrow from multiple banks, and 56% of lending is in the form of working capital. In an example for developed countries, in this case, Japan, Amiti and Weinstein (2018) show the median firm borrows from seven banks, and 97% of the firms in their sample borrowed from more than one bank.

Formally, the firm will solve a standard problem and I assume loans are differentiated by sector according to a CES functional form[8]:

$$\max_{\{L^1_j, L^2_j\}} \mathrm{WC}_{t,j} = \left(\sum_{i=1}^{2} (\nu_j)^{\frac{1-\sigma}{\sigma}} (L^i_j)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \quad s.t. \quad \left(\frac{1}{q^1_j}\right) L^1_j + \left(\frac{1}{q^2_j}\right) L^2_j = \left(\frac{1}{Q_j}\right) \hat{\mathrm{WC}}_j$$

where ν_j is a weight parameter, σ is the elasticity of substitution between the two types of loans, L^i_j denotes bank $i \in \{1, 2\}$ loans in sector $j \in \{H, L\}$, $\hat{\mathrm{WC}}_j$ is the amount of working capital needed for firm j, and Q_j is the aggregate-loan-price index of both banks' loans prices for firm j

[8]This preference for a variety of goods is very common in the international trade literature.

The solution to this problem provides the demand for loans as:

$$L^i_{t,j} = \overbrace{\left(\frac{\frac{1}{Q_{t,j}}}{\frac{1}{q^i_{t,j}}}\right)^{\sigma} (\nu_j)^{1-\sigma} \times \underbrace{\phi^j w_{t,j}\bar{l}_{t,j}}_{\text{working capital } (\bar{\mathrm{W}}\mathrm{C}_{t,j})}}^{\text{Loan's firm j (sector) demand for bank } j}.$$

Fundamentally, this assumption allows me to endogenously determine what fraction of working capital is provided by each bank. This fraction will depend on the interest rate, which in turn will depend on the recovery value of each bank, which is a technology parameter. Additionally, in equilibrium, banks coexist with an interior solution of portfolio composition.

Stage II: Given borrowing decisions, firms hire labor and buy capital at price p^K_{jt} to maximize the present discounted value of dividends paid to shareholders and produce final goods using the Cobb-Douglas production function. Failed producers are replaced by new producers.

The flow of profit for the firm is:

$$\underbrace{\omega_j k_j^{1-\alpha} l^{\alpha} - (1-\phi) w_j l - \frac{1}{Q_j}\mathrm{wc}_j}_{\text{profit flow}} \tag{7}$$

Producers with a negative profit flow are in default and shut down. Alternatively, a firm defaults if its sales do produce enough cash to pay back working-capital loans. The equation 7 implies a default threshold:

$$\omega^*_j = \frac{(1 + \phi^j(\frac{1}{Q_j} - 1)) w_j \bar{l}_j}{y_j} \tag{8}$$

Note that firms with low idiosyncratic shock $\omega_{t,j} < \omega^*_{t,j}$ default.
The firm's recursive problem is

$$V_j(n_j) = \max_{k'} div_j + \mathbb{E}_t[\mathcal{M}_{t,t+1} \tilde{V}_j(k'_j)] \tag{9}$$

$$\overbrace{n_j - p^{k_j} k'_j + \underbrace{\text{wc}_j}_{\text{new debt}}}^{\text{div}^j_{ft}} \geq 0 \tag{10}$$

$$n_j = \underbrace{\omega_j k_j^{1-\alpha} l^{\alpha} - (1-\phi) w_j l - \frac{1}{Q_j} \text{wc}_j}_{\text{profit flow}} + p^{k_j}(1-\delta^{k_j}) k_j \tag{11}$$

where $m_{t,t+1}$ is the stochastic discount factor for the firm, and

$$\tilde{V}_j(k_j) = \max_{l_j} [\Omega(\omega_j^*) \mathbb{E}_t (V_j(n_j) | \omega_j > \omega_j^*)] \tag{12}$$

Note that a firm hires labor before the idiosyncratic shock occurs. This equation 12 implies the firm chooses labor with the expected value of the firm's idiosyncratic productivity conditional on not defaulting. The complete solution of the firm problem is in Appendix F.1.

Banking-sector block

The banking-sector block consists of two banks $i \in \{1, 2\}$ that are intermediaries and grant loans to both sectors (high and low risk). The supply of deposits is perfectly elastic to the policy rate. These banks are owned by consumers and face equity-issuance costs. These two banks are heterogeneous in their default recovery rates $(1 - \zeta_j^i)$. They will receive a coupon payment on performing loans $\Omega(\omega_{t,j}^*) L_{t,L}^i$, and firms that default go into liquidation and banks repossess them, sell the current period's output, pay the current period's wage, and sell off the assets. Therefore, the total payoff per loan type unit j is:

$$\tilde{M}_{t,j}^i = \underbrace{\Omega(\omega_{t,j}^*)}_{\text{No default}} + \underbrace{\frac{(1-\Omega(\omega_{t,j}^*))}{L_{t,j}^i / q_{t,j}^i} \left[\varpi_{t,j}^i (1-\zeta_j^i) \left(\mathbb{E}_\omega[\omega < \omega^*] Y_t + ((1-\delta_j^k) p_t^{K_j}) K_{t,j} \right) - \varpi_{t,j}^i w_{t,j} \bar{l}_j \right]}_{\text{default (recovery value)}} \tag{13}$$

where ζ is the fraction of firm assets and output lost to banks in bankruptcy.

The bank portfolio consists of choosing the loan interest rate for each type of firm, subject to bank-capital regulation, that is a risk-weighted capital constraint:

$$\text{Networth}^i \geq \theta \underbrace{(\varpi_H L^i_{H,t} + \varpi_L L^i_{L,t})}_{\text{risk weighted assets}},$$

where ϖ_H, ϖ_L, are the risk weights for each type of loan.

The bank problem is:

$$V^i(N^i_t) = \max_{q_{Ai,t}, D^i_t, e^i_t} \underbrace{div^i_{bt} - e^i_t}_{Netdiv^i_{bt}} + E_t[\mathcal{M}^B_{t+1,t} V^i(N^i_{t+1})] \tag{14}$$

$$N^i_{t-1} + D^i_t + e^i_t = L^i_{t,H} + L^i_{t,L} + div^i_t + \Psi^i(e^i_t) \qquad \text{(budget constraint)} \tag{15}$$

$$D^i_t \leq \xi_H L^i_{t,H} + \xi_L L^i_{t,L} \qquad \text{(leverage constraint)} \tag{16}$$

$$\pi^i_t = (\frac{\tilde{M}^i_{t,j}}{q^i_{t,H}} - 1)L^i_{t,H} + (\frac{\tilde{M}^i_{t,j}}{q^i_{t,L}} - 1)L^i_{t,L} - (R_t - 1)D^i_t \qquad \text{(profit flow)} \tag{17}$$

$$N^i_t = N_{t-1} + \underbrace{\pi^i_t - div^i_t + e^i_t - \Psi^i(e^i_t)}_{\text{retaining earnings + equity injections}} \qquad \text{(Law of motion of networth)} \tag{18}$$

The complete solution to the bank problem is in appendix F.2.

Representative household

A representative household with log-utility preferences over consumption is represented by an expected utility function:

$$\mathbb{E}_t \left[\sum_{t=0}^{\infty} \beta^t \left[log(C_t \right] \right] \tag{19}$$

where β is the discount factor. Households are the owners of firms and banks. They provide labor in fixed supply and choose consumption and investment in both sectors subject to a budget constraint. The consumer problem is:

$$\max_{C_t, X_t^A, X_t^M} \mathbb{E}_t \left[\sum_{t=0}^{\infty} \beta^t \left[log(C_t \right] \right] \tag{20}$$

s.t.

$$C_t + \sum_{i=1}^{2} (X_t^j + \Psi(X_t^j, K_t^j)) \leq w^j \bar{L} + \sum_{j=1}^{2} \text{div}_t^j + \sum_{i=1}^{2} \text{Netdiv}_t^i + \sum_{j=1}^{2} p_t^{K^j} X_t^j \tag{21}$$

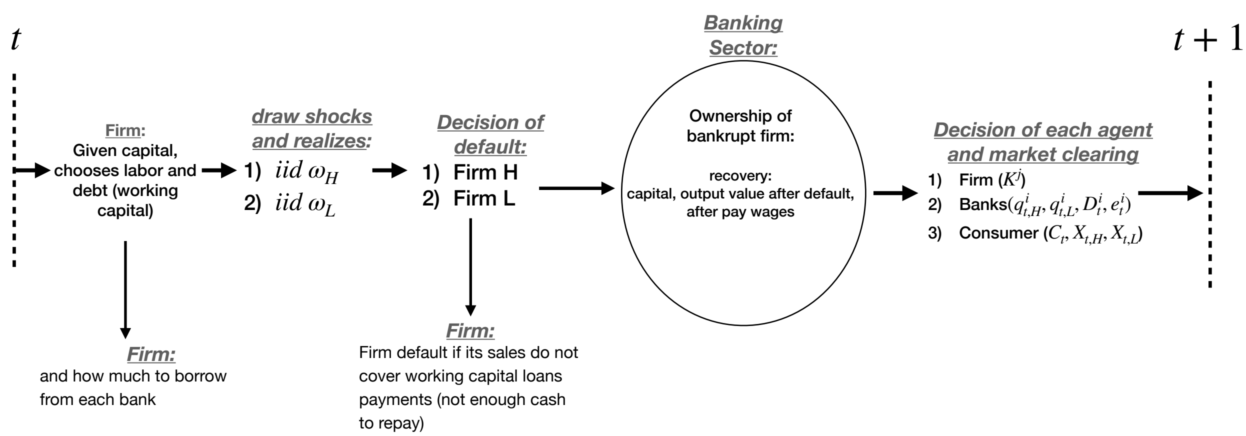
$$K_{t+1}^j = (1 - \delta_K) K_t^j + X_t^j \tag{22}$$

The complete solution of the consumer problem is in Appendix G.

Timing:

Figure 15 summarizes the timing of the model.

Figure 15: Timing



At the beginning of period t, given capital, firms choose labor and working capital. Firms also decide how much to borrow from each bank. Idiosyncratic productivity shocks for intermediate-good producers are realized in each sector and then their production occurs. Firms default if their sales do not cover working-capital loans payments or they do not have enough cash to repay. Banks assume ownership of bankrupt firms. Firms decide how much of the capital to take. All agents solve their consumption and portfolio choice problems. The market clears and all agents consume.

Competitive Equilibrium

Equilibrium is defined in the standard way. Competitive equilibrium is a sequence of monetary-policy shocks $\{\epsilon_t^{MP}\}$, and an idiosyncratic productivity shock $\{\omega_{t,j}\}$ for each sector $j \in \{H, L\}$, and competitive equilibrium is defined as an allocation of:

- $\{C_t, X_{t,H}, X_{t,L}\}$ for consumers
- $\{K_{t,j}\}$ for firms $j \in \{H, L\}$
- $\{D_{t,i}, e_{t,i}, q_{t,i}^j\}$ for banks i in $\{1, 2\}$
- A set of prices

Such that given prices:

1. Consumers maximize life-time utility subject to their constraint.
2. Producers in each sector maximize dividends subject their constraints.
3. Banks maximize net dividends subject to their constraints.
4. The market clears.

3.2 Mechanism

This section explains how the primitive model delivers the qualitative results that I show in the empirical-evidence section.

First, I explain the relationship between recovery rates and risky portfolio share. Higher-recovery banks wish to lend more. In particular, they allocate a higher share of their portfolio to the riskier sector. Additionally, as these banks grant more loans, they need more funds to provide more loans (both deposit and equity issuance). The underlying idea is comparative advantage. The easy way to approach the matter is that if a bank has a 100% recovery (i.e., it is good at risky-business recovery), then it will specialize in those kinds of loans. By contrast, if the other bank has a lower recovery performance (i.e., cannot recover 100 %), it will try to specialize in relatively less risky (safer) business.

Second, I explain the recovery and capitalization rates. The financing constraint is a function of risk-weighted assets. The regulator does not understand one bank has better technology than the other (i.e., they do not know the recovery rates for each bank) and imposes the same risk-weighted constraint on both banks. Therefore, banks with better skills or with higher recovery rates are able to invest in risky firms (or risky sectors), but they might not have the necessary capital to do so. Therefore, they need to be better capitalized. Note that, in my model, the recovery rate is not a property of the asset: it is a property of the bank, namely its technology.

The following example can illustrate the situation: Two banks exist. One of them has a comparative advantage in asset management, but it is mandated to deploy the same amount of capital as a less efficient bank. In a two-sector economy, the better bank is able to manage the riskier sector better; that is, it is willing to invest more in the risky sector because it has a comparative advantage, which makes its portfolio riskier. The regulator mandates a higher capital requirement on this bank than on the bank that invests in safer assets (less risky portfolio). Providing the capital is costly for the more efficient bank, so imposing the risk-weighted constraint actually pushes it away from the risky sector. This constraint affects the better bank more than proportionally, because it is investing more in the risky sector. Therefore, the bank with portfolio riskier will tend to withdraw more intensively away from the riskier sector, but to the extent that it equalizes its portfolio composition with the worse bank. The better bank will actually push the portfolio composition to the same structure as the worse bank. Therefore, now they will face the same collateral constraint (or regulatory constraint), because they have the same asset composition. However, the better bank has the same constraint, but the advantage of managing the riskier sector; therefore, it would still be willing to invest more in the riskier sector, but would need to be better capitalized to do so.

Note that with these two relationships, banks with higher recovery rates will have a riskier portfolio share and a higher capitalization rate to meet regulations.

Third, considering the sensitivity of well-capitalized banks to monetary-policy shocks is important. The sequence is as follows: increase in the policy interest rate, increase in loan rates, the firm's loan default probabilities increase. All banks respond by reducing their lending, but higher capitalized banks- the ones with riskier assets- do so by more.

3.3 Parameterization and Results

In this section, I use the model to analyze in detail the novel channel of heterogeneous transmission of monetary-policy shocks through differences in capitalization rates. I calibrate the model under the assumption of bank heterogeneity on recovery defaulting loans, as primitive parameter, that face risk-weighted capital requirement. Then, I compute the deterministic steady-state, and I shock the economy with a positive monetary policy-shock to verify the model performance in terms of my key features of the micro data.

3.3.1 Calibration

Household preferences and production function. For simplicity, I assume standard preferences for the consumer $u(C) = logC_t$ or I set the intertemporal elasticity of substitution (IES) to 1. The consumer's discount factor β is set to 0.85. On the production side, the labor share α in the final good is set to 0.71, which is a standard value in the business-cycle literature. For the investment sector, I also assume standard quadratic specification for the investment adjustment cost, and I set the marginal adjustment-cost parameter Ψ to 2 to match the adjustment cost and its first derivative to zero in the steady-state. For the working capital loan, the corporate-finance literature shows a firm requires to cover its cash-flow mismatch between the payments made at the beginning of the period and the realization of revenues; see Mahmoudzadeh et al. (2018). I set the working capital parameters to 0.8, which is in line with Galindo Gil (2020) and Christiano et al. (2010). In the case of the CES functional form to the firm, I set an elasticity of substitution between loans $\sigma = 7$, implying a standard elasticity between these banks typically used between monopolistically competitive goods. Also, I set the weighting parameters $\nu_1 = 1.12$ and $\nu_2 = \left(1 - \nu_1^{1-\sigma}\right)^{\frac{1}{(1-\sigma)}}$ to banks hold 50 $\%$ of the loans in equilibrium when no heterogeneity exists in recovery rates.

Idiosyncratic Productivity. Idiosyncratic shocks are assumed to be gamma distributed with parameters μ_ω and σ_ω. I normalize the mean of idiosyncratic productivity at $\mu_\omega = 1$ for both sector $j \in \{H, L\}$. In the case of the low-risk productive sector, the cross-sectional standard deviation of the idiosyncratic productivity $\sigma_{\omega,L}$ targets the unconditional mean of the default rate. The model-implied average default rate of 2% is similar to the data corresponding to the average delinquency rate of 2% for the residential real estate loans. In the case of the high-risk productive sector, the cross-sectional standard deviation of the idiosyncratic productivity $\sigma_{\omega,H}$ targets the unconditional mean of the default rate. The model-implied average default rate of 3% is similar to the data corresponding to the average delinquency rate of 3% for the commercial and industrial loans.[9]

Banking sector. The intermediaries face the risk-weighted capital constraint. The capital requirement or minimum regulatory equity-capital requirement θ is set to 8% of risk-weighted assets, the risk weights for the riskier type of loan is set ϖ_H set to 1, and risk weight to less risky type of loan is set ϖ_H set to 0.8, consistent with the general requirement for banks under Basel I regulatory framework (BCBS (1998)). The dividend target of banks ϕ_0 and the marginal bank equity-issuance cost ϕ_1 are set to 0.096 and 7, respectively, as in Elenev et al. (2020). Two parameters drive the heterogeneity in the banking sector, namely, the recovery rates on defaulting loans. I construct a proxy of recovery rates using the bank-level data. Over my period of analysis, the top 90th percentile of the bank capitalization rate have, on average, 0.4 of recovery rates in personal loans and have, on average 0.32 of recovery rates in real estate loans. In addition, the bottom 10th percentile of the bank capitalization rate have, on average, 0.33 of recovery rates in personal loans and have, on average, 0.21 of recovery rates in real estate loans.

I construct a proxy of recovery rates as a ratio of recoveries on allowances for loan and lease losses to charge-offs on allowances for loan and lease losses using the bank-level data.[10] Over my period of analysis, the top 75th percentile of bank's recovery rates in $C\&I$ loans and real estate loans are, on average, 0.8 and 0.5, re-

[9] From the Federal Reserve Board of Governors, I obtained delinquency rates on Residential Real Estate, and Commercial and Industrial loans by U.S. Commercial Banks for the period 1990-2007.

[10] The recoveries on allowance for loan and lease losses and charge-offs on allowance for loan and lease losses can be found in the "Call Report" data base as (*RIAD4605*),(*RIAD4265*) respectively. For further references, see The Fed- Micro Data Reference Manual.

spectively, over the sample. Then, I assume bank 1, has a higher recovery rate in both sectors equal to 0.8, and bank 2 has a lower recovery rate of 0.2 in the high-risk sector and 0.5 in the low-risk sector. Finally, Christiano et al. (2010) suggest that the persistence and the standard deviation of the interest-rate shock in terms of monetary policy are 0.87 and 0.51, respectively. However, not all the volatility of the monetary shock is transmitted to the interest rate of loans. As a result, I assume the relevant volatility of the interest rate shock for the firm is one fifth of the corresponding to monetary policy $\sigma_R = 0.01$ and less the persistence $\rho_R = 0.7$.

Table 5: Parameters of the model

Parameter	Name	Value	Target/Sources
	Preferences		
β	Discount factor	0.85	See text
η	IES	1	Log Utility
	Technology $j \in \{H, L\}$		
α	labor share	0.71	Standard
Ψ	capital-adjustment cost	2	Standard
δ_K	depreciation rate	8.25%	Standard
ϕ_K	working-capital parameter	0.8	Christiano et al. (2010)
σ	elasticity of substitution	7	See text
ν	weighting parameter	1.12	See text
	Banking: Banks $i \in \{1, 2\}$		
$[1-\zeta_H^1, 1-\zeta_L^1]$	bank 1 recovery rates on defaulting loans	[0.8,0.8]	See text
$[1-\zeta_H^2, 1-\zeta_L^2]$	bank 2 recovery rates on defaulting loans	[0.2,0.5]	Elenev et al. (2020)
ϕ_0	target bank dividend	0.096	Elenev et al. (2020)
ϕ_1	bank equity-issuance cost	7	Elenev et al. (2020)
θ	regulatory constraint	0.08	Basilea I
$[\varpi_H, \varpi_L]$	risk weights to each type loan	[1, 0.8]	Basilea I
	Shock parameters or shock structure		
ρ_R	persistence of policy rate	0.7	Standard
σ_R	volatility of policy rate	0.01	Standard
σ_{ω_L}	volatility idiosyncratic low-risk sector	0.03	Default rate 2%
σ_{ω_H}	volatility idiosyncratic high-risk sector	0.05	Default rate rate 3%

Steady state and monetary policy analysis

Table 6 shows the portfolio composition in the steady state. I find that higher-capitalized banks have a higher portfolio share of risky assets than lower-capitalized banks. This finding proves a qualitative result that I find in my empirical exercise. Figures 16 and 17 show the response of variables such as deposits, loans, and default rates after a one-percentage-point increase in the interest rate.

