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Bank size and the transmission of monetary policy: Revisiting the lending channel

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ABSTRACT

We model how monetary policy shocks affect the lending behavior of small and large banks. Other things being equal, small banks are riskier than large banks since the latter are more likely to be bailed out. Thus, small banks face a higher cost of non-deposit financing and are unable to finance liquidity shocks at a cost below a certain threshold. Consequently, we show that under a tight monetary regime small bank lending is more sensitive to monetary shocks. This relation reverses under loose monetary regimes where large bank lending is more responsive to monetary shocks. Our empirical results strongly support our analysis.

1. Introduction

The "bank lending channel" of monetary policy suggests that monetary policy affects not only the risk-free interest rate ("the money channel") but also influences the economy by affecting banks' lending behavior.[1] Indeed, Bernanke and Blinder (1992) find that changes in the monetary policy stance significantly impact aggregate bank lending volume. An influential paper by Kashyap and Stein (1995) finds support for this channel and shows that this channel works predominantly through the actions of small banks. They argue that the ability of large banks to raise external non-deposit finance to fund liquidity shocks makes them less sensitive to changes in monetary policy.

However, large banks control a significant percentage of assets in the U.S. economy. Indeed, recent data indicates that the top 5 banks hold more than 44% of the banking assets in the United States, a significant increase from 10% in 1990 (Vanderpool, 2014).[2] If monetary policy works predominantly through small banks, as previously found, an increase in the concentration of assets in large banks serves to blunt the bank lending channel of monetary policy and its associated effects on the economy.

Large banks differ from smaller ones in one other significant way - they can be termed as 'too big to fail'. Indeed, Kim (2016) estimates that the expected bailout probability conditional on bankruptcy for large banks is 76%, compared to 36% for small banks. Kelly et al. (2016) document differences in put prices and credit default swap rates across banks. They find that risk-adjusted crash insurance prices for large banks are lower than those of their smaller peers, indicating investors perceive differences in bailout likelihoods across institutions consistent with implicit 'too big to fail' guarantees. Acharya et al. (2022); Gandhi and Lustig (2015), and Santos (2014) also find evidence consistent with government guarantees to large banks.

In this paper, we present and test a more nuanced mechanism of the bank lending channel that accounts for the higher expected bailout likelihood of large banks, and the impact bailouts have on ex-ante lending activity. We argue that, ceteris paribus, a larger bailout likelihood should reduce the ex-ante cost of capital for large banks and incentivize them to lend more. Our model and empirical results show that large banks, despite their ability to raise external finance, are more sensitive to monetary policy when monetary policy is *loose*. Overall, we show that the bank lending channel may not be as "limited" to small banks as previously thought.

Our model consists of two types of banks: a "small" bank and a "big" bank. Both types of banks receive deposits and make investments in (risky) projects after setting aside a fraction of the deposits in liquid reserves. In the interim period, a fraction of depositors may "run" and withdraw their endowments early.

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[1] See, for instance, Bernanke and Blinder (1988), Bernanke and Gertler (1995), Kashyap and Stein (1994; 1995; 2000), and Peek and Rosengren (2013).

[2] Fig. 3 documents the aggregate increase in interest-earning assets (loans) for the Top 100 large banks in the U.S. economy compared to banks not in the Top 100 (smaller banks). From 1992 to 2018, total interest-earning assets in the Top 100 banks grew by 441%. In the same period, total interest-earning assets for smaller banks showed an increase of only 42%.

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Consequently, if the amount of reserves that the banks hold are insufficient to service the withdrawals, then they may need external funding to finance such liquidity shocks.[3]

The "financiers" providing the external funding can make investments in Treasury Bills (the yields of which are determined by monetary policy); thus, when lending to banks, these financiers require a rate of return commensurate to their opportunity cost of capital adjusted for the banks' risk. In other words, the banks' nominal cost of external funding depends on both monetary policy and their underlying risk. Thus, a monetary tightening increases the cost of such financing, whilst a monetary loosening decreases the cost of such funding.

However, Rajan (2006) noted that many institutions (e.g. insurance companies, pension funds, endowments, etc.) have fixed-rate commitments with their investors.[4] These institutional investors need to earn a minimum return on their investments to avoid a default on their contracts. When such institutions or "financiers" lend to banks, they expect to earn a rate of return greater than their *own* minimum return requirement.