Table 6: Portfolio composition, **Fact 3**

Steady State		
	Portfolio Composition	
	High-risk sector	Less-risk sector
High-cap bank	53%	47%
Low-cap bank	45%	55%

Figure 16: Experiment: Monetary-policy shock and Fact 1

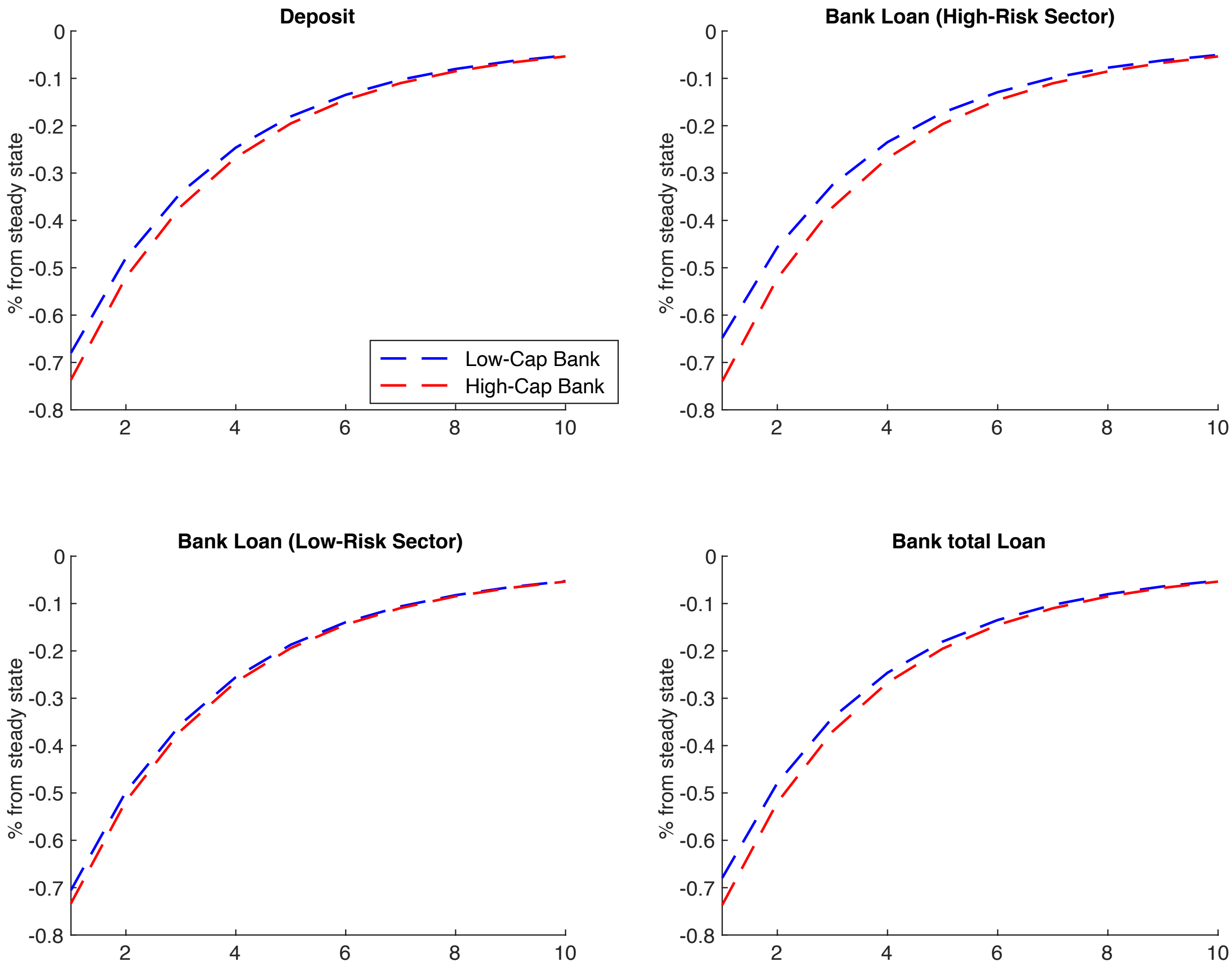
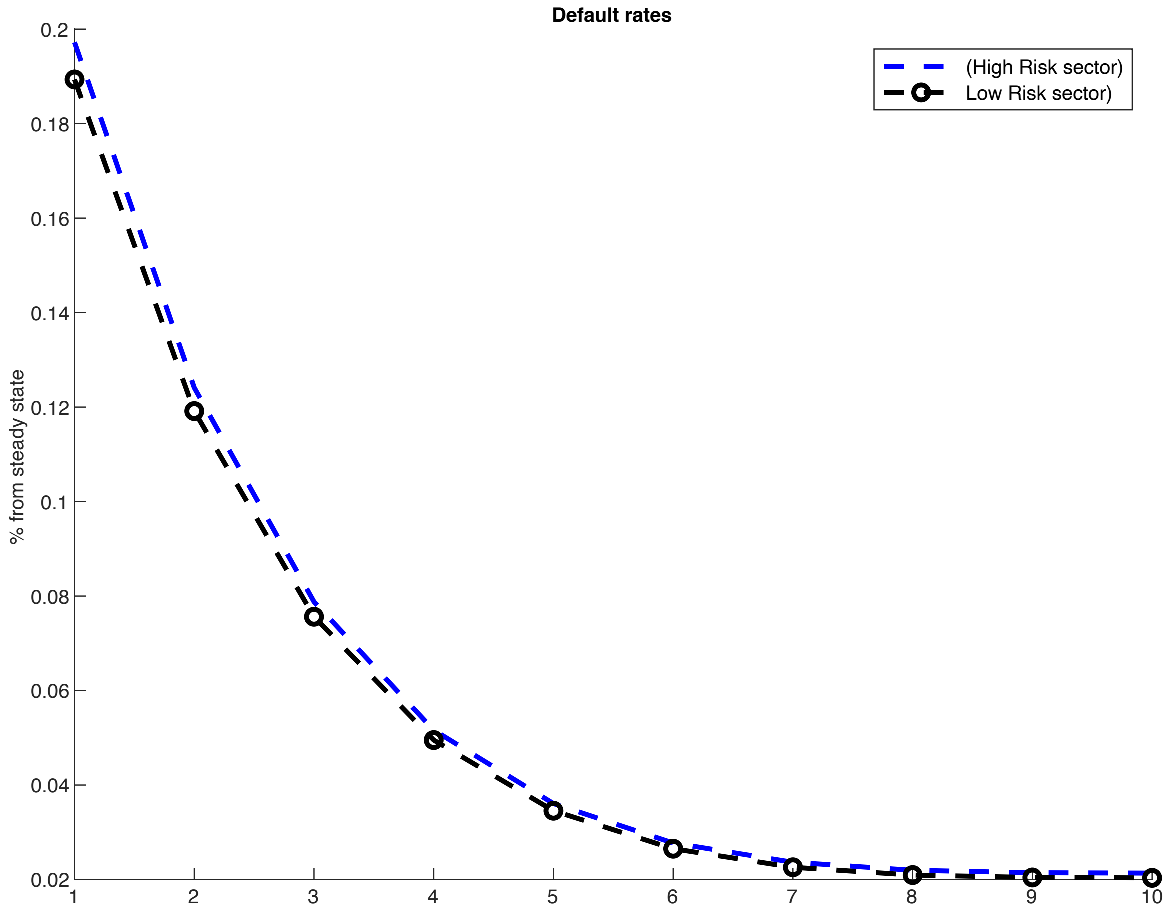


Figure 17: Experiment: Monetary-policy shock and Fact 2



3.4 Model vs. Data

This section compare the empirical regression on impact to the model, and show some evidence on the link between capitalization rate and recovery rates.

Banks' lending response vs. cross-sectional interaction coefficients

This section discusses how the model captures the interaction coefficient from the empirical evidence in terms of the sensitivity of the response to a monetary shock as a function of the capitalization rate. First note that from the data, a standard deviation of the bank capitalization rate is 4.5 percentage points, and banks with a capitalization rate of one standard deviation above the mean reduce lending by $\beta^{\text{micro}} = -0.76$ percentage points.

In the model, the steady-state difference between high and low bank capitalization rates is $\Delta_{HL}^{model} = 0.2$ percentage points. At this point, I perform an exercise to compare the lending response of banks whose capitalization rates differ by as much as the capitalization rate in the model. First, the high-capitalization relative response of lending, normalized = $\frac{\beta^{\text{micro}}}{SD_{data}} \times \Delta_{HL}^{model}$ =-0.033 percentage points. Second, the model's high-capitalization relative response of lending: a 100-basis-point increase in the interest rate leads to a high-capitalization relative response of -0.0565 percentage points. Therefore, the model generates enough sensitivity in the response to capitalization rates as the data, but not enough difference in capitalization rates.

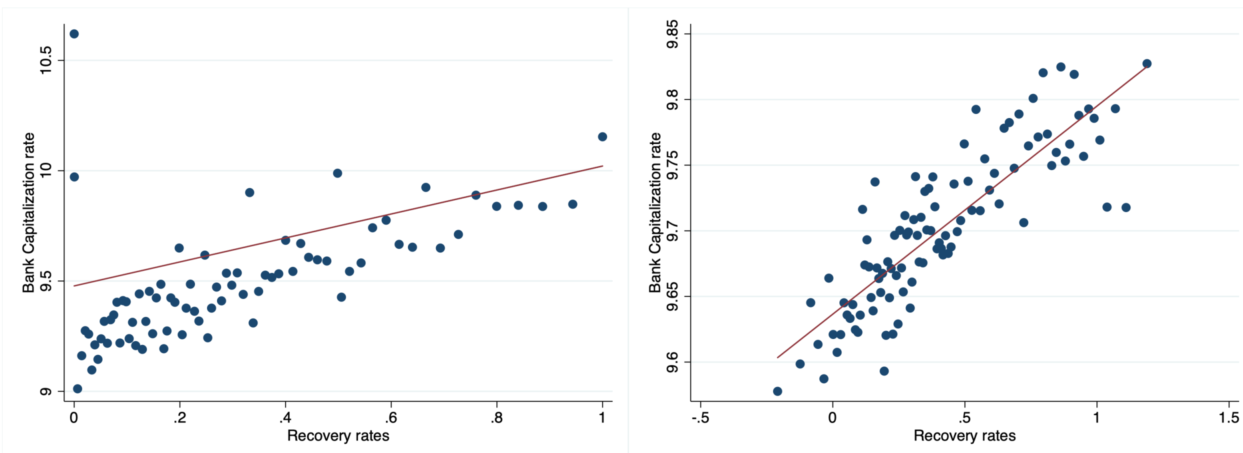
Proxy of recovery rates and capitalization rates in the data

In this subsection, I provide direct evidence of the relation between recovery rates and bank capitalization rates. In the model, I assume recovery rates on defaulting loans generate heterogeneity in capitalization rates. From the data, I construct a proxy of banks' recovery rates as a ratio of recoveries on allowances for loan and lease losses to charge-offs on allowances for loan and lease losses.[11] The left panel

[11] Recoveries on allowance for loan and lease losses(*RIAD4605*) and charge-offs on allowance for loan ans lease losses(*RIAD4265*) on the "Call Reports" data base. For further references, see The

of Figure 18 presents bin scatter plots of the bank capitalization rate against my proxy for bank recovery rates. It shows a positive relation between bank recovery rates and bank capitalization rates. This result is in line with the prediction of my model. Therefore, banks that are better at recovery tend to have a higher capitalization rate. The right panel is the same bin-scatter plot including bank fixed effects. This relation is strongly positive. This evidence strengthens the rationale of the proposed mechanism. See Appendix I for further details and the same analysis by loan type.

Figure 18: Proxy for recovery rates and capitalization rate



Fed- Micro Data Reference Manual.

Alternatively, I construct another proxy for recovery rates based on the recovery rates as a fraction of non-performing loans (past due 90 plus non-accrual). This information is available for my period of analysis at the Call Reports, but not for the full period in the case of loan type.. See Appendix J for further details. Figure 19 presents the average of the recovery rates on non-performing loans ratio by each capitalization-rate percentile group in the full sample. I show a positive relation between recovery rates and bank capitalization rate. Higher-capitalization-rate banks have, on average, a higher recovery rates on non-performing loans. In addition, Figure 20 presents bin-scatter plots of the bank capitalization rate against my proxy of banks' recovery rates on non-performing loans.

Figure 19: Recovery rates and capitalization rate

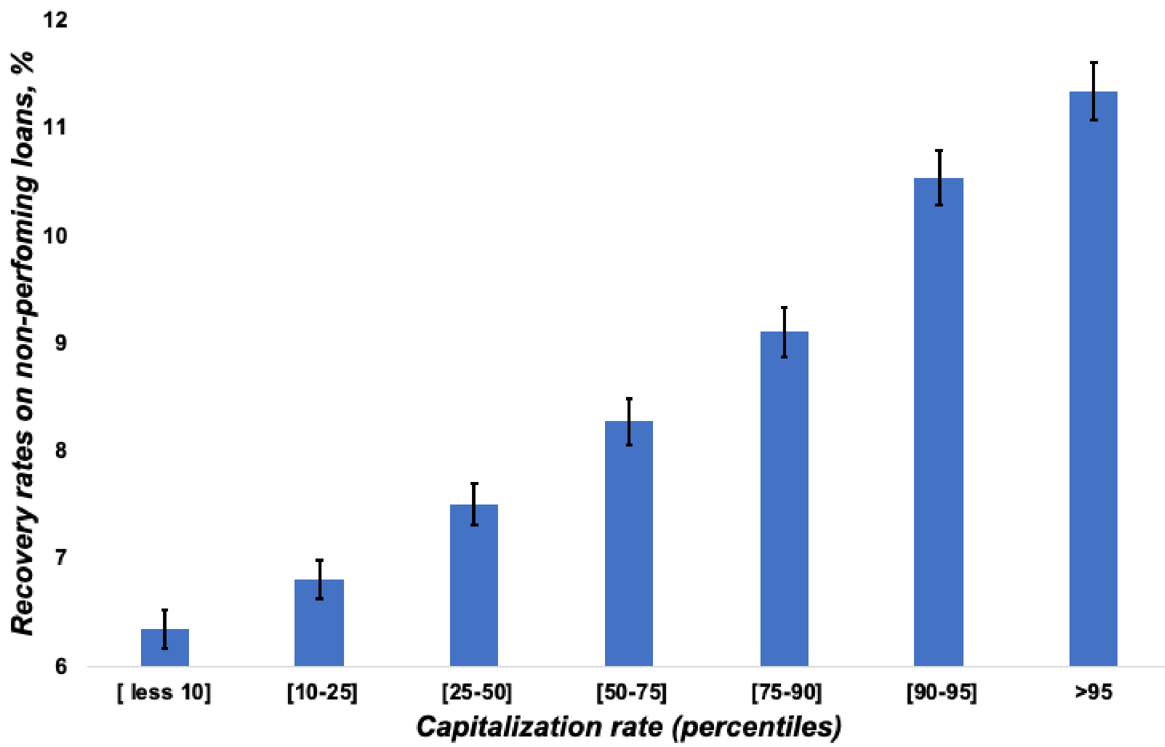
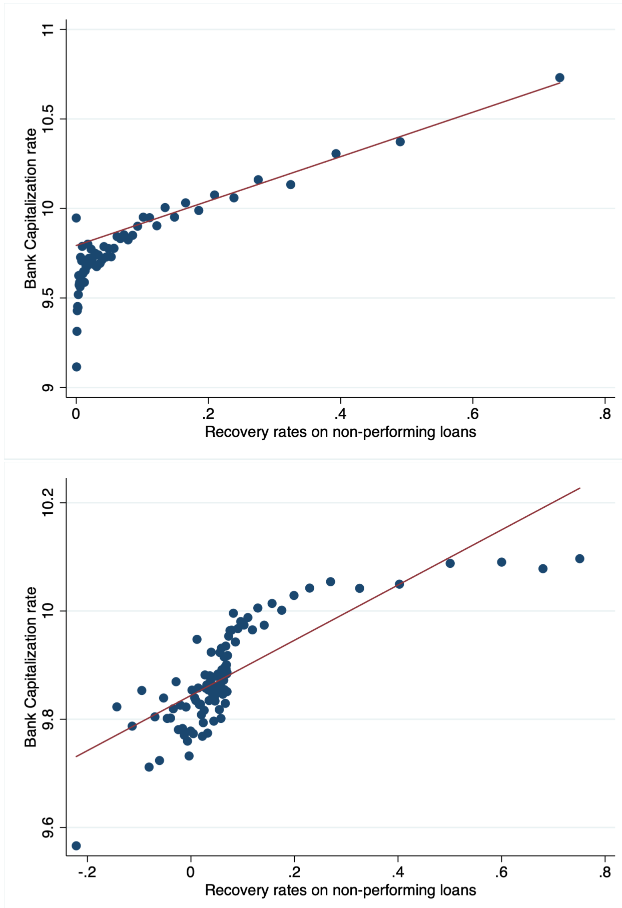


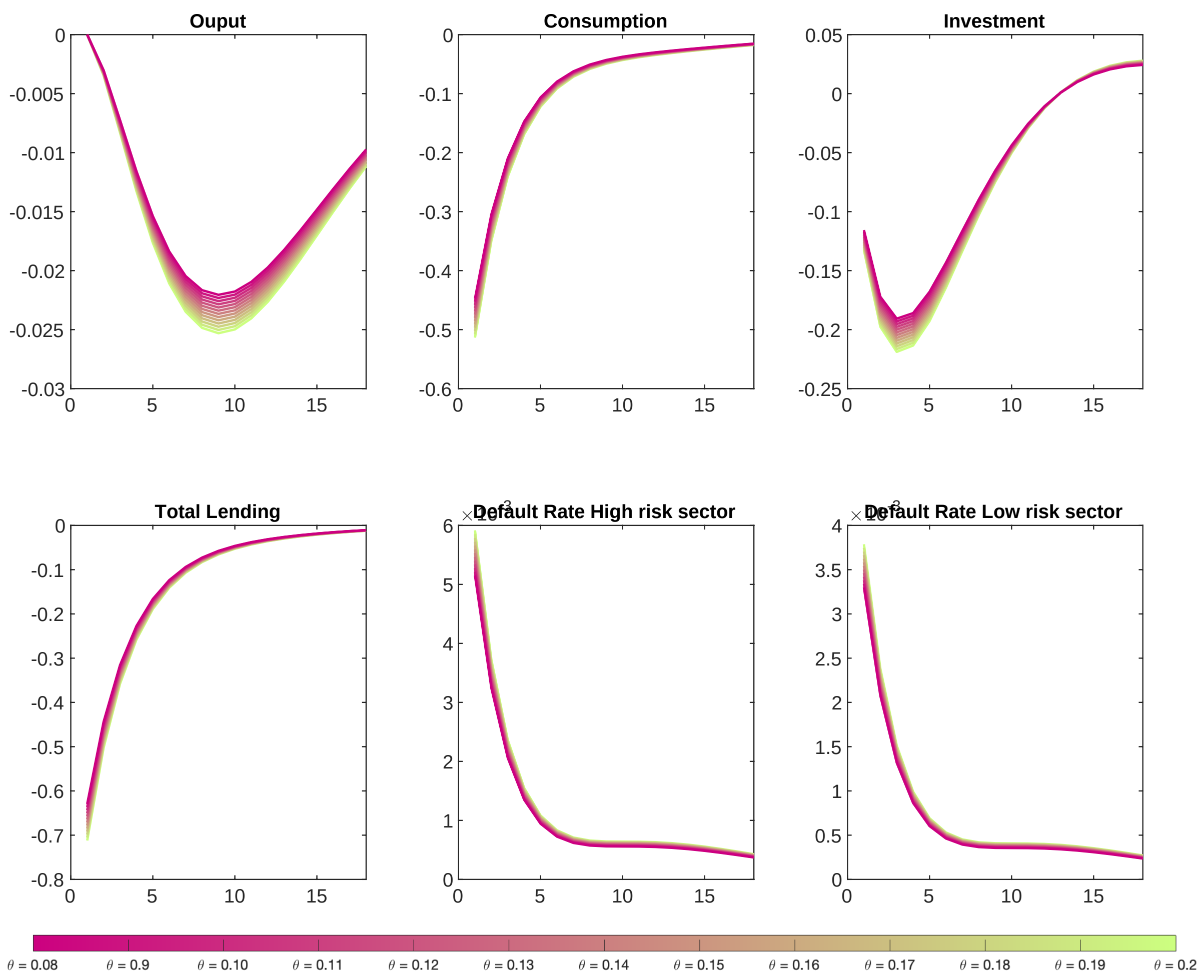
Figure 20: Recovery rates and capitalization rate



3.5 Counterfactual Analysis

This section discusses the effect of changing capital requirements. Figure 21 shows the effect on aggregate economic variables such as consumption, output, investment, total lending, and default rates. The dark red line represents the baseline case in which the capital requirement is 0.08, and the green line represents 0.2 of the minimum capital requirement. I find that as the capital requirement increases, the effects of a monetary shock are more adverse; that is, higher capital requirements amplify the effects of a monetary-policy shock.

Figure 21: Aggregate: Delinquency responses to monetary-policy shock



4. Conclusion

In this paper, I assess the role of heterogeneity in bank capitalization in the pass-through of monetary policy to bank lending. I provides new empirical evidence using bank-level data, where I find the capitalization rate plays a crucial role in the transmission of monetary policy to bank lending. Highly capitalized banks have a higher share of commercial and industrial loans and personal loans, which are riskier than real estate loans. Highly capitalized banks contract more after a monetary-policy tightening, in contrast to the "capital view" Van den Heuvel (2002). I also propose a theoretical mechanism to support the empirical evidence, based on the default channel and the risk composition of banks' portfolios. In addition, I develop a dynamic macro model with a novel bank-heterogeneity feature in the recovery rates for defaulting loans and the interaction with a risk-weighted asset constraint. Finally, I show in a counterfactual exercise that a higher capital requirement amplifies the effects of monetary policy.

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A. Empirical Appendix

A.1 Capitalization rate distribution

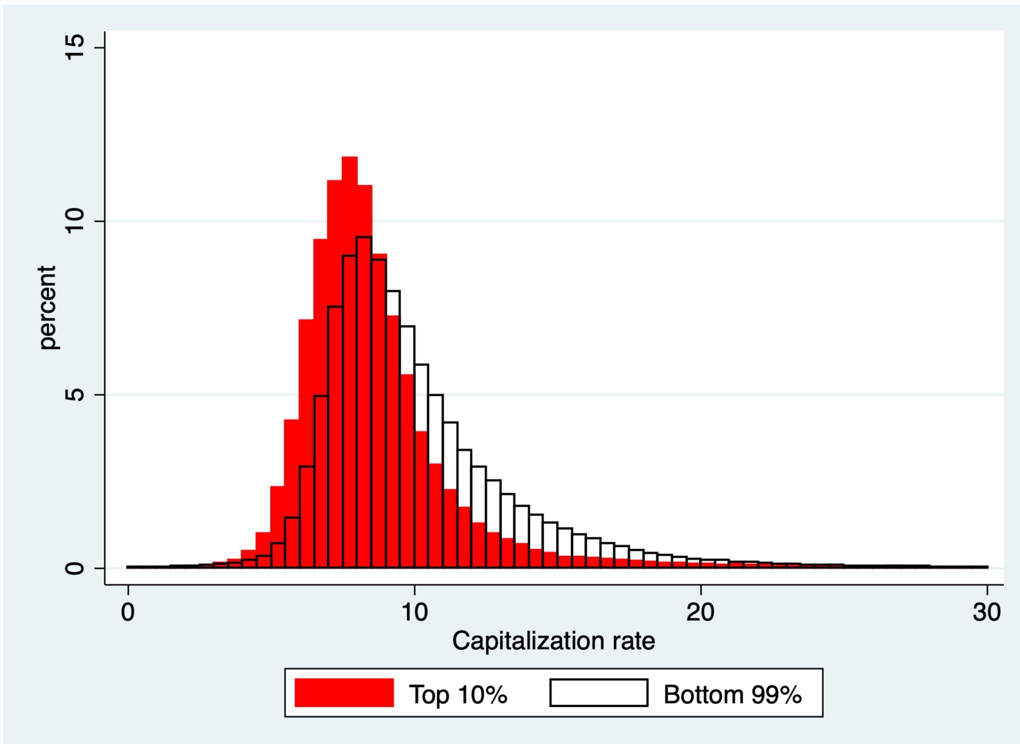


Figure 22: Summary Statistics:

fraction total assets (%)	1990		2000		2007	
	top 10 %	bottom 90%	top 10 %	bottom 90%	top 10 %	bottom 90%
Cash/ fed fund repo	12.3	13.9	7.8	9.2	5.8	9.7
Securities	20.7	30.2	23.2	26.0	17.6	20.9
Loans	63.8	52.8	64.7	61.3	70.2	65.1
Deposits	81.1	88.4	73.9	83.4	74.3	81.8
Other borrowing, fed funds repo	8.0	0.9	13.2	4.1	12.2	4.8
Equity	7.2	9.4	9.1	11.4	10.6	12.5

(Top 10% and bottom 90% refers to total assets)

This table shows deposits and loans are the most important parts of the balance sheet.

A.2 Monetary-policy shock

The measure of monetary shocks is using the high-frequency movements in the Federal funds rate in a short window of time around the FOMC announcements or policy meeting (known as an event-study approach). Following Gurkaynak (2005), Gorodnichenko and Weber (2016), Wong (2019), and Ottonello and Winberry (2020). The monetary-policy shock is constructed as

$$\epsilon_t^{MP} = \frac{M}{M-t}\left(r_{t+\Delta^+}^{FFR} - r_{t-\Delta^-}^{FFR}\right),$$

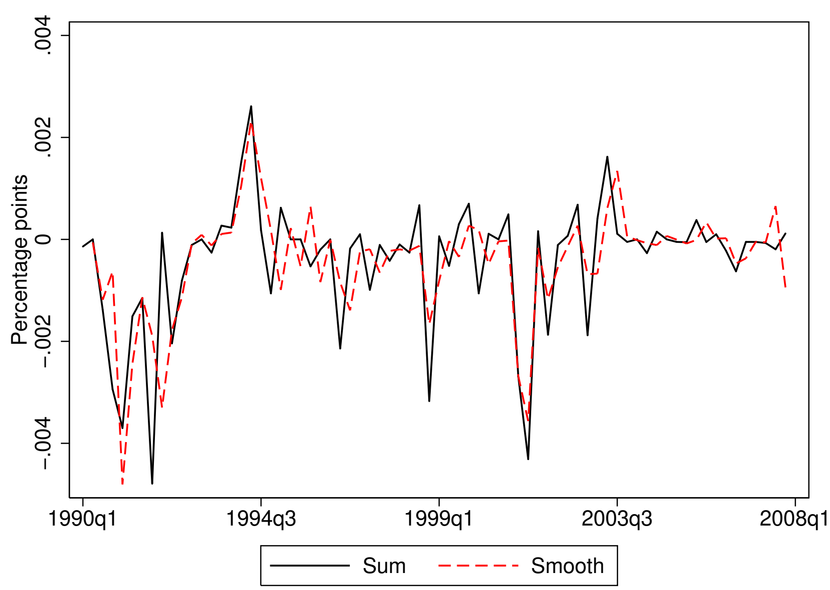
where M is the number of days in a month, t is the time of the monetary announcement, r_t^{FFR} is the average Fed funds rate in the month based on Fed funds futures contract rate up to time t[12], Δ^- is 15 minutes before the policy announcement, and Δ^+ is 45 minutes after the announcement. The shock series begins, in 1990 and ends in 2007 in order to focus on conventional monetary policy. Table 7 shows some moments of the shocks. First, the raw data have 164 shocks with a mean of approximately zero and a standard deviation of 9 basis points. Second, the second column of the table shows the statistics of the monetary-policy shock smoothed , as, for example, in Ottonello and Winberry (2020). I construct a moving average of the raw shocks weighted by the number of days in the quarter after the shock occurs. Third, I show the statistics of monetary-policy shocks by simply summing all the shocks that occur within a quarter, as, for example, in Wong (2019). Figure 23 shows a time-series graph of the monetary-policy shocks for different time aggregations. All my results are based on the monetary-policy shocks, using the time aggregation of simply summing all the shocks within any quarter. For robustness, I also use the alternative time aggregation of monetary-policy shock smoothed. My results using these alternative shocks do not significantly differs.

[12]Fed funds futures have been traded on Chicago Board of Trade since 1988. The contract for a particular month that pays the average of the effective Federal funds rate over the month.

Table 7: Summary statistics of monetary-policy shock

	high frequency	smoothed (quarterly)	Sum (quarterly)
mean	-0.019	-0.043	-0.042
median	0	-0.0127	-0.0051
std	0.086	0.108	0.124
min	-0.463	-0.480	-0.479
max	0.152	0.233	0.261
num	164	71	72

Figure 23: Monetary-policy shocks



B. Comparison to Existing Empirical Literature

This subsection relates my findings to empirical studies documenting heterogeneous responses across banks with different market power on deposits. Subsection B.1 replicates the results of Drechsler et al. (2017) with my sample and shows including their measure of market power does not affect my results. Subsection B.2 reconciles the empirical evidence of Van den Heuvel (2002) regarding the capitalization rate. Subsection B.3 reconciles the empirical evidence of Kashyap and Stein (2000) regarding the liquidity variable. Note my results differ from the abovementioned due to three main characteristics: (1) I use an identified monetary policy shock instead of changes on the Fed funds rate;[13] (2) I use a different sample period; and (3) the econometric specification is a panel-data regression. Table 8 summarizes the main differences concerning the main empirical literature that studies the heterogeneous response across banks with different capitalization rates, market power on deposits, and liquidity in the U.S. economy.

B.1 Relation for Drechsler et al. (2017) and market power on deposit

Drechsler et al. (2017) show banks with more market power are more sensitive to changes in the Fed funds rate. First, I replicate their result using my bank-level data, their measure of market power on deposits, and their specification. Table 9 shows my results, which are consistent with Table VIII in Drechsler et al. (2017). Note the data are at the bank-quarter level and cover all commercial banks from January 1994 to December 2013. My estimates are consistent with their paper. Second, I replicate the same table, but I consider standard errors clustered at the time and bank levels on the regression.[14] Table 10 shows the results where I consider

[13]The Fed's action creates a well known endogeneity problem in response to changes in economic conditions.

[14]Clustering at the bank level allows for fully flexible dependence in the error terms across time within each bank, thereby affecting the estimated standard error. To provide the most conservative confidence intervals, I also cluster at the time level. Without doing so, any confidence intervals on

Table 8: Comparison with main existing empirical literature

	Monetary-Policy Measure	**Sample Period** and **frequency**	**Individual Analysis**	**Econometric Specification**
Paz (2020)	High-frequency identification	1990-2007 quarterly	Bank Level	-Linear regression with bank controls, interaction term, bank fixed effect, state X times fixed effects. Standard errors are clustered at bank and time level, macro controls. -Dynamic: Local projection Method -Robustness: Non-linear regression
Drechsler, I., Savov, A., and Schnabl, P. (2017, QJE)	Change in Fed funds	1994-2013 quarterly	Bank Level	Linear regression with interaction term, bank fixed effect, and quarter fixed effects. Standard error are clustered by bank.
Van den Heuvel, (2012,BEJM)	Change in Fed funds, Bernanke-Mihov indicator	1969-1995 annual	State Level	Linear regression with interaction term, with state fixed effects.
Kashyap, A. K. and Stein, J. C. (2000, AER)	Change in Fed funds, Bernanke-Mihov indicator	1973-1996 quarterly	Bank Level	Two-Step regression for different size class.

standard errors clustered at the time and bank levels. The results on the deposit side are still negative and significant. Still, the result on the asset side, particularly for total loans and real estate loans, is not significant. Third, I want to be able to compare my results with their table. Therefore, I replicate the same table, but considering my sample period until 2007, because I focus only on conventional monetary policy and end the sample before the GFC. Additionally, after 2008, monetary policy is not based on the interest rate, but on unconventional monetary policy such as QE and forward guidance. Therefore, using the interaction with the Fed-funds-rate changes could yield misleading results, because it was not the main monetary policy tool after 2008. Tables 11 and 12 show the results considering the pre-crisis period, but for the case standard errors clustered at the bank level and the case standard errors at the time and bank levels, respectively. In the case of deposits, the interaction coefficient is negative and statistically significant. Banks with higher market power are more sensitive to monetary-policy tightening measures by changes in the Fed funds rate. In addition, in the case of loans, the

estimates presented tend to be considerably narrower.

interaction coefficient is positive and not statistically significant. I use this coefficient interaction to compare with my result at impact response and the dynamic response.

Table 9: Bank-level results replication of deposit channel - Bank liabilities and lending,1994-2013

VARIABLES	ΔTotal deposit (1)	Δ Deposit spreads (2)	Δ Savdep (3)	Δ Time deposit (4)	Δ Wholesale (5)	Δ Tot liab (6)
$\Delta FF\times$ bank HHI	-1.493***	0.063***	-1.212***	-2.181***	2.403**	-1.296***
	[0.145]	[0.009]	[0.244]	[0.213]	[0.947]	[0.139]
Bank f.e.	Y	Y	Y	Y	Y	Y
Quarter f.e.	Y	Y	Y	Y	Y	Y
Cluster Bank Level	Y	Y	Y	Y	Y	Y
Cluster Time Level	N	N	N	N	N	N
Observation	565,341	565,341	565,341	565,341	565,341	565,341
R^2	0.160	0.364	0.078	0.166	0.033	0.172
VARIABLES	Δ Total assets (1)	Δ Cash (2)	Δ Securities (3)	Δ Total loans (4)	Δ Real estate loans (5)	Δ C&I loans (6)
$\Delta FF\times$ bank HHI	-1.215***	-2.393***	-0.948***	-0.491***	-0.878***	-0.973***
	[0.124]	[0.664]	[0.337]	[0.152]	[0.200]	[0.353]
Bank f.e.	Y	Y	Y	Y	Y	Y
Quarter f.e.	Y	Y	Y	Y	Y	Y
Cluster Bank Level	Y	Y	Y	Y	Y	Y
Cluster Time Level	N	N	N	N	N	N
Observation	565,341	565,341	565,341	565,341	565,341	565,341
R^2	0.173	0.050	0.062	0.219	0.172	0.060

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 10: Bank-level results replication of deposit channel - Bank liabilities and lending, 1994-2013

VARIABLES	ΔTotal deposit (1)	Δ Deposit spreads (2)	Δ Savdep (3)	Δ Time deposit (4)	Δ Wholesale (5)	Δ Tot liab (6)
$\Delta FF\times$ bank HHI	-1.493***	0.063***	-1.212	-2.181***	2.403	-1.296***
	[0.506]	[0.020]	[0.939]	[0.447]	[2.822]	[0.460]
Bank f.e.	Y	Y	Y	Y	Y	Y
Quarter f.e.	Y	Y	Y	Y	Y	Y
Cluster Bank Level	Y	Y	Y	Y	Y	Y
Cluster Time Level	Y	Y	Y	Y	Y	Y
Observation	565,341	565,341	565,341	565,341	565,341	565,341
R^2	0.160	0.364	0.078	0.166	0.033	0.172
VARIABLES	Δ Total assets (1)	Δ Cash (2)	Δ Securities (3)	Δ Total loans (4)	Δ Real estate loans (5)	Δ C&I loans (6)
$\Delta FF\times$ bank HHI	-1.215***	-2.393**	-0.948	-0.491	-0.878	-0.973**
	[0.408]	[1.072]	[0.738]	[0.502]	[0.549]	[0.462]
Bank f.e.	Y	Y	Y	Y	Y	Y
Quarter f.e.	Y	Y	Y	Y	Y	Y
Cluster Bank Level	Y	Y	Y	Y	Y	Y
Cluster Time Level	Y	Y	Y	Y	Y	Y
Observation	565,341	565,341	565,341	565,341	565,341	565,341
R^2	0.173	0.050	0.062	0.219	0.172	0.060

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 11: Bank-level results replication of deposit channel - Bank liabilities and lending, 1994-2007

VARIABLES	ΔTotal deposit (1)	Δ Deposit spreads (2)	Δ Savdep (3)	Δ Time deposit (4)	Δ Wholesale (5)	Δ Tot liab (6)
$\Delta FF\times$ bank HHI	-0.676***	0.087***	0.421	-2.112***	4.656***	-0.475***
	[0.156]	[0.011]	[0.272]	[0.257]	[1.118]	[0.152]
Bank f.e.	Y	Y	Y	Y	Y	Y
Quarter f.e.	Y	Y	Y	Y	Y	Y
Cluster Bank Level	Y	Y	Y	Y	Y	Y
Cluster Time Level	N	N	N	N	N	N
Observation	416,901	416,901	416,901	416,901	416,901	416,901
R2	0.159	0.309	0.079	0.146	0.028	0.169
VARIABLES	Δ Total assets (1)	Δ Cash (2)	Δ Securities (3)	Δ Total loans (4)	Δ Real estate loans (5)	Δ C&I loans (6)
$\Delta FF\times$ bank HHI	-0.465***	-3.079***	0.113	0.195	0.143	-0.148
	[0.135]	[0.644]	[0.380]	[0.195]	[0.255]	[0.428]
Bank f.e.	Y	Y	Y	Y	Y	Y
Quarter f.e.	Y	Y	Y	Y	Y	Y
Cluster Bank Level	Y	Y	Y	Y	Y	Y
Cluster Time Level	N	N	N	N	N	N
Observation	416,901	416,901	416,901	416,901	416,901	416,901
R2	0.170	0.057	0.058	0.199	0.150	0.050

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 12: Bank-level results replication of deposit channel - Bank liabilities and lending, 1994-2007

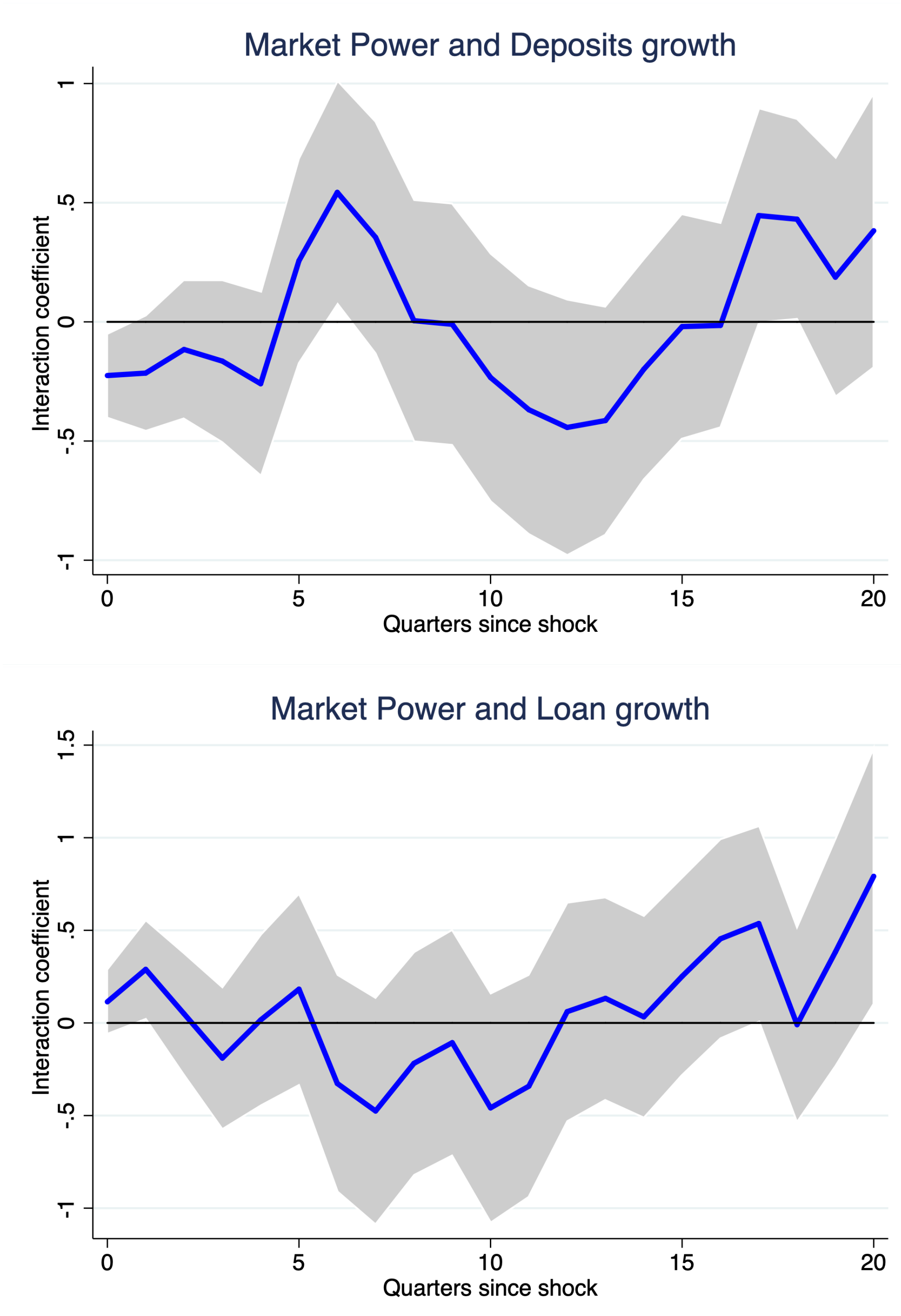
VARIABLES	ΔTotal deposit (1)	Δ Deposit spreads (2)	Δ Savdep (3)	Δ Time deposit (4)	Δ Wholesale (5)	Δ Tot liab (6)
$\Delta FF\times$ bank HHI	-0.676	0.087***	0.421	-2.112***	4.656	-0.475
	[0.509]	[0.015]	[0.884]	[0.550]	[3.760]	[0.408]
Bank f.e.	Y	Y	Y	Y	Y	Y
Quarter f.e.	Y	Y	Y	Y	Y	Y
Cluster Bank Level	Y	Y	Y	Y	Y	Y
Cluster Time Level	Y	Y	Y	Y	Y	Y
Observation	416,901	416,901	416,901	416,901	416,901	416,901
R2	0.159	0.309	0.079	0.146	0.028	0.169
VARIABLES	Δ Total assets (1)	Δ Cash (2)	Δ Securities (3)	Δ Total loans (4)	Δ Real estate loans (5)	Δ C&I loans (6)
$\Delta FF\times$ bank HHI	-0.465	-3.079**	0.113	0.195	0.143	-0.148
	[0.334]	[1.520]	[0.794]	[0.618]	[0.477]	[0.532]
Bank f.e.	Y	Y	Y	Y	Y	Y
Quarter f.e.	Y	Y	Y	Y	Y	Y
Cluster Bank Level	Y	Y	Y	Y	Y	Y
Cluster Time Level	Y	Y	Y	Y	Y	Y
Observation	416,901	416,901	416,901	416,901	416,901	416,901
R2	0.170	0.057	0.058	0.199	0.150	0.050

*** p<0.01, ** p<0.05, * p<0.1

In this section, I show my results using the main econometric specification used in the paper, with my measure of monetary-policy shocks for the dependent variables, deposit growth and loan growth. First, for the case of deposit growth, the top part of Figure 24 shows the response of deposit growth to monetary policy-shock considering the interaction with market power. I find that banks with higher market power reduce their deposit on impact more than banks with lower market power. I conclude this finding is consistent with the deposit channel's replication Table 11, which considers the sample until 2007. Second, for the dependent variable loan growth, I find the loan response is positive and not significant on impact. Again, I conclude this finding is consistent with the deposit channel's replication Table 11.[15]

[15]This result shows my specification and my measure of monetary-policy shock are consistent with the effect on impact on the QJE's paper for deposit growth and loan growth.

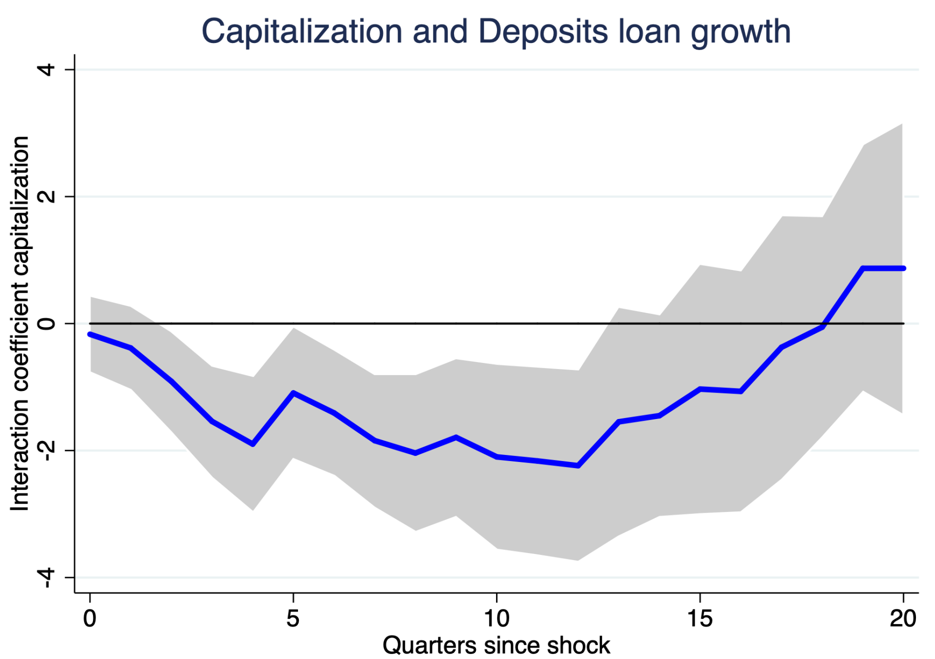
Figure 24: Dynamics of differential response to monetary shocks: Market power

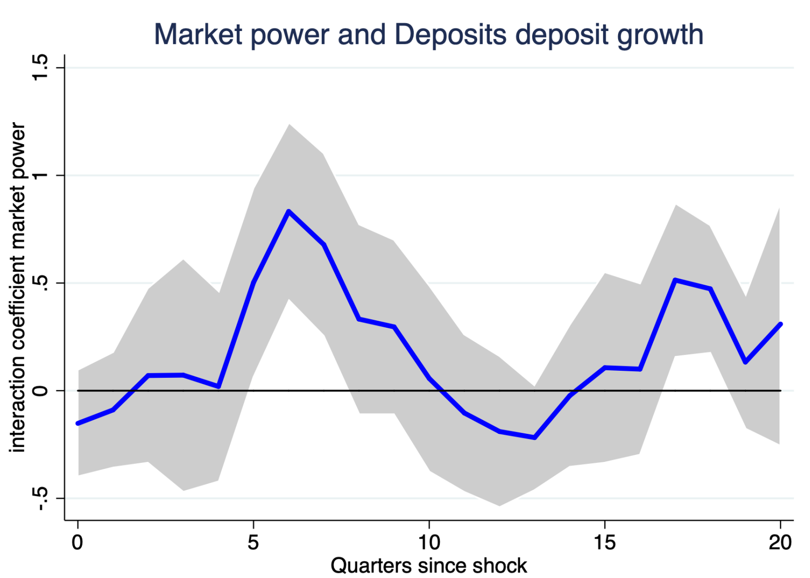


Notes: Dynamics of the interaction coefficient between the capitalization rate and monetary shocks over time.

Now, I show whether the above result survives considering the capitalization rate jointly with market power. First, in the case of deposit growth, the top part of Figure 25 shows the coefficient of interaction associated with the capitalization rate and monetary-policy shock, and the bottom part of the figure shows the coefficient of interaction associated with market power and monetary-policy shock. I find the market power's effect on deposit growth disappears or is not statistically significant on impact. Also, the effect of the capitalization rate is negative on impact, and then persistently negative and statistically significant going forward. Therefore, the effect of the capitalization rate is important. Second, in the case of loan growth, the top part of Figure 26 shows the coefficient of interaction associated with the capitalization rate and monetary-policy shock, and the bottom part of the figure shows the coefficient of interaction associated with market power and monetary-policy shock. I find the effect on loan growth of market power disappears or is not statistically significant on impact and going forward. Also, the effect of the capitalization rate is, on average, negative and persistently negative going forward. Therefore, the effect of the capitalization rate is essential.

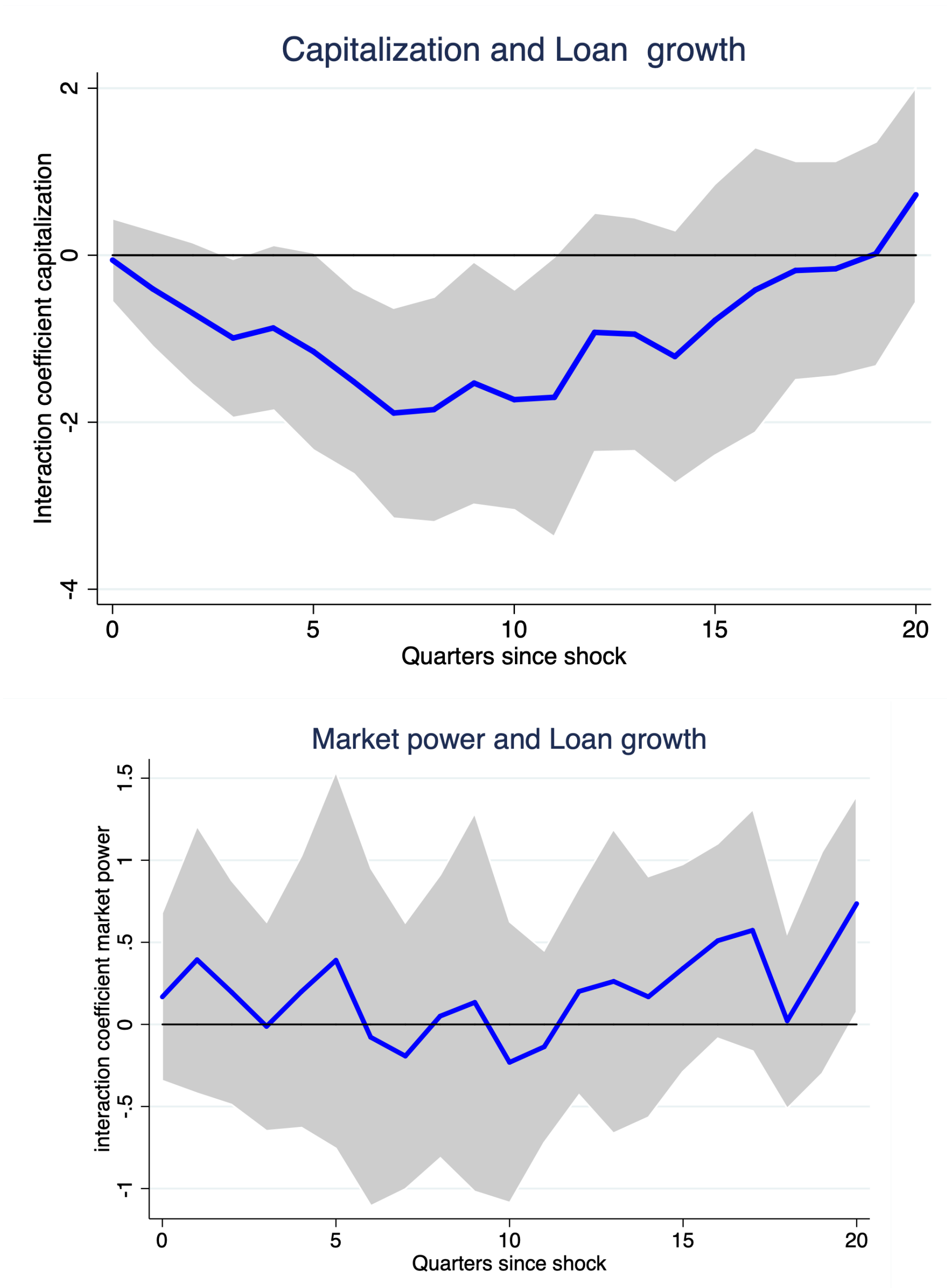
Figure 25: Dynamics of differential response to monetary shocks: Market power





Notes: Dynamics of the interaction coefficient between the capitalization rate and monetary shocks over time.

Figure 26: Dynamics of differential response to monetary shocks: Market power

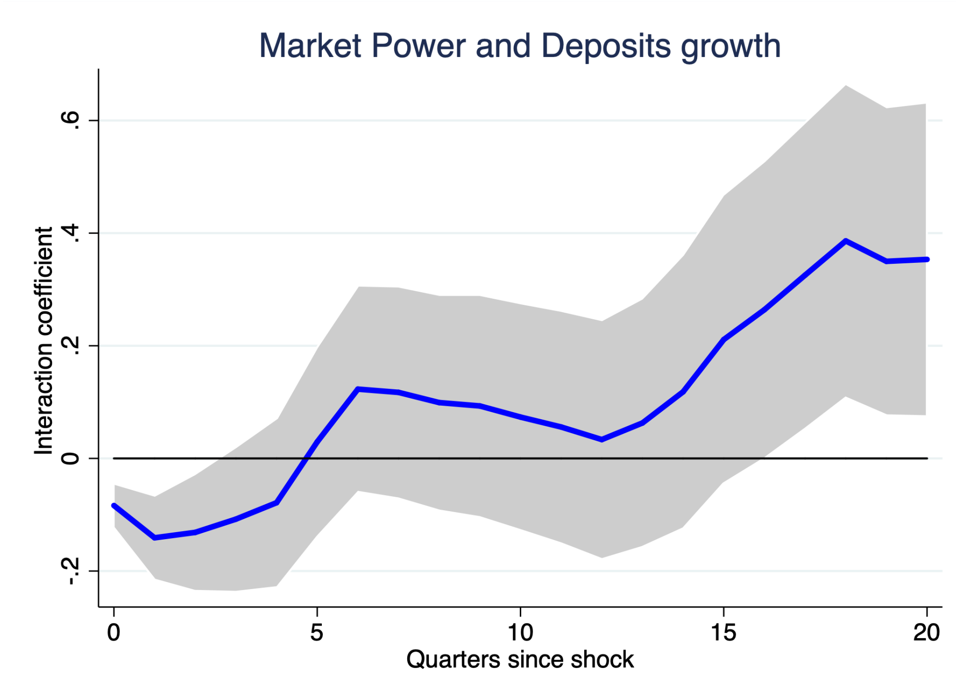


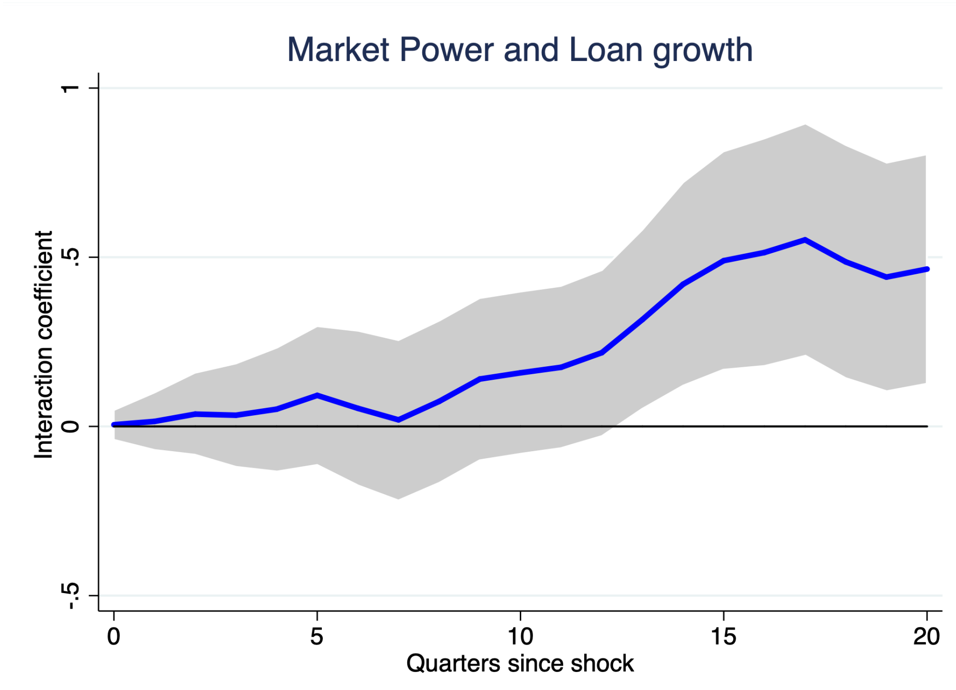
Notes: Dynamics of the interaction coefficient between the capitalization rate and monetary shocks over time.

Finally, I reproduce the same econometric specification for the dynamic response but using Fed funds rate change as a measure of monetary-policy shock, following Drechsler et al. (2017). Figure 27 shows the result considering only market power for the dependent variable of deposits and loan growth. Figure 28 considers the double interaction of market power and the capitalization rate for the dependent variable of deposit growth. Similarly, I find market power's effect on deposit growth disappears or is not statistically significant on impact, and the effect of the bank capitalization rate is negative and statistically significant and persistently negative going forward. Therefore, again, the effect of the capitalization rate is important. Figure 29 considers the double interaction of market power and the capitalization rate for the dependent variable of loan growth. I find my results hold qualitatively on impact, but the dynamic results are different using their monetary-policy tightening measure.

I view these findings as reflecting that the market-power mechanism loses significance or power for explanation when I consider bank capitalization in the regressions.

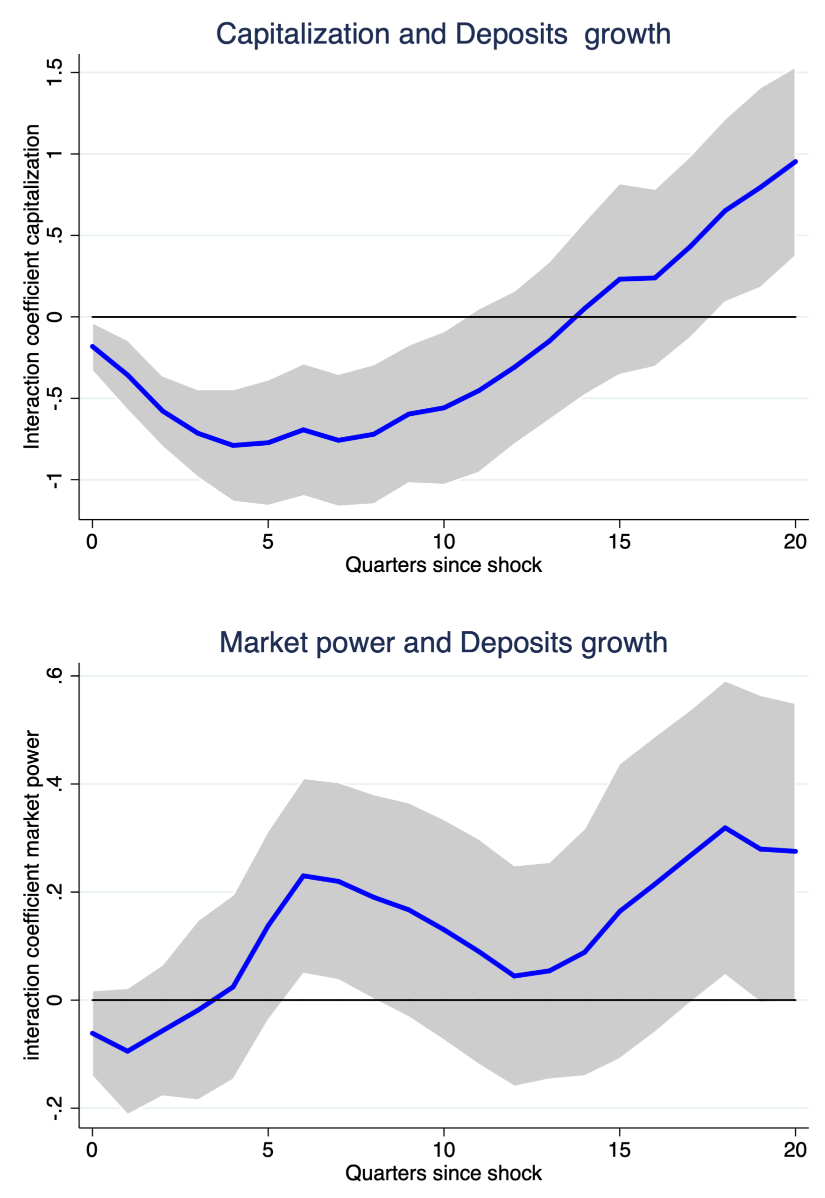
Figure 27: Dynamics of differential response to Fed funds rate: Market power





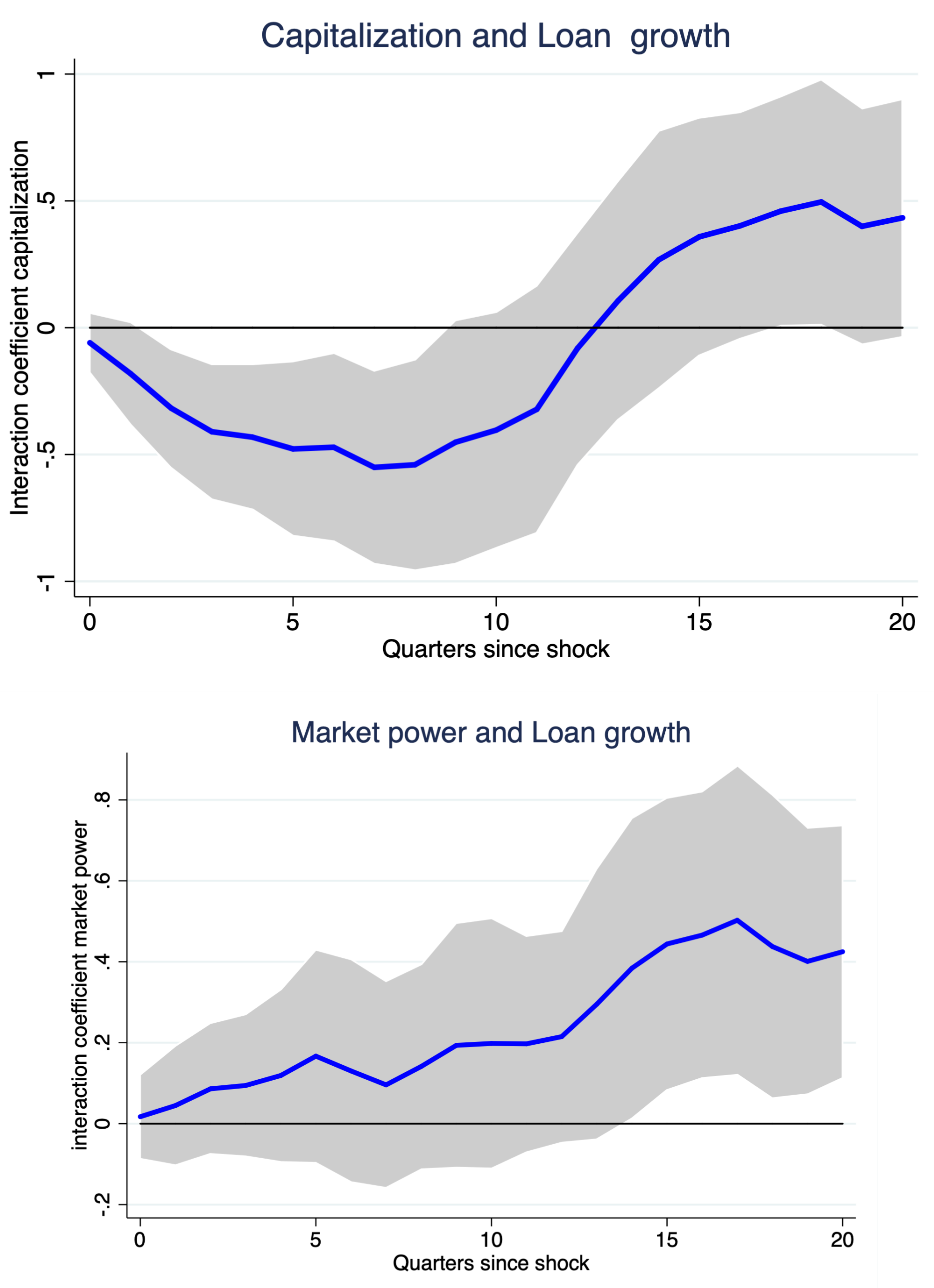
Notes: Dynamics of the interaction coefficient between the capitalization rate and monetary shocks over time.

Figure 28: Dynamics of differential response to Fed funds rate: Capitalization rate and market power



Notes: Dynamics of the interaction coefficient between the capitalization rate and monetary shocks over time.

Figure 29: Dynamics of differential response to Fed funds rate: Capitalization rate and market power



Notes: Dynamics of the interaction coefficient between the capitalization rate and monetary shocks over time.

B.2 Relation to Van den Heuvel (2002)

In this subsection, I explain the main differences between my paper and Van den Heuvel (2002). Van den Heuvel (2002) shows lower-capitalized states are more sensitive to monetary policy. First, the main difference is the data limitation, specifically the type of data. His data set is at the state-level and not the individual bank-level. Second, his econometric specification is different. I could say that there is an aggregation problem. His analysis is at the state level; therefore, the analysis of the heterogeneity at the bank level is lost, and the relation can be misleading. For example, for the aggregate capitalization rate in a given state, no information about the capitalization-rate distribution across banks in that state is available. Any state might have a higher capitalization rate because one bank could have a high capitalization rate. Still, the other banks in the same state could have lower capitalization rates, but the banks with lower capitalization rates can account for more loans. Therefore, a misleading relationship could exist, which could be the case of a state with a higher-capitalization bank responding less to its lending. Thus, all the changes in loans come from the banks that have a lower capitalization rate, but the higher-capitalized bank moves the main variable of interest, that is, the capitalization rate at the state level. Thus, the state that is highly capitalized may not respond to monetary policy, which is not the same thing as higher-capitalized banks not responding to monetary policy, because it comes only because of the aggregation at the state level. I view these findings as reflecting the fact that I analyze a different dimension of the data. The main differences are individual analysis, monetary-policy shock, the sample period, and econometric specification.

B.3 Relation to Kashyap and Stein (2000)

In this subsection, I explain the main differences between this paper and Kashyap and Stein (2000). Kashyap and Stein (2000) shows bank lending contracts when monetary policy tightens, the contraction is stronger for less liquid banks, and the sensitivity of the contraction to liquidity is stronger for small banks. This traditional result comes from a close connection between reserves and deposits, and the idea is that a bank has a reserve requirement. A contractionary monetary policy reduces the amount of reserves, which then has an impact on deposits, unless banks have sufficient liquidity or sufficient capacity to replace deposits with other types of funds. Therefore, if a bank is less liquid, it contracts its lending more. The main differences in my paper are the following: First, I used an identified monetary-policy shock using high-frequency data. They instead use the Fed funds rate, Bernanke and Mihov, and Boschen-Mills indexes as different monetary measures, respectively. Second, I used bank-level quarterly data for the period 1990-2007, focusing on all commercial banks in the sample. They also use bank-level data, but the period of analysis is 1973-1996 quarterly, and they split banks into three size groups ($<$95th percentile, 95th$-$99th percentile, > 99th percentile) and the measure of liquidity is the ratio of securities and Fed funds contracts sold to total assets.

Third, my econometric specification is more general and considers a cutting-edge identification strategy of the measure of monetary-policy shock. My baseline dynamic model is robust to bank controls, bank fixed effects, state-time fixed effect, and size-weighted regression, and clustered at the bank and time level. Kashyap and Stein (2000) have a different econometric specification, which consists of running a two-part regression. First, for all t in their sample and for each size group g, they individually estimate:

$$\Delta log(L_{it}) = \sum_{j=1}^{4} \alpha_{gtj} \Delta log(L_{i,t-j}) + \beta_{gt} B_{it-1} + \sum_{k=1}^{12} \Psi_{gkt} FRB_{ik} + \epsilon_{it}$$

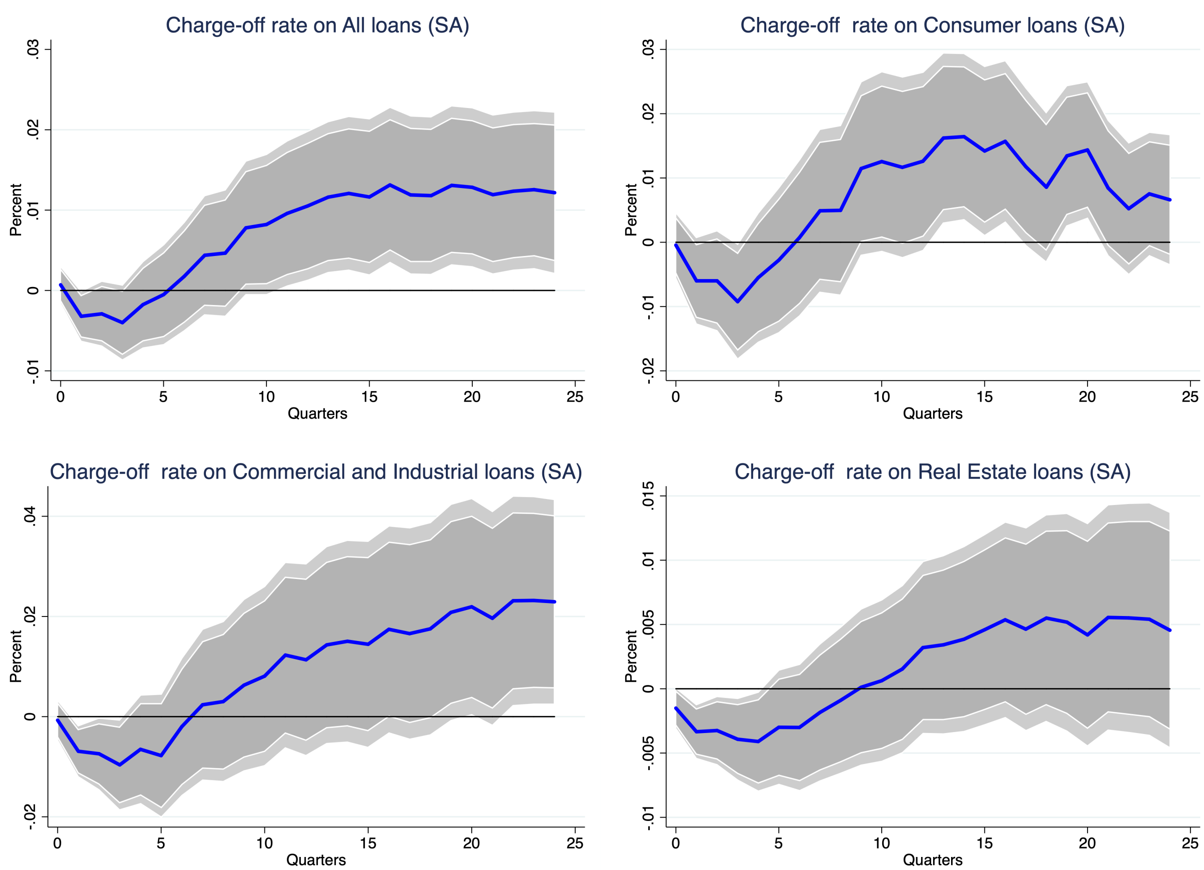
where $\beta_{g,t}$ captures the sensitivity of lending changes to liquidity for size group g in period t, L_{it} is total lending, and B_{it-1} liquidity . Then, they estimate

$$\hat{\beta}_{g,t} = \eta_g + \sum_{j=0}^{4} \phi_{j,g} \Delta M_{t-j} + \delta_g t + u_{g,t}$$

where M_t is the measure of monetary policy, and $\sum_{j=0}^{4} \phi_{j,g}$ captures the correlation between lagged monetary policy and lending sensitivity to liquidity for size group g. They also try a 'bivariate' regression, where they add a four-quarter flexible-form-distributed lag function on GDP growth. This technique is a precursor of modern empirical macro literature. The paper does not meet the standard for identification today.

C. Default Rates and Monetary Policy

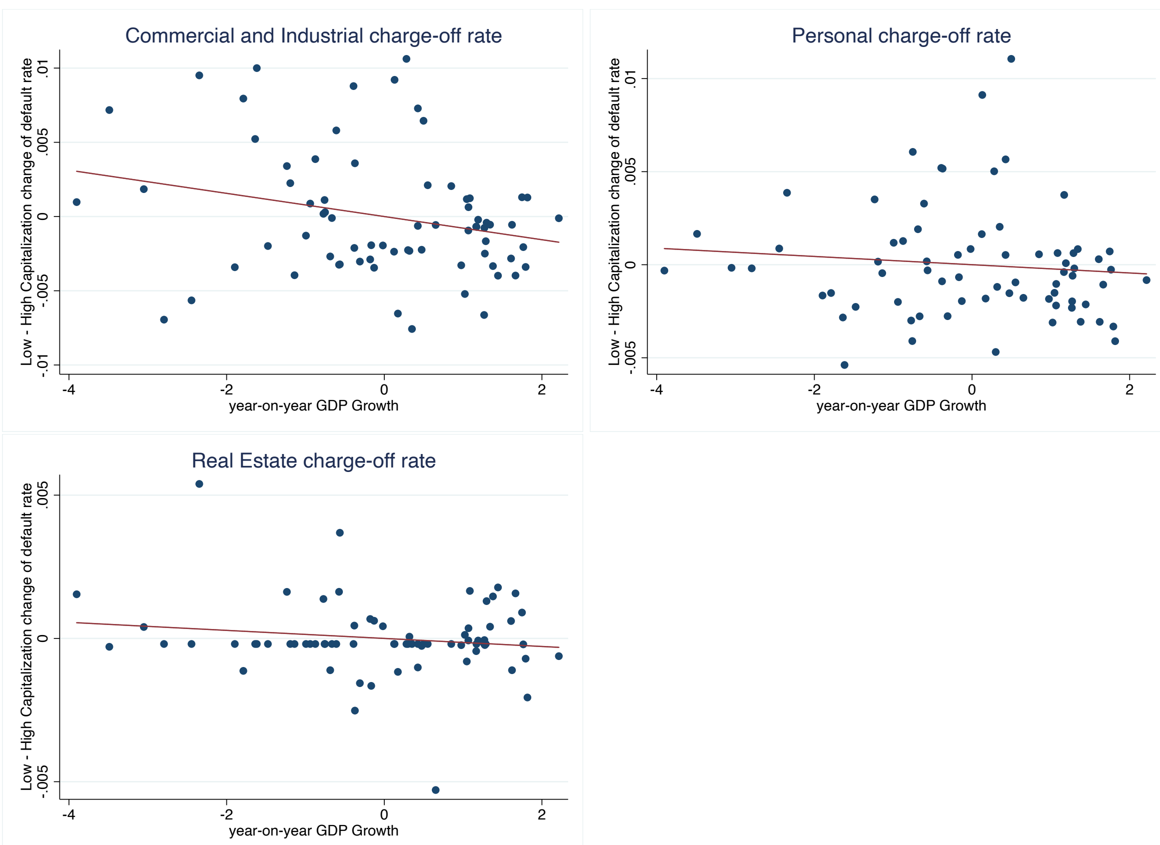
Figure 30: Aggregate: Charge-off responses to monetary policy shock



D. Relationship between Bank Capitalization, Default Rates, and Business Cycles

This section documents the the between relationship bank capitalization rate, default rates, and business cycles. First, I study how GDP growth affects the default rate of lower-capitalization banks minus the default rate of higher-capitalization banks. I find a negative relation between the default rate and GDP growth, but the effect across banks is not statistically different.

Figure 31: Difference between low and high capitalization of charge-off rates and year-on-year GDP growth



Second, I study the same question but now with the following especification that allows me to control for banks fixed effects and state fixed effects. The empirical model is as follows:

$$y_{i,t} = \sum_{j \in J} (\beta_j + \alpha_j \Delta\text{GDP}_t) \, \mathbb{1}_{\{i=I\}} + \sum_{s \in S} (\gamma_s + \delta_s \Delta\text{GDP}_t) \, \mathbb{1}_{\{i=S\}} + \epsilon_{i,t} \tag{23}$$

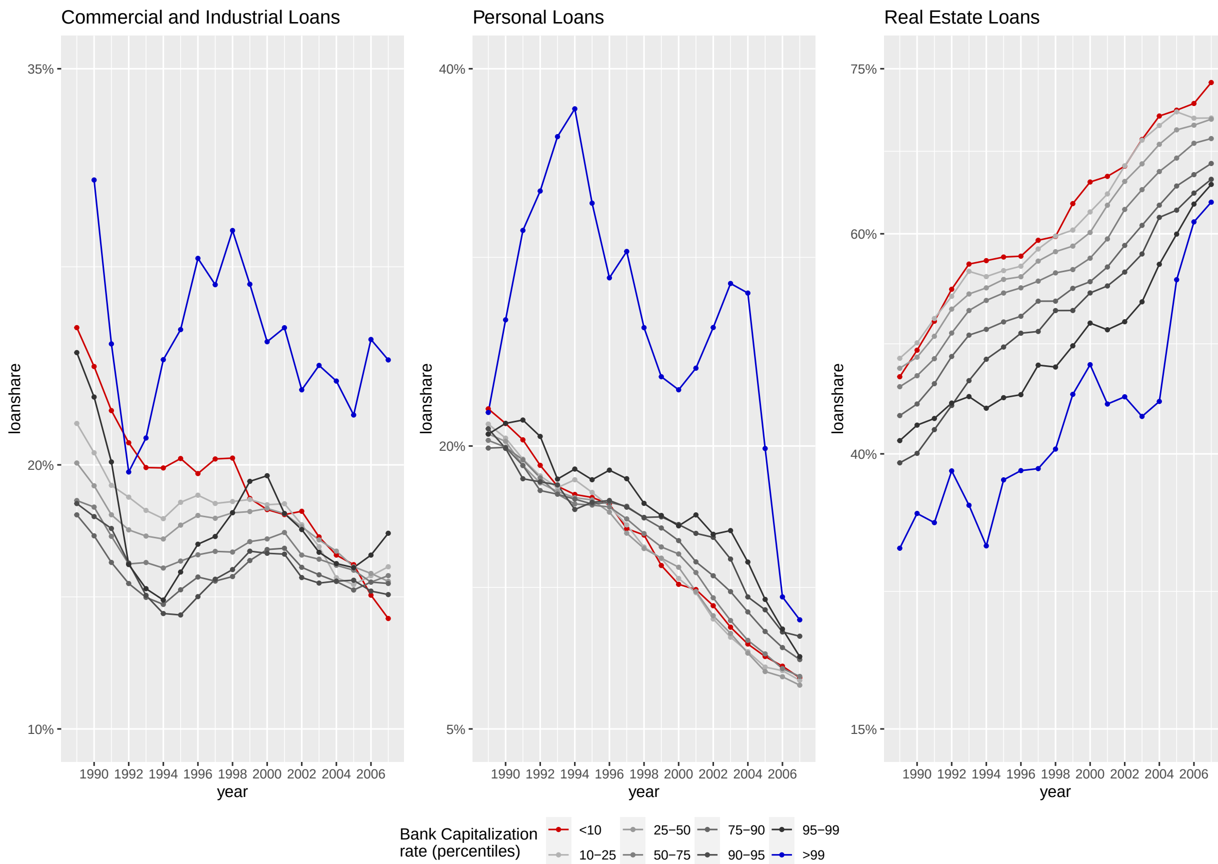
where i identified a bank, and t a quarter. The dependent variable $y_{i,t}$ is the year-on-year change in the charge-off rate. The set J defines a capitalization-rate group, I define five groups and each group has a 20$\%$ of assets. Moreover, $\Delta\text{GDP}_t = log(\frac{GDP_t}{GDP_{t-4}})$ is the year-on-year growth rate of GDP, and S is a set of U.S. states. Table 13 shows GDPgrowth does not affect the default rates across capitalization rates and across types of loans. There is only statistically significant for lower-capitalization banks at the bottom of the distribution.

Table 13: Regression of charge-off rates on GDP growth for banks

	(1)	(2)	(3)
[10-25]x GDP growth	0.035***	0.004	0.012
	(0.01)	(0.00)	(0.01)
[25-50]x GDP growth	0.034**	0.003	0.015*
	(0.01)	(0.00)	(0.01)
[50-75]x GDP growth	0.036**	0.007**	0.009
	(0.01)	(0.00)	(0.01)
[75-90]x GDP growth	0.061***	0.002	0.011
	(0.02)	(0.00)	(0.01)
[90-95]x GDP growth	0.033	0.005	0.043**
	(0.02)	(0.00)	(0.02)
[>95,100]x GDP growth	0.010	0.003	0.039
	(0.04)	(0.00)	(0.03)
GDPgrowth	-0.114***	-0.006	-0.042**
	(0.03)	(0.00)	(0.02)
Observations	216108	392147	216879
R^2	0.041	0.043	0.056
State controls	yes	yes	yes
Bank fixed effects	yes	yes	yes
Quarter fixed effects	yes	yes	yes
Bank Time clustering	yes	yes	yes

E. Loan-Portfolio Composition of Banks:

Figure 32: Average portfolio share for real estate loan across bank capitalization percentiles



F. Baseline Model

F.1 Firm problem

$$
\begin{aligned}
&V(n; q^a) = \max_{k'} div + \mathbb{E}_t[\mathcal{M}^B_{t,t+1}\tilde{V}(k'; q^{a'})] \\
&\textbf{div}(k, k', l; q^a, \omega) = \underbrace{\omega k^{1-\alpha} l^{\alpha}}_{\text{Revenues}} - \underbrace{(k' - (1-\delta_k)k)}_{\text{investment}} - [(1-\phi)wl + a(\frac{1}{q^a})] \\
&a = \phi wl \\
&\omega^* = \frac{(1 + \phi(\frac{1}{q^a_t} - 1))w_t l_t}{k^{1-\alpha} l^{\alpha}} \\
&\tilde{V}(k; q^a) = \max_{l_t}[\Omega_A(\omega^*_t)\mathbb{E}_t(V(n; q^a)|\omega_t > \omega^*_t)]
\end{aligned}
$$

Solution:

$$
\begin{aligned}
&V(n; q^a) = \max_{k'} div + \mathbb{E}_t[\mathcal{M}^B_{t,t+1}\tilde{V}(k'; q^{a'})] \\
&\textbf{div} = \omega k^{1-\alpha} l^{\alpha} - [1 + \phi(\frac{1}{q^a} - 1)]wl + (1-\delta_k)k = n - k' + a \\
&\tilde{V}(k; q^a) = \max_{l_t}[\Omega_A(\omega^*_t)\mathbb{E}_t(V(n; q^a)|\omega_t > \omega^*_t)] \\
&\omega^* = \frac{(1 + \phi(\frac{1}{q^a_t} - 1))w_t l_t}{k^{1-\alpha} l^{\alpha}}
\end{aligned}
$$

Step 1:

$$
\tilde{V}(k; q^a) = \max_{l}[\Omega_A(\omega^*_t)\mathbb{E}_t(V(n; q^a)|\omega_t > \omega^*_t)] = \max_{l_t}[\Omega_A(\omega^*_t)v(q^a)\mathbb{E}_t(n|\omega > \omega^*)]
$$

$\Omega_A(\omega^*) = 1 - F(\omega^*)$ where F is the probability of default.

$n = \omega k^{1-\alpha} l^{\alpha} - (1-\phi)wl - (\frac{1}{q^a})a + (1-\delta_k)k \Rightarrow \mathbb{E}_t(n^P_t|\omega > \omega^*) = (1-\delta_k)k$

Note:

$$\mathbb{E}_t(n|\omega > \omega^*) = \mathbb{E}_t\left(\left[\omega k^{1-\alpha}l^{\alpha} - (1-\phi)wl - (\frac{1}{q^a})a + (1-\delta_k)k\right]|\omega_t > \omega_t^*\right)$$

If $E[]$ is over ω,check:

$$\begin{aligned}
E([\omega k^{1-\alpha}l^{\alpha} - (1-\phi)wl - (\frac{1}{q^a})a + (1-\delta_k)k]|\omega > \omega^*) \\
E([\omega|\omega > \omega^*)]k^{1-\alpha}l^{\alpha} - (1-\phi)wl - (\frac{1}{q^a})a + (1-\delta_k)k \\
\omega^+ k^{1-\alpha}l^{\alpha} - (1-\phi)wl - (\frac{1}{q^a})(\phi wl) + (1-\delta_k)k \\
\omega^+ y - (1-\phi+\frac{1}{q^a}\phi)wl + (1-\delta_k)k \\
y\left(\omega^+ - (1-\phi+\frac{1}{q^a}\phi)\frac{wl}{y} + (1-\delta_k)\frac{k}{y}\right) \\
y\left(\omega^+ - \omega^* + (1-\delta_k)\frac{k}{y}\right) \\
y\left(\omega^+ - \omega^*\right) + (1-\delta_k)k
\end{aligned}$$

$$\mathbb{E}_t(n_t|\omega_t > \omega_t^*) = y\left(\omega^+ - \omega^*\right) + (1-\delta_k)k$$

$$\begin{aligned}
&V(n;q^a) = \max_{k'} div + \mathbb{E}_t[\mathcal{M}^B_{t,t+1}\tilde{V}(k';q^{a'})] \\
&V(n;q^a) = \max_{k'} \omega k^{1-\alpha}l^{\alpha} - [1+\phi(\frac{1}{q^a}-1)]wl + (1-\delta_k)k + \mathbb{E}_t[\mathcal{M}^B_{t,t+1}\tilde{V}(k';q^{a'})] \\
&V(n;q^a) = n - k' + a + \mathbb{E}_t[\mathcal{M}^B_{t,t+1}\tilde{V}(k';q^{a'})] \\
&\tilde{V}(k;q^a) = \max_{l_t}[\Omega_A(\omega_t^*)\mathbb{E}_t(V(n;q^a)|\omega_t > \omega_t^*)] \\
&\omega^* = \frac{(1+\phi(\frac{1}{q_t^a}-1))w_t l_t}{k^{1-\alpha}l^{\alpha}}
\end{aligned}$$

Thus, $V(n)$ is a homogeneous of degree 1 in n.

l_t:

$$\frac{\partial[\Omega_A(\omega_t^*)v(q^a)\mathbb{E}_t(n|\omega > \omega^*)]}{\partial l} = 0$$
$$\frac{\partial[\Omega_A(\omega_t^*)]}{\partial l}\mathbb{E}_t(n|\omega > \omega^*) + \Omega_A(\omega_t^*)\frac{\partial[\mathbb{E}_t(n|\omega > \omega^*)]}{\partial l} = 0$$
$$(-f_{\omega^*})\frac{\partial\omega_t^*}{\partial l_t}\mathbb{E}_t(n_t^P|\omega_t > \omega_t^*)] + \Omega_A(\omega_t^*)\frac{\partial[\mathbb{E}_t(n|\omega > \omega^*)]}{\partial l} = 0$$

Observation:

$$\frac{\partial[\mathbb{E}_t(n|\omega > \omega^*)]}{\partial l} = (\omega_t^+\text{MPL} - [(1+\phi^i(\frac{1}{q^a}-1)]w_t)$$

where $\omega_t^+ = E(\omega|\omega_t > \omega_t^*)$

$$(-f_{\omega^*})\frac{\partial\omega_t^*}{\partial l_t}[y\left(\omega^+ - \omega^*\right) + (1-\delta_k)k] + \Omega_A(\omega_t^*)(\omega_t^+\text{MPL} - [(1+\phi^i(\frac{1}{q^a}-1)]w_t) = 0$$

Note:

$$\frac{\partial\omega_t^*}{\partial l_t} = \frac{1}{y}\left((1+\phi(\frac{1}{q_t^a}-1))w_t - \text{MPL}_t\omega^*\right)$$

$$\Omega_A(\omega_t^*)(\omega_t^+\text{MPL}) = f_\omega^*\frac{[y\left(\omega^+ - \omega^*\right) + (1-\delta_k)k]}{y}\left((1+\phi(\frac{1}{q_t^a}-1))w_t - \text{MPL}_t\omega^*\right) + [1+\phi^i(\frac{1}{q_t^a}-1)]w_t\Omega_A$$

$$\text{MPL} = w_t\left(\frac{\left[\Omega_A(\omega_t^*) + \frac{f_\omega^*[y\left(\omega^+-\omega^*\right)+(1-\delta_k)k]}{y}\right]}{\left[\Omega_A(\omega_t^*)(\omega_t^+) + f_\omega^*\frac{\omega^*[y(\omega^+-\omega^*)+(1-\delta_k)k]}{y}\right]}\left(1+\phi(\frac{1}{q_t^a}-1)\right)\right)$$

Now FOC k':

$$1 - E_t[\mathcal{M}^B \frac{\partial \tilde{V}(k'; q^{a'})}{\partial k'}] = 0$$
$$1 - E_t[\mathcal{M}^B \frac{\partial[\Omega_A(\omega^{*'})\mathbb{E}_t(n'|\omega' > \omega^{*'})]}{\partial k'}] = 0$$
$$1 - E_t[\mathcal{M}^B v(q^{a'}) \left(\frac{\partial[\Omega_A(\omega^{*'})]}{\partial k'} \mathbb{E}_t(n'|\omega' > \omega^{*'}) + \Omega_A(\omega^{*'}) \frac{\partial[\mathbb{E}_t(n'|\omega' > \omega^{*'})]}{\partial k'} \right) = 0$$
$$1 - E_t[\mathcal{M}^B v(q^{a'}) \left((-f_{\omega^*}) \frac{\partial \omega_t^*}{\partial k'} \mathbb{E}_t(n'|\omega' > \omega^{*'})] + \Omega_A(\omega_t^*) \frac{\partial[\mathbb{E}_t(n'|\omega > \omega^{*'})]}{\partial k'} \right) = 0$$
$$1 - E_t[\mathcal{M}^B v(q^{a'}) \left((-f_{\omega^{*'}}) \frac{\partial \omega^{*'}}{\partial k'} [y' \left(\omega_{t+1}^+ - \omega_{t+1}^* \right) + (1-\delta_k) p_{t+1}^K k'] + \Omega_A(\omega^{*'}) \frac{\partial[\mathbb{E}_t(n'|\omega' > \omega^{*'})]}{\partial k'} \right) = 0$$

Observation:

$$\frac{\partial[\mathbb{E}_t(n|\omega > \omega^*)]}{\partial k'} = \omega^{+'}\text{MPK}' + (1-\delta_K)$$
$$\frac{\partial \omega^{*'}}{\partial k'} = \frac{1}{y} \left(-\text{MPK}'\omega^{*'} \right)$$

$$1 - E_t[\mathcal{M}^B v(q^{a'}) \left((-f_{\omega^{*'}}) \left(\frac{1}{y} \left(-\text{MPK}'\omega^{*'} \right) \right) \right) [y' \left(\omega_{t+1}^+ - \omega_{t+1}^* \right) + (1-\delta_k) p_{t+1}^K k'] + \Omega_A(\omega^{*'}) \left(\omega^{+'}\text{MPK}' + \right.$$
$$1 = E_t[\mathcal{M}^B v(q^{a'}) \left(f_{\omega^{*'}} \left(\frac{\text{MPK}'\omega^{*'}}{y} \right) [y' \left(\omega_{t+1}^+ - \omega_{t+1}^* \right) + (1-\delta_k) p_{t+1}^K k'] + \Omega_A(\omega^{*'}) \left(\omega^{+'}\text{MPK}' + (1-\delta_K) \right) \right.$$

Define $\mathcal{M}^P = \mathcal{M}^B v(q^{a'})$

$$1 = E_t[\mathcal{M}^P \left(\Omega_A(\omega^{+'}) \left(\omega^{*'}\text{MPK}' + (1-\delta_K) \right) + f_{\omega^{*'}} \left(\frac{\text{MPK}'\omega^{*'}}{y'} \right) [y' \left(\omega_{t+1}^+ - \omega_{t+1}^* \right) + (1-\delta_k) p_{t+1}^K k'] \right)$$

In the standard RBC without adjustment cost, the optimal investment:

$$1 = \beta E(\text{MPK}' + (1-\delta_K))$$

Stage I:

CES:

$$A_t^{P_A} = \left((\nu_A^F)^{\frac{1-\sigma_A^F}{\sigma_A^F}} A_{1t}^{\frac{\sigma_A^F - 1}{\sigma_A^F}} + (1-\nu_A^F)^{\frac{1-\sigma_A^F}{\sigma_A^F}} A_{2t}^{\frac{\sigma_A^F - 1}{\sigma_A^F}} \right)^{\frac{\sigma_A^F}{\sigma_A^F - 1}}$$

Loan's firm(sector) A demand for each bank:

$$A_{1t} = \left(\frac{\frac{1}{Q_t^a}}{\frac{1}{q_{1t}^a}} \right)^{\sigma_A^F} (\nu_A^F)^{1-\sigma_A^F} A_t^{P_A}$$

$$A_{2t} = \left(\frac{\frac{1}{Q_t^a}}{\frac{1}{q_{2t}^a}} \right)^{\sigma_A^F} (1-\nu_A^F)^{1-\sigma_A^F} A_t^{P_A}$$

where

$$Q_t^a = 1 / \left(\left(\frac{\nu_A^F}{q_{1t}^a} \right)^{1-\sigma_A^F} + \left(\frac{1-\nu_A^F}{q_{2t}^a} \right)^{1-\sigma_A^F} \right)^{\frac{1}{1-\sigma_A^F}}$$

$$A_t^{P_A} = \phi^A w_t^A L_t^A$$

$$V_j(n_j) = \max_{k'} div_j + \mathbb{E}_t[\mathcal{M}_{t,t+1} \tilde{V}_j(k_j')]$$

$$\overbrace{n_j - p^{k_j} k_j' + \underbrace{\text{wc}_j}_{\text{new debt}}}^{\text{div}_{ft}^j} \geq 0$$

$$n_j = \underbrace{\omega_j k_j^{1-\alpha} l^{\alpha} - (1-\phi) w_j l - \frac{1}{Q_j} \text{wc}_j}_{\text{profit flow}} + p^{k_j}(1-\delta^{k_j}) k_j$$

$$\omega_j^* = \frac{(1+\phi^j(\frac{1}{Q_j}-1)) w_j \bar{l}_j}{y_j} \quad , \quad \tilde{V}_j(k_j) = \max_{l_j} [\Omega(\omega_j^*) \mathbb{E}_t (V_j(n_j) | \omega_j > \omega_j^*)]$$

F.2 Bank problem

The bank problem is the following:

$$V^i(N_t^i, \mathcal{S}_t) = \max_{q_{Ai,t}, D_t^i, e_t^i} div_t^i - e_t^i + E_t[\mathcal{M}_{t+1,t}^B V^i(N_{t+1}^i)]$$

s.t

$$N_t^i + D_t^i + e_t \geq L_{At}^i + div_t^i + \Psi^i(e_t^i)$$

$$D_t^i \leq \xi_A L_{At}^i$$

$$N_{t+1}^i = (\frac{\tilde{M}_{t+1}^A}{q_{Ai,t}})L_{A,t}^i - (R_t)D_t^i$$

where:

$$div_t^i = \phi_0 N_t^i \quad \Psi^i(e_t^i) = \frac{\phi_1^i}{2}(e_t^i)^2$$

$$L_{At}^i = \left(\frac{\frac{1}{Q_A}}{\frac{1}{q_{Ai}}}\right)^\sigma (\nu)^{1-\sigma}\bar{A}$$

$$\tilde{M}_t = \underbrace{\Omega(\omega_t^*)}_{\text{No default}} + \underbrace{\frac{(1-\Omega(\omega_t^*))}{L_t^i/q_{Ai,t}}\left[\varpi^i(1-\zeta^i)\left(\mathbb{E}_{\omega,t}[\omega<\omega^*]Y_t + ((1-\delta^k)p_t^K)K_t\right) - \varpi^i w_t \bar{L}\right]}_{\text{default (recovery value)}}$$

Assumptions:

- Everything that has a t subscript is known at time t, and everything that has a $t+1$ subscript is not known at time t.
- In the law of motion of networth, at time t, the bank decides how much to charge $q_{Ai,t}$, but the return on the loan is uncertain, because it depends of the firm default or not. For this reason, $\tilde{M}_{t+1}^A$ has a $t+1$ subscript. On the other hand, the payment on D_t is known at time t, so we have R_t not R_{t+1}.
- In the equation for N_{t+1}^i, N_{t+1}^i would be banks $t+1$ networth N_{t+1}^i, that would be used for next-period lending. Now the action today afffects tomorrow state N_{t+1}^i.

Note $L^i_{At} = \left(\frac{\frac{1}{Q_A}}{\frac{1}{q_{A1}}}\right)^{\sigma} (\nu)^{1-\sigma}\bar{A}$ and $\varpi^i = \frac{\frac{1}{q_{Ai}}L^i_{At}}{\frac{1}{Q_A}\bar{A}_t}$

STEP 1:

$$V^i(N^i_t) = \phi_0 N^i_t - e^i_t + E_t[\mathcal{M}^B_{t+1,t}V^i(N^i_{t+1}, \mathcal{S}_t)] + \lambda_t[(1-\phi)N_t \quad + e_t - \Psi(e_t) - L^i_{Ai} - D_t] + \mu_t[\xi_A L^i_{At} - D^i_t]$$

where

$$N^i_t = (\frac{\tilde{M}^A_t}{q_{Ai,t}})L^i_{At} - (R_t)D^i_t$$

$$L^i_{At} = (\frac{q_{Ai}}{Q_A})^2 \bar{A}_t$$

$$\Psi^i(e^i_t) = \frac{\phi^i_1}{2}(e^i_t)^2$$

$$\tilde{M}_t = \underbrace{\Omega(\omega^*_t)}_{\text{No default}} + \underbrace{\frac{(1-\Omega(\omega^*_t))}{L^i_t/q_{Ai,t}}\left[\varpi^i(1-\zeta^i)\left(\mathbb{E}_{\omega,t}[\omega<\omega^*]Y_t + ((1-\delta^k)p^K_t)K_t\right) - \varpi^i w_t \bar{L}\right]}_{\text{default (recovery value)}}$$

$$\varpi^i = \frac{\frac{1}{q_{Ai}}L^i_{At}}{\frac{1}{Q_A}\bar{A}_t}$$

FOC of q_{Ai}:

$$\frac{1}{q_{Ai}} = \left(\frac{\frac{\partial L_{Ai}}{\partial q_{Ai}}\frac{q_{Ai}}{L_{Ai}}}{\frac{\partial L_{Ai}}{\partial q_{Ai}}\frac{q_{Ai}}{L_{Ai}} - 1}\right)\left(\frac{1-\tilde{\mu}\xi_A}{\frac{m^I_t}{m^B_t}}\right)\frac{1}{\left(\Omega(\omega^*_t) + (1-\Omega(\omega^*_t))\frac{(X_t - Z_t)}{\frac{1}{Q_A}\bar{A}}\right)}$$

$$\frac{1}{q_{Ai}} = \left(\frac{\sigma}{\sigma-1}\right)\left(\frac{1-\tilde{\mu}\xi_A}{\frac{m^I_t}{m^B_t}}\right)\frac{1}{\left(\Omega(\omega^*_t) + (1-\Omega(\omega^*_t))\frac{(X_t - Z_t)}{\frac{1}{Q_A}\bar{A}}\right)}$$

where: $X_t = (1-\zeta^i)\left(\mathbb{E}_{\omega,t}[\omega<\omega^*]Y_t + ((1-\delta^k)p^K_t)K_t\right)$

$Z_t = w_t \bar{L}$

FOC of e_t:

$$-1+\lambda_t(1-\Psi_e(e))=0 \Rightarrow \lambda_t=\frac{1}{1-\Psi_e(e)}$$

FOC of N_t:

$$\frac{\partial V}{\partial N}=\phi_0+(1-\phi_0)\lambda_t \Rightarrow \frac{\partial V_{t+1}}{\partial N_{t+1}}=\phi_0+(1-\phi_0)\lambda_{t+1}$$

Define: $\mathcal{M}^I_{t+1,t}\equiv \mathcal{M}^B_{t+1,t}\frac{\partial V_{t+1}}{\partial N_{t+1}}\frac{1}{\lambda_t}$ and define $\tilde{\mu}=\frac{\mu}{\lambda}$to simplify the notation that I use below.

FOC of D_{it}:

$$\begin{aligned}
&E_t[\mathcal{M}^B_{t+1,t}\frac{\partial V^i(N^i_{t+1})}{\partial N_{t+1}}\frac{\partial N_{t+1}}{\partial D_{it}}]-\lambda_t-\mu_t=0\\
&E_t[\mathcal{M}^B_{t+1,t}\frac{\partial V^i(N^i_{t+1})}{\partial N_{t+1}}(-R_t)]+\lambda_t-\mu_t=0\\
&1=\tilde{\mu}_t+E_t[\mathcal{M}^I_{t+1,t}]R_t
\end{aligned}$$

G. Consumer Problem

$$\max_{C_t,X^A_t,X^M_t}\mathbb{E}_t\left[\sum_{t=0}^{\infty}\beta^t\left[log(C_t)\right]\right.$$

s.t.

$$C_t+\sum_{i=1}^{2}(X^j_t+\Psi(X^j_t,K^j_t))\leq w^j\bar{L}+\sum_{j=1}^{2}\text{div}^j_t+\sum_{i=1}^{2}\text{Netdiv}^i_t+\sum_{j=1}^{2}p^{K^j}_tX^j_t$$

$$K^j_{t+1}=(1-\delta_K)K^j_t+X^j_t$$

H. Resource Constraint Derivation

Resource-constraint derivation:

$$C^B = w^B \bar{L}^B + Div_t^P + NetDiv_t^1 + NetDiv_t^2 + pX_t - X_t - \Psi(X,K) \quad \text{consumer's B.C}$$
$$A_{1,t}^I - D_{1t}^I = N^{I_1} - \phi_0^I N^{I_1} + e^{I_1} - \Psi^{I_1}(.) \quad \text{Bank 1's Budget constraint}$$
$$A_{2,t}^I - D_{2t}^I = N^{I_2} - \phi_0^I N^{I_2} + e^{I_2} - \Psi^{I_2}(.) \quad \text{Bank 2's Budget constraint}$$

This implies:

$$\begin{aligned} C^B + (A_{1,t}^I + A_{2,t}^I) - (D_{1t}^I + D_{2t}^I) = {} & w^B \bar{L}^B + Div_t^P + NetDiv_t^1 + NetDiv_t^2 + pX_t - X_t - \Psi(X,K) \\ & + N^{I_1} - \phi_0^I N^{I_1} + e^{I_1} - \Psi^{I_1}(.) \\ & + N^{I_2} - \phi_0^I N^{I_2} + e^{I_2} - \Psi^{I_2}(.) \end{aligned}$$

Using:

$$\begin{aligned} A^P &= \phi w L \\ A_{1,t}^I &= \left(\frac{\frac{1}{Q_A}}{\frac{1}{q_{A1}}}\right)^{\sigma} (\nu)^{1-\sigma} A^P \\ A_{2,t}^I &= \left(\frac{\frac{1}{Q_A}}{\frac{1}{q_{A2}}}\right)^{\sigma} (\nu)^{1-\sigma} A^P \\ Div_t^P &= N^P - (p_t K_{t+1}) + A_t^P - F(\omega^*) n^0 \\ NetDiv_{1t}^I &= N_1^I \phi_0^I - e_1^I \\ NetDiv_{2t}^I &= N_2^I \phi_0^I - e_2^I \\ K_{t+1} &= (1-\delta_K) K_t + X_t \end{aligned}$$

$$C^B + X_t + \Psi(X,K) + \Psi^{I_2}(.) + \Psi^{I_1}(.) = w^B \bar{L}^B + N^P - (1-\delta_K)p_t K_t + (A_t^P - (A_{1,t}^I + A_{2,t}^I)) \\ - (1-\Omega(\omega^*))n^0 + N^{I_1} + N^{I_2} + (D_{1t}^I + D_{2t}^I)$$

Using:

$$N^P = \left[\Omega(\omega^*)E(\omega|\omega > \omega^*)Y - \Omega(\omega^*)w^B\bar{L}^B - \Omega(\omega^*)(\frac{1}{Q_A})A^P\right] \\ + (\Omega(\omega^*))(1+\delta_K)p_t K_t + (1-\Omega(\omega^*))n^0$$

$$N_t^{I_1} = (\frac{\tilde{M}_t^{A1}}{q_{A1,t}})L_{At}^1 - (R_t)D_t^1$$

$$N_t^{I_2} = (\frac{\tilde{M}_t^{A2}}{q_{A2,t}})L_{At}^2 - (R_t)D_t^2$$

n^0 is an initial net worth.

$$\tilde{M}_t^{A1} = \underbrace{\Omega(\omega_t^*)}_{\text{No default}} + \underbrace{\frac{(1-\Omega(\omega_t^*))}{L_t^1/q_{A1,t}}\left[\varpi^1(1-\zeta^1)\left(\mathbb{E}_{\omega,t}[\omega < \omega^*]Y_t + ((1-\delta^k)p_t^K)K_t\right) - \varpi^1 w_t \bar{L}\right]}_{\text{default (recovery value)}}$$

$$\tilde{M}_t^{A2} = \underbrace{\Omega(\omega_t^*)}_{\text{No default}} + \underbrace{\frac{(1-\Omega(\omega_t^*))}{L_t^2/q_{A2,t}}\left[\varpi^2(1-\zeta^2)\left(\mathbb{E}_{\omega,t}[\omega < \omega^*]Y_t + ((1-\delta^k)p_t^K)K_t\right) - \varpi^2 w_t \bar{L}\right]}_{\text{default (recovery value)}}$$

Define:

$\Sigma(\zeta^1) = \left[(1-\zeta^1)\left(\mathbb{E}_{\omega,t}[\omega < \omega^*]Y_t + ((1-\delta^k)p_t^K)K_t\right) - w_t\bar{L}\right]$

$\Sigma(\zeta^2) = \left[(1-\zeta^2)\left(\mathbb{E}_{\omega,t}[\omega < \omega^*]Y_t + ((1-\delta^k)p_t^K)K_t\right) - w_t\bar{L}\right]$

$$N_t^{I_1} = \Omega(\omega_t^*)\frac{L_{At}^1}{q_{A1,t}} + (1-\Omega(\omega_t^*))\varpi^1\Sigma(\zeta^1) - (R_t)D_t^1$$

$$N_t^{I_2} = \Omega(\omega_t^*)\frac{L_{At}^2}{q_{A2,t}} + (1-\Omega(\omega_t^*))\varpi^2\Sigma(\zeta^2) - (R_t)D_t^1$$

$D \equiv D_{1t}^I + D_{2t}^I$

The resource constraint becomes:

$$C^B + X_t + \Psi(X,K) + \Psi^{I_2}(.) + \Psi^{I_1}(.) + DWL + D(R-1) = Y$$
$$+ A_t^P(1 - \frac{\Omega(\omega^*)}{Q_A}) - A_{1,t}^I(1 - \frac{\Omega(\omega_t^*)}{q_{A1,t}}) - A_{2,t}^I(1 - \frac{\Omega(\omega_t^*)}{q_{A2,t}})$$

where:

$$\text{DWL} = (1 - \Omega(\omega_t^*)) \left[\mathbb{E}_{\omega,t}[\omega < \omega^*]Y_t + ((1-\delta^k)p_t^K)K_t\right] (\varpi^1\zeta^1 + \varpi^2\zeta^2))$$

I. Recovery Rates and Capitalization Rates in the Data

This subsection describes the bank-level variables used to calculate the relation between recovery rates for each type of loan and bank capitalization rates, based on Call Reports. First, I construct a proxy for banks' recovery rates using the variable recoveries on allowance for loan and lease losses. First, in the case of recoveries on commercial loans, recoveries on loans to individual for households, and recoveries on real estate loans, I use *riad4608*,*riad4609*, and *riad4257*, respectively. Second, charge-offs on allowance for loan and lease losses for commercial loans, individual for households, real estate loans are *riad4638*,*riad4639*, and *riad4256*, respectively. I divide t. Then, I winsorize the observation for the proxy of banks' recovery rates to have a recovery rate on the interval [0,1]. Figure 18 presents binscatter plots of the bank capitalization rate against my proxy of banks' recovery rates for each loan type.

Figure 33: Recovery rates on personal loans and capitalization rate

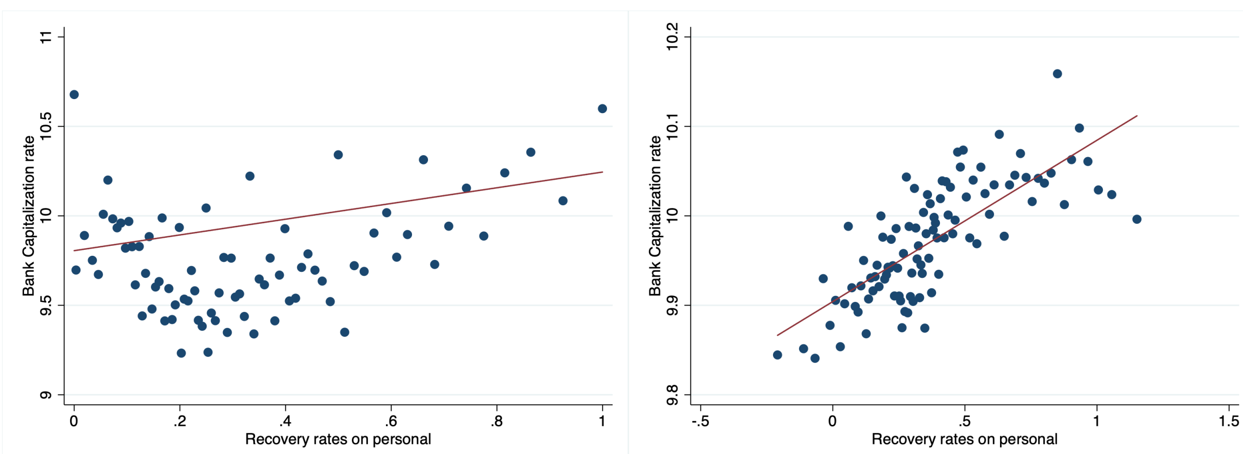


Figure 34: Recovery rates on real estate loans and capitalization rate

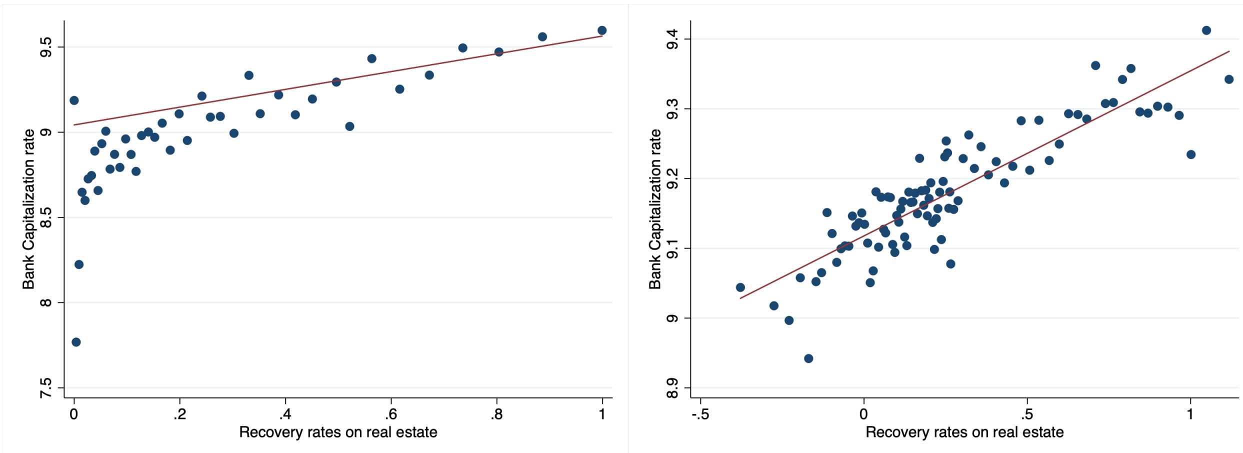
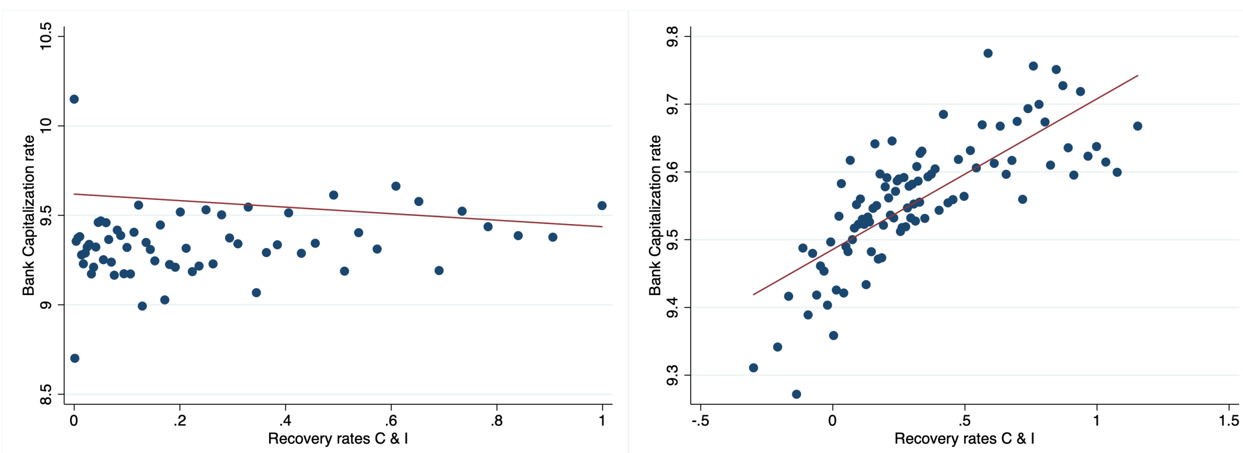


Figure 35: Recovery rates on commercial and industrial loans and capitalization rate



J. Alternative Measure of Recovery Rates

First, in the case of non-accrual on total loans and lease, I use *rcfd1403*. Second, for total loans and lease past 90 or more and still accruing, I use *rcfd1407*. I sum them and define them as non-performing loans. Then, I construct a proxy for the recovery rate by summing the recovery of each loan type. Finally, I divide them. Then, I winsorize the observation for the proxy for banks' recovery rates to have the recovery rate on the interval [0,1]. Figure 18 presents bin-scatter plots of the bank capitalization rate against my proxy for banks' recovery rates for each loan type.

This subsection describes the bank-level variables used to calculate the relation between recovery rates and bank capitalization rates, based on Call Reports. First, in the case of non-accrual on C&I loans, non-accrual loans to individual for households, non-accrual loans secured by real estate, I use*rcfd1608*, *rcfd1981*,and *rcfd1423*, respectively. Second, for loans past 90 or more and still accruing on C&I loans, non-accrual loans to individuals for households, and non-accrual loans secured by real estate, I use *rcfd1607*, *rcfd1979*, and *rcfd1422*, respectively. I sum them and define them as non-performing loans. Then, I use the recovery rate for each loan type for a given bank and I divide them. Then, I winsorize the observation for the proxy for banks' recovery rates to have the recovery rate on the interval [0,1]. Figure 18 presents bin scatter plots of the bank capitalization rate against my proxy for banks' recovery rates for each loan type.[16]. Then I winsorize the observation of bank's recovery rates to have recovery rate on the interval [0,1]. Figure 18 presents bin-scatter plots of the bank capitalization rate against my proxy of banks' recovery rates for each loans type.

[16]For further references, see The Fed- Micro Data Reference Manual.

Figure 36: Recovery rates on commercial and industrial loans and capitalization rate

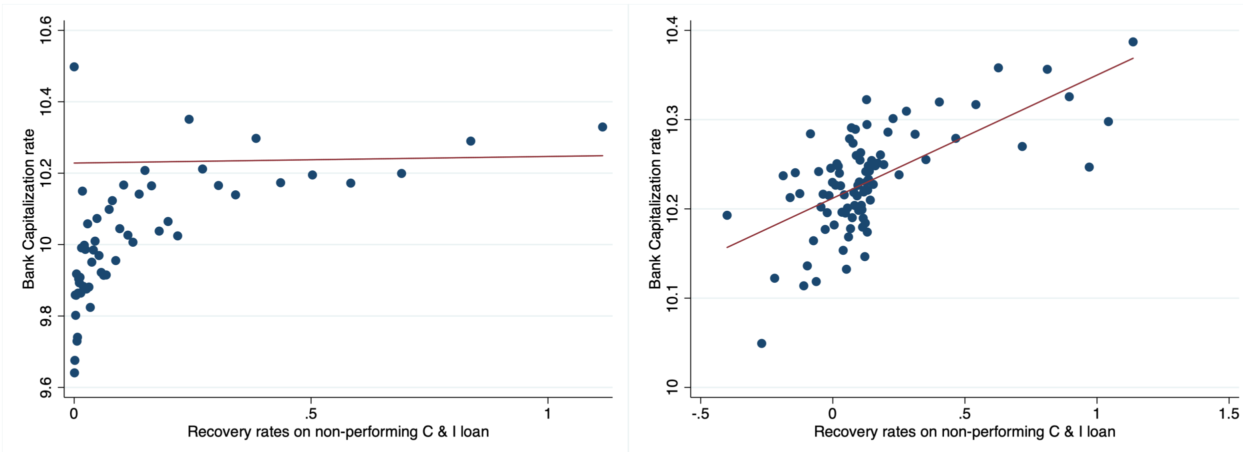


Figure 37: Recovery rates on personal loans and capitalization rate

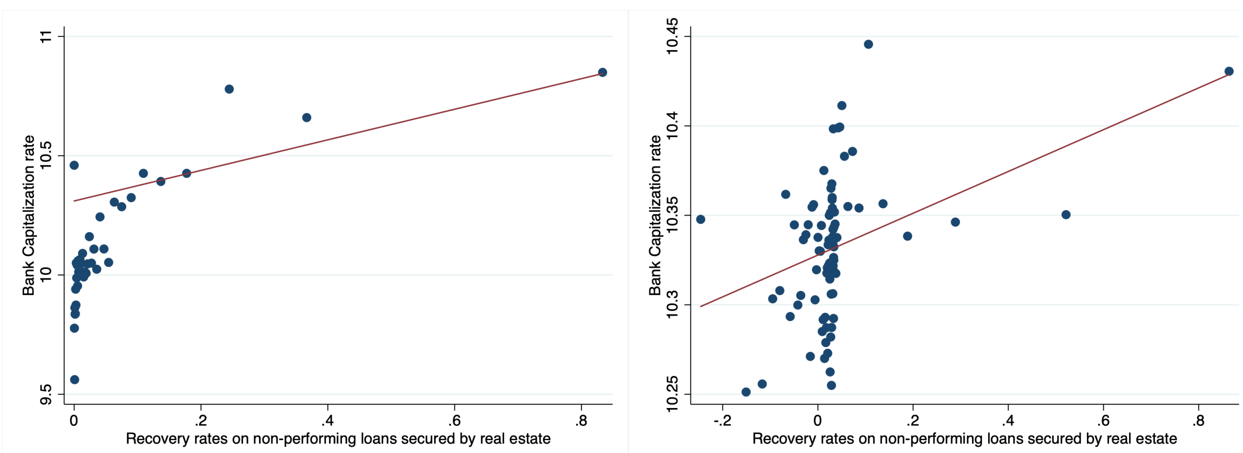
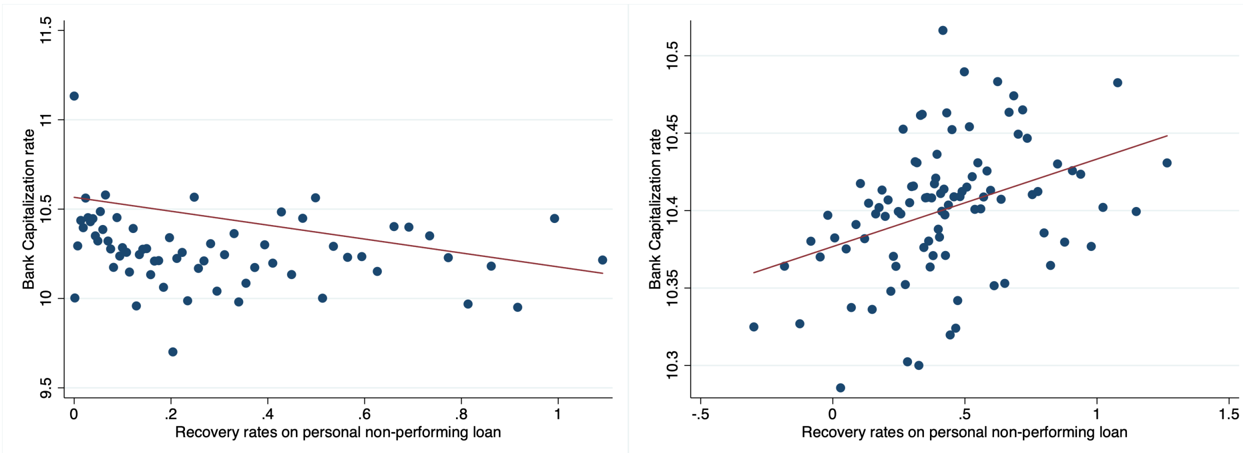


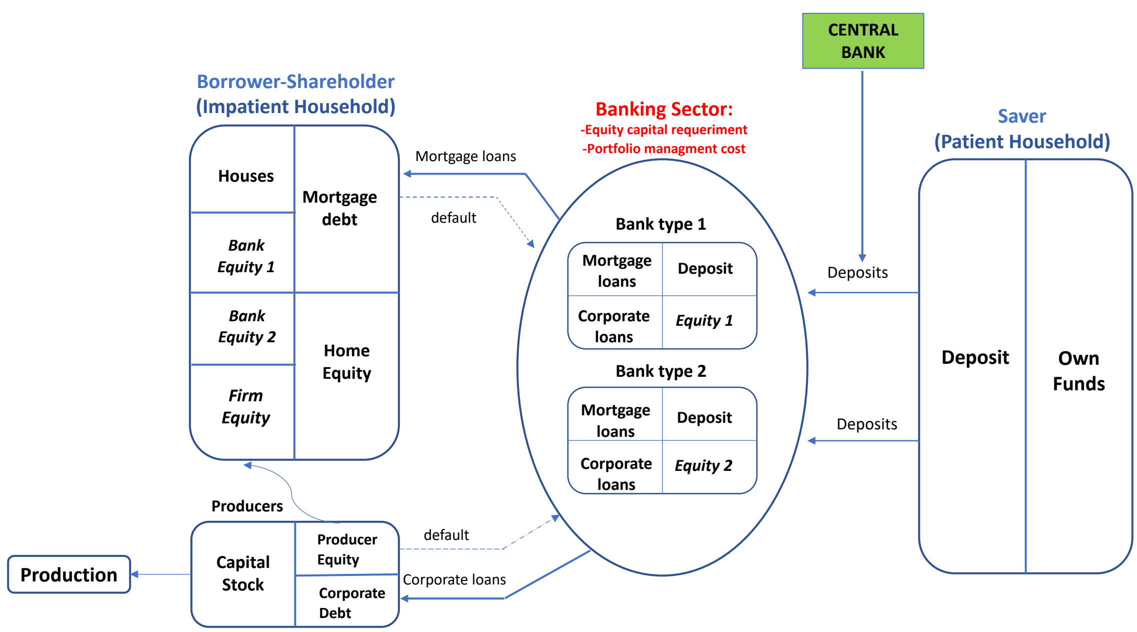
Figure 38: Recovery rates on personal loans and capitalization rate



K. Extension of the Baseline Model

In this section, I develop a heterogeneous-bank New Keynesian model. This dynamic stochastic general equilibrium model is based on Elenev et al. (2020) framework. The proposed model captures several realistic features of the loan types and banking heterogeneity; therefore, my approach is to build a general equilibrium model with two key parts: (1) two banks with different level of capitalization rate, (2) two loans (assets) with different riskiness, which can be interpreted as defaultable debt. Figure 39 depicts the connection between the balance sheet of different agents in the economy. The *representative saver* takes the consumption and saving decision to maximize inter-temporal expected utility. She inelastically supplies labor and can invest its saving in bank deposits. *Banks* maximize the present discounted dividends paid to their shareholder. They borrow from savers and issue equity from the borrower-shareholder, and they extend loans to borrower-shareholders and producers (non-financial firms) as mortgage loans and corporate loans, respectively. Banks are different in the tightening of the capital-requirements constraint and in the portfolio management cost. The *borrower-shareholder* (who can be thinking as capitalist or entreprenuer) maximizes inter-temporal expected utility. She also inelastically supplies labor and has housing, and then is funded by long-term defaultable mortgage debt that she issues to banks and has home equity. *Producers or intermediate-good producer* maximize profit and operate a production technology using labor and capital. They are funded by long-term defaultable corporate debt that they issue to banks and by equity issued by the household shareholders. Also, they buy capital from borrower and sell their intermediate output to retailers, in which this retailer have a monopolistic competition and faces a quadratic price-adjustment cost. Finally, to close the model, a representative final good producer combines retailer good, into final goods, and the monetary authority follows a standard Taylor rule.

Figure 39: Overview of the model



K.1 Environment

The model is formulated in discrete time with an infinite horizon.

Demographics Two groups of households exist: borrower-shareholders (which can be thought of as entrepreneurs or capitalists) and savers. I assume savers are more patient than borrower-shareholders. Also, the model contains other agents, namely, two banks, an intermediary firm producer, retailers, a final-good producer, and a monetary authority.

Preferences The households have logarithm preferences over consumption and housing services:

$$U_t^j = log(C_t^j) + \xi^j log(H_t^j) \qquad\qquad j \in \{S, B\}$$

I assume the housing market is segmented so that savers do not consume housing ($\xi^S = 0$). I make this assumption for simplicity.

Technology and housing Each intermediate-good producer uses a Cobb-Douglas production function using capital and labor. The level of housing is a fixed supply.

Financial assets The economy has three assets. The first is deposits, which is a one-period short-term bond. The second is mortgage debt, which correspond to the mortgage loan made to all borrower-entrepreneurs households. The third is the corporate bond, which correspond to all firms. Both types of loans have two characteristics: (1) Long-term bond as a perpetuity with coupon payments decay geometrically (δ^M, δ^A) and face value of individual bonds (F^M, F^A), respectively, for mortgage and corporate loans; and (2) defaultable debt. First, in the case of mortgage loan, borrowers receive an idiosyncratic house-valuation shock $\omega_{i,t}^H \overset{\text{iid}}{\sim} F_{\omega^H,t}$, then the value of the house after the shock is $\omega_i^H q_t^H H_t^B$, then the borrower-shareholder optimally chooses which member default $\Rightarrow$ threshold $\omega_t^{H,*}$

s.t. default for all $\omega_i < \omega_t^{H,*}$, and finally, banks seize housing capital and erase the debt of defaulting borrowers. Second, in the case of corporate loans, each firm-producer receives an idiosyncratic productivity shock $\omega_{i,t} \overset{\text{iid}}{\sim} F_{\omega,t}$, and each firm-producer defaults on debt if flow of profit $\pi(\omega_{i,t}) < 0$. This negative profit implies a ω_t^* threshold. Alternatively, producers with low productivity $\omega_t < \omega_t^*$ default. Therefore, the bank seizes the bankrupt firm and unwinds it.

Timing: The summary of the timing is the following. At the beginning of period t,

1. Intermediate-good producers choose labor inputs and pay a fixed cost of production, and borrower-shareholders enter with housing, and with mortgage debt.

2. Idiosyncratic housing-valuation shocks for borrower-shareholders are realized. Also, idiosyncratic productivity shocks for intermediate-good producers are realized, and then their production occurs.

3. Borrowers decide on mortgage default, and firms with negative profits default. Banks repossess the house in the case for borrowers. In the case of firm, banks assume ownership of bankrupt firms,.

4. Borrowers choose how much of the remaining mortgage balance to refinance. Firms decide how much of the capital and corporate loan to take. All agents solve their consumption, and portfolio-choice problems. Markets clear. All agents consume.

I describe the model in four blocks: the banking-sector block, which captures the heterogeneous banks; intermediate-good-production and borrower block, which capture the corporate and mortgage sector in the model; a New Keynesian block, which generates a New Keynesian Phillips curve; and representative saver households, which represent the depositors.

Banking-sector block

My banking-sector block consists of two banks that intermediates between savers and borrower-shareholders and firm-producers. These banks are owned by borrower-shareholders and pay them dividends subject to convex adjustment costs. These two banks are heterogenous in (i) equity-capital requirements, and (ii) portfolio-management cost. The bank portfolio consist of choosing (i) how many new corporate loans to make A_t^i with price q_t^a. Then, they will receive a coupon payment on performing loans $\Omega_A(\omega_t^*)A_t^i$, and firms that default go into liquidation and the recovery is:

$$\underbrace{[1-\zeta]}_{\text{not lost}}[\underbrace{(1-\Omega_A(\omega_t^*))}_{\text{frac. of default}}\underbrace{((1-\delta_K)p_t-\varsigma)K}_{\text{sell off capital}}+\underbrace{(1-\Omega_A(\omega_t^*))E_{\omega,t}[\omega|\omega<\omega^*]}_{\text{average product.}}\underbrace{MC_tY_t}_{\text{sell ouput}}]\underbrace{-(1-\Omega_A(\omega_t^*))\sum_j w^jL^j}_{\text{fraction of default,pay wages}}$$

where ζ is the fraction of firm assets and output lost to banks in bankruptcy. The next choice is (ii) the number of mortgage loans M_t^i with price q_t^m. Then they receive a coupon payment on performing loans $\Omega_M(\omega_t^{h^*})M_t^i$, and for borrower-households that default, the mortgage goes into foreclosure and the recovery is $\underbrace{[1-\zeta^h]}_{\text{not lost}}\times\underbrace{\left(\mu_{\omega^h}-\Omega_H(\omega_t^{h^*})\right)q_t^hH_t^{B^h}}_{\text{value of home after after default decisions have been made}}$ where ζ^h is the fraction of home value destroyed or lost in a foreclosure (measures the foreclosure costs). Finally, the bank chooses (iii) The number of deposits (D^i) for next period to borrow with price q^f. I assume savers are indifferent to taking deposits in either type (see appendix L.4 for the bank's complete problem description).

Borrower-shareholders and intermediate-good producers firm block

Borrower-shareholders (denoted by B)

The borrower-shareholder owns the firm and each type of bank. Then, she receives dividend payments. Also, she builds new capital goods X_t, and requires $X_t+\Phi(X_t/K_t)K_t$ where the adjustment cost Φ satisfies $\Phi(\delta_K)=\Phi'(\delta_K)=0$ and $\Phi''(\delta_K)>0$. Let $\iota(\omega^h):[0,\infty)\to\{0,1\}$ indicate the borrower's family decision to default on a house quality ω. The default decision is characterized by a threshold level ω^{h*}. Given this threshold, define

$$Z_M(\omega_t^{h*}) = \int_0^{\infty} (1-\iota(\omega^h)) dF_{\omega^h,t}(\omega_t^h) = Pr[\omega_{i,t}^h \geq \omega^{h*}]$$

$$Z_H(\omega^{h*}) = \int_0^{\infty} (1-\iota(\omega^h))\omega^h dF_{\omega^h,t}(\omega_t^h) = Pr[\omega_{i,t}^h \geq \omega_t^{h*}] \times E[\omega_{i,t}^h | \omega_{i,t}^h \geq \omega_t^{h*}]$$

$Z_M(\omega^{h*})$ is the fraction of debt repaid to banks, and $Z_H(\omega^{h*})$ is the value of the borrower of the residual (non-defaulted) housing stock after the default decision has been made. After making a coupon payment of one per unit of outstanding debt, the amount of outstanding debt declines to $\delta Z_M(\omega^{h*})M_t$. The borrowing constraint on shareholder leverage with max LTV Φ^B is

$$F^H M_{t+1+j}^B \leq \Phi^B q_{t+j}^h H_{t+1+j}$$

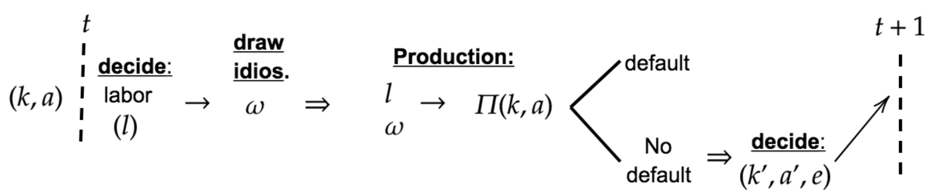
The borrower-shareholder produces new capital and sells it to the final firm. She supply inelastically her unit of labor $\bar{L}^B$ and earn wage w_t^B. The budget constraint is

$$\begin{aligned} & C_{t+j}^B + X_{t+j} + \Psi(X_{t+j}, K_{t+j})K_{t+j} + Z_M(\omega_{t+j}^{h^*})M_{t+j}^B(1+\delta_m q_{t+j}^m) + q_{t+j}^h H_{t+1+j} \\ & \leq w_{t+j}^B \bar{L}^B + p_{t+j}X_{t+j} + q_{t+j}^m M_{t+1+j}^B + Z_H(\omega_{t+j}^{h^*}) q_{t+j}^h H_{t+j} + Div_{t+j}^P + Div_{1,t+j}^I + Div_{2,t+j}^I \end{aligned}$$

Intermediate-good producers (denoted by P):

The firm maximizes the present discount of dividends paid to their shareholders. The firm combines capital k and labor l to produce the final good using the Cobb-Douglas production function and face an idiosyncratic productivity shock ω. Also, she buys capital at price p_t in a competitive market, and issues long-term debt defaultable bonds a at price q_t^a. I assume she faces a borrowing constraint on firm leverage with a maximum loan to value (LTV) Φ^P , and capital depreciates at rate δ_K (see appendix L.2 for the firm's complete problem description). Figure 7shows the timing of the firm within period: given capital and outstanding debt, the producer choose labor inputs and pays a fixs operational cost, then idiosyncratic shocks are realized, production occurs, and some firms that do not default pay dividends and issue new debt and new capital for next period.

Figure 40: Timing of events within period for the firm is as follows



K.1.1 New Keynesian block

The New Keynesian block of the model is designed to generate a New Keynesian Phillips curve relation between nominal variables and the real economy.

Retail-good producers:

I assume the presence of monopolistically competitive **retailers** (fixed mass of retailer $i \in [0,1]$) at the retail level. They buy inputs from the intermediate-good firms. They have a technology that can transform them one-for-one into retail-good varieties $\tilde{Y}_{it} = Y_{it}$, and sell these to final-good producers. Each retailer set P_{it} and Rotemberg sticky prices given demand curve $Y_t^d(P_{i,t})$ and the price of intermediate good P_t^y implies a marginal cost $MC_t = \frac{P_t^y}{P_t}$. The New Keynesian Phillips curve is

$$\frac{\Pi_t}{\bar{\Pi}}\left(\frac{\Pi_t}{\bar{\Pi}} - 1\right) = \frac{1}{\kappa}(1 - \eta + \eta MC_t) + \mathbb{E}_t\left[m^S_{t,t+1}(\frac{\Pi_{t+1}}{\bar{\Pi}} - 1)\frac{\Pi_{t+1}}{\bar{\Pi}_t}\frac{Y_{t+1}}{Y_t}\right]$$

Final-good Producers:

I assume a competitive representative final-good producer that combines the continuum of differentiated retailer goods indexed by $i \in [0,1]$ into final output using a Dixit-Stiglitz technology, $Y_t = \left(\int Y_{it}^{\frac{\gamma-1}{\gamma}} di\right)^{\frac{\gamma}{\gamma-1}}$, where γ is the elasticity of substitution across retail goods.

Monetary authority

Monetary authority follows a Taylor rule:

$$i_t = (\frac{1}{\beta_S} - 1) + (1-\rho_i)\left[\gamma_Y\left(Y_t - \bar{Y}\right) + \gamma_\Pi\left(\frac{\Pi_t}{\bar{\Pi}} - 1\right)\right] + \rho_i\left[i_{t-1} - (\frac{1}{\beta^S} - 1)\right] + \epsilon_t^{mp}$$

K.1.2 Representative-saver block (denoted by S)

The saver household is infinitely lived, and in each period t, obtains utility from consumption of non-durable good C_t^S, where $U(.)$ is a standard concave, twice continuously differentiable function. She inelastically supplies labor $\bar{L}^S$ remunerated with a wage w_t^S. The problem of the saver involves choosing consumption C^S and deposits D_{t+1} with price q_t^f to maximize its expected discounted lifetime utility (see appendix L.3 for the saver's complete problem description). I assume the saver can invest in government bonds (zero net supply) that pay nominal interest rate i_t. Then, by the arbitrage condition and the representative saver, no trade in bonds will occur. Then $B = 0$ in equilibrium. This condition allows to obtain a relation between deposit and the nominal rate:

$$\frac{1}{q_t^f} = \frac{1 + i_{t-1}}{\Pi_t}$$

K.1.3 Equilibrium and market-clearing conditions

Definition: Given a sequence of a monetary-policy shock $\{\epsilon_t^{mp}\}$, an idiosyncratic housing-quality shocks $\{\omega_t^h\}$, and an idiosyncratic productivity shock $\{\omega_t\}$, a **competitive equilibrium** is an allocation $\{C_t^B, H_t^B, M_t^B, \omega_t^{h*}, X_t\}$ for borrower-shareholder; $\{K_t^P, A_t^P, e_t^P\}$ for producer; $\{M_t^{I_i}, A_t^{I_i}, D_t^{I_i}, e_t^{I_i}\}$ for banks type $i \in \{1,2\}$; $\{C_t^S, D_t^S\}$ for savers (depositors); and $\{\{Y_t(i)\}_{i\in[0,1]}\}$ for retail firms and a set of prices $\{q_t^f, q_t^m, q_t^a, q_t^h, p_t^K, mc_t, w_t^B, w_t^S$ such that given prices:

- The borrower-shareholder and saver maximize life-time utility subject to their constraints.
- The producer and each type of banks maximize dividends subject to their constraints.
- The nominal interest rate is given by the Taylor rule.
- Markets clears:
  - **Corporate loan**
$$A_t^P = A_t^{I_1} + A_t^{I_2}$$
  - **Mortgage loan**
$$M_t^B = M_t^{I_1} + M_t^{I_2}$$
  - **Deposits**
$$D_t^S = D_t^{I_1} + D_t^{I_2}$$
  - **Capital**
$$K_t = (1-\delta_K)K_{t-1} + X_t$$
  - **Housing**
$$\bar{H} = H_t^B$$
  - **Labor**
$$L_t^j = \bar{L}^j \quad \text{for } j = B, S$$

– **Final goods**

$$Y_t = C^S + C^B + X_t + \Psi(X_t, K_t) + \sum_{i=1}^{2}(\Psi^{I_i}(e_t^{I_i}) + \Psi^{I_i}(A_t^{I_i}) + \Psi^{I_i}(M_t^{I_i})) + \Psi(e_t^P, N_t^P) + \sum_{i=h,k}^{2} DWL^i$$

With the model in hand, I intend to explore a better interpretation of my proposed mechanism and do some policy exercises to evaluate the interplay between monetary policy and financial stability.

K.2 Inspecting the mechanism or channel of monetary transmission

This section illustrates the mechanism of how policy ratesaffect the economy through the banking sector. I study the effect of an unexpected innovation to the Taylor rule followed by a perfect foresight transition back to the steady state. Focusing on the financial intermediaries or bank, the optimal choice of A^i and M^i, D^i satisfy the following conditions:

$$q_t^a(1 - \xi_A^i \tilde{\nu}_t^i) + \varphi_{A1}^i \left(\frac{A_t^i}{\varphi_{A0}^i} - 1\right) = \mathbb{E}_t \left[\frac{m_{t,t+1}^i}{\Pi_{t+1}} \left[\tilde{M}_{t+1}^A + \Omega_A(\omega_{t+1}^*)\delta_A q_{t+1}^a\right]\right] \text{ for bank } i \in \{1, 2\}$$

$$q_t^m(1 - \xi_M^i \tilde{\nu}_t^i) + \varphi_{M1}^i \left(\frac{M_t^i}{\varphi_{M0}^i} - 1\right) = \mathbb{E}_t \left[\frac{m_{t,t+1}^i}{\Pi_{t+1}} \left(\tilde{M}_{t+1}^H + \Omega_M(\omega_{t+1}^{h*})\delta_M q_{t+1}^m\right)\right] \text{ for bank } i \in \{1, 2\}$$

$$q_t^f(1 - \tilde{\nu}_t^i) = \frac{\mathbb{E}_t[m_{t,t+1}^i]}{\Pi_{t+1}} \text{ for bank } i \in \{1, 2\}$$

$$\frac{1}{q_t^f} = \frac{1 + i_{t-1}}{\Pi_t}$$

where the payoff per unit of long-term debt for corporate loans and mortgage loans is in appendix L.4. In addition, the default thresholds of corporate and mortgage loans are:

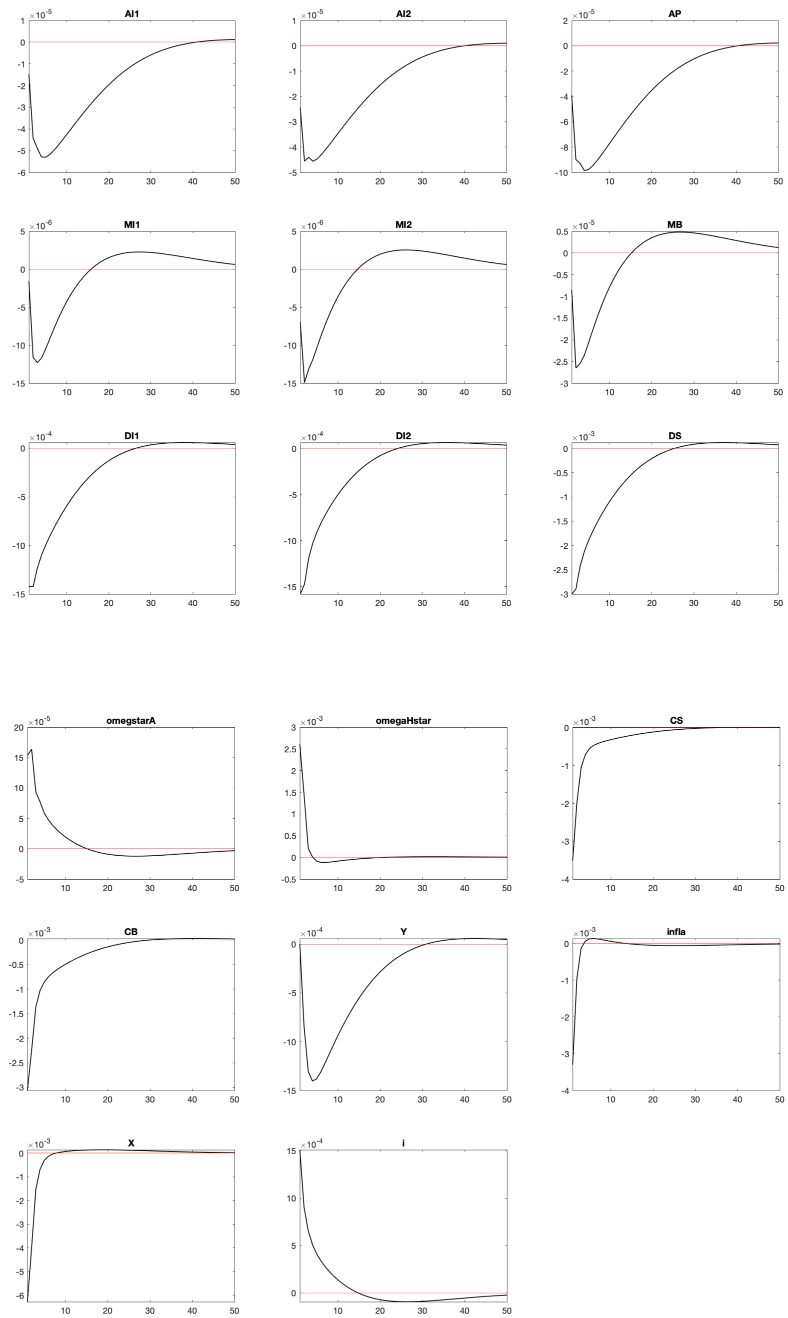
$$\omega_t^* = \frac{\frac{A_{t-1}^P}{\Pi_t} + \varsigma \frac{K_{t-1}}{\Pi_t} + (\sum_j w_t^j \bar{L}^j)}{MC_t Y_t} \qquad \omega^{*h} = \frac{(1 + \delta_m q_t^m)\frac{M_{t-1}^B}{\Pi_t}}{q_t^h H_{t-1}}$$

A key parameter in the FOC of banks is ξ_A^i and $\xi_M^{I_i}$, which are related the regulatory capital constraint, for example, $\xi_A^{I_i} = 1 - \Theta^i \varpi_A$, which implies higher Θ^{I_i}, higher capitalization rate.

K.3 Calibration and monetary-policy shocks

This section presents some preliminary results. First, I show the calibrations and then the results. The calibration strategy for this version is based on Elenev et al. (2020). One difference is that the corporate sector has a higher default rate than the mortgage sector, which implies the corporate sector is riskier than the mortgage sector to match my empirical evidence. Figure 41 shows the response to a contractive monetary-policy shock under the case of bank 1 having a higher capitalization rate than bank 2 and bank 1 having a higher share of corporate loans than bank 2 at the SS. This preliminary result is only qualitative, and I show some qualitative result of an unexpected increase in interest rates which have higher default rate in both sector, and this can be shown by the increase in default thresholds in both sector $\omega^*, \omega^{h,*}$, which implies a higher default rate. Also, both banks decrease their loans in both sectors.

Figure 41: Response to a contractive monetary-policy shock



L. Extension of the Baseline Model

L.1 Borrower-shareholder problem:

$$\max_{C_t^B, X_t, M_t, \omega_t^{h*}, H_t} \mathbb{E}_t[\sum_{t=0}^{\infty} \beta_B^t log(C_t^B) + \xi^B \log(H_t^B)]$$

$$s.t$$

$$C_t^B + X_t + \Psi(X_t, K_{t-1}) + \underbrace{Z_M(\omega_t^{h^*})\frac{M_{t-1}^B}{\Pi_t}}_{\text{repayment to bank on outstanding debt net of defaults}} + q_t^h H_t$$

$$\leq w_t^B \bar{L}^B + Div_t^P + Div_{1,t}^I + Div_{2,t}^I + p_t X_t + q_t^h H_{t-1} Z_H(\omega_{t+j}^{h^*}) + \underbrace{q_t^m * NM_t^B}_{\text{new bonds issued at price } q^m}$$

$$q_t^m M_t^B \leq \Phi^B q_t^h H_t \qquad NM_t^B = M_t^B - \underbrace{\delta_m Z_M(\omega_t^{h^*})\frac{M_{t-1}^B}{\Pi_t}}_{\text{remaining mortgage debt after default}}$$

Note the payment per unit of mortgage bond is 1 in the current period, and M_t^B is mortgage payment and the number of outstanding units of the mortgage bond. Also, Π_t is inflation.

L.2 Firm producer's problem

$$V^P(a_{t-1}^P, k_{t-1}, \mathcal{S}_t) = \max_{e^P, k_t, a_t^P} div_t^P - e_t^P + \mathbb{E}_t[\mathcal{M}_{t,t+1}^B V^{P,+}(a_{t+1}^P, k_{t+1}, \mathcal{S}_{t+1})]$$

subject to

$$div_t^P = \underbrace{\pi_t + e_t^P - \Psi(e_t^P, n_t^P)}_{\text{profit net of equity issuance}} - \underbrace{\delta q_t^a(a_{t-1}^P/\Pi_t)}_{\text{debt repay}} + \underbrace{(1-\delta_K)p_t^K(k_{t-1}/\Pi_t)}_{\text{depreciated k}} - \underbrace{p_t^K k_t}_{\text{buy new k}} + \underbrace{q_t^a a_t^P}_{\text{new debt}}$$

$$Fa_t \leq \Phi^P p_t^K k_t \qquad n_t^P = \pi_t + (1-\delta_K)p_t^K(k_{t-1}/\Pi_t) - \delta q_t^a(a_{t-1}^P/\Pi_t)$$

$$\pi_t = \max_l \omega \frac{P_t^y}{P_t} k_{t-1}^{1-\alpha} l_t^\alpha - \sum_j w_t^j l_t^j - \frac{a_{t-1}^P}{\Pi_t} - \varsigma \frac{k_{t-1}}{\Pi_t}$$

$V^{P,+}(k_t, a_t, \mathcal{S}_t) = \max_{l_t^j}(1 - F_{\omega,t}(\omega_t^*))\mathbb{E}_{\omega,t}[V^P(n_t^P, \mathcal{S}_t)|\omega_t > \omega*)]$
$\mathcal{S}_t$: represents the aggregate state variable.

1. Given k, a^P, producer choose l, pays a fixed cost of production $\varsigma \Rightarrow \omega^* = \frac{a^P + \varsigma k + \sum w^j l^j}{k^{1-\alpha} l^\alpha}$

2. $\omega_{i,t}$ is realized, production occurs, default occurs.

3. Failed firms are replaced by new firms to keep constant mass. Firm chose $k', (a^P)', e^P$

L.3 Saver's problem

$$\max_{C_t^S, D_t^S} \mathbb{E}_t[\sum_{t=0}^{\infty} \beta_S^t log(C_t^S) + \xi^S \log(H_t^S)]$$

$$s.t$$

$$C_t^S + q_t^f D_t^S \leq w_t^S \bar{L}^S + \frac{D_{t-1}^S}{\Pi_t}$$

Assume: $\xi^S = 0$; that is, the saver do not consume housing.

L.4 Banks's problem

$$V^g(N^g_{t-1}, \mathcal{S}_t) = \max_{A^g_t, M^g_t, D^g_t, e^g_t} \underbrace{\phi^g_0 N^g_t}_{\text{dividend}} - e^g_t + E_t[m^B_{t,t+1} V^g(N^g_{t+1}, \mathcal{S}_{t+1})]$$

subject to:

$$N^g_t - \phi^g_0 N^g_t + e^g_t - \Psi^g(e^g_t) \geq q^a_t A^g_t + q^m_t M^g_t - q^f_t D^g_t + \Psi^{I_i}(A^g_t) + \Psi^{I_i}(M^g_t) \quad \text{(budget constraint)}$$

$$q^f_t D^g_t \leq (1 - \Theta^g \varpi^a) q^a_t A^g_t + (1 - \Theta^g \varpi^m) q^m_t M^g_t \quad \text{(leverage constraint)}$$

$$N^g_t = [\tilde{M}^A_t + \Omega_{\omega,t}(\omega^*_t)\delta_A q^a_{t-1}] \frac{A^g_{t-1}}{\Pi_{t-1}} + [\tilde{M}^M_t + \Omega_{\omega^h,t}(\omega^{h*}_t)\delta_M q^m_{t-1}] \frac{M^{I_i}_{t-1}}{\Pi_{t-1}} - \frac{D^{I_i}_{t-1}}{\Pi_{t-1}} \quad \text{(LoM bank's wealth)}$$

The payoff per unit of long term debt (corporate loan):

$$\tilde{M}^A_t = \underbrace{\Omega_A(\omega^*_t)}_{\text{No default}} + \underbrace{\frac{(1 - \Omega_A(\omega^*_t))}{A^P_{t-1}/\Pi_t} \left[(1-\zeta) \left(\mathbb{E}_{\omega,t}[\omega < \omega^*] MC_t Y_t + ((1-\delta_K) p^K_t - \varsigma) K_t \right) - \sum_j w^j_t \bar{L}^j \right]}_{\text{default (recovery value)}}$$

$$\tilde{M}^M_t = \Omega_M(\omega^{h*}_t) + (1 - \zeta^h) \left(\mu^h_\omega - Z_H(\omega^{h,*}_t) q^h_t H_{t-1} \right)$$