In our model, smaller banks offer higher average returns but are riskier because they have a lower likelihood of a bail-out. In other words, from the investor's perspective, large bank riskiness can be mitigated due to perceived external "too big to fail" subsidies.[5]

We show that funds with relatively higher fixed-rate commitments are riskier and are incentivized to reach for yield to satisfy their contracts.[6] Such financiers invest in smaller banks. On the other hand, financiers with relatively lower fixed-rate commitments are safer and prefer to invest in larger banks. We then show that given the self-selection of financiers, the smaller banks have a higher minimum return requirement than larger banks.

After the global financial crisis of 2008, a series of empirical studies have debated the existence and extent of funding cost differentials between large and small banks related to too big to fail government support. These studies have documented an approximately 35 to 67 basis funding cost advantage on average for large banks and 121 basis points funding cost advantage on average for globally systemically important financial institutions (Bijlsma et al., 2014; Kroszner, 2016). Similarly, Acharya et al. (2022) find that for systemically important banks, the spreads on unsecured bonds are insensitive to risk. Jacewitz and Pogach (2018) report that between 2007 and 2008, the risk premium on uninsured deposits paid by the largest banks was 35 basis points lower than at other banks. Santos (2014) shows that the spread of bonds issued by the largest banks are, on average, 41 basis points below the smaller banks' bond spreads after controlling for bond characteristics.

The implication is that as monetary policy loosens, the cost of external funds for all banks decreases, but for small banks, the cost of funding eventually hits a lower bound such that any further monetary loosening does not decrease the cost of external financing. This is because external liquidity providers are unwilling to provide liquidity at a lower rate due to the underlying riskiness of such banks.[7]

Our model analyzes the sensitivity of banks' lending to monetary policy shocks in the presence of two frictions. The first friction relates to the higher likelihood of bailouts for large banks. The second friction is related to Rajan's (2006) observation that many non-bank intermediaries (e.g., pension funds) have fixed-rate commitments, which motivates such financiers to require a minimum return on their lending to banks. We study how the interaction of these frictions impacts the sensitivity of bank lending to monetary policy shocks.

In our model, the impact of monetary policy on bank lending works primarily via its effect on the cost of external funding. A monetary tightening increases a bank's external cost of funding. Consequently, the banks pass a fraction of this cost to their borrowers in the form of higher lending rates, which dampens bank lending. Intuitively, if the cost of funding any liquidity shortfalls increases (following a tightening), then it is in the interest of the bank to reduce lending. Conversely, if monetary loosening lowers a bank's cost of funding then a fraction of such savings are passed on to the bank's borrowers in the form of lower lending rates, increasing loan demand and boosting bank lending. In other words, as the cost of funding decreases, the bank is incentivized to increase lending. Nevertheless, as discussed above, if monetary loosening is unable to lower a bank's cost of funding beyond a certain threshold then such a bank's lending behavior becomes relatively less responsive to monetary policy shocks compared to other banks. As the central bank progressively loosens monetary policy by lowering the policy rate, the sensitivity of lending with respect to monetary policy of smaller banks will decrease relative to that of large banks.

This implies that large banks will be more sensitive to monetary policy shocks under a loose monetary policy regime where the policy rate is below a certain threshold. On the other hand, small bank lending will be more sensitive to monetary policy shocks under a relatively tight monetary policy regime. Intuitively, a bank's cost of funding is given by the opportunity cost of funds scaled by the underlying risk. Since small banks are riskier, any changes in monetary policy (in a tight regime) have a more significant effect on their lending behavior than larger banks.

Kashyap and Stein (2000) show that the impact of monetary policy is large for banks with liquidity constraints, which are mostly smaller banks in the bottom 95% of the bank size distribution. In a related paper, Campello (2002) shows that smaller banks affiliated with large multi-bank holding companies are less sensitive to a tightening in monetary policy. Further, Cetorelli and Goldberg (2012) show that even amongst large banks, global banks are less affected by domestic monetary policy or liquidity shocks than non-global banks. They argue that this is due to global banks' internal capital markets that allows the transmission of funds across borders. We contribute to this literature by showing an asymmetry in response to liquidity shocks of large and small banks in tight and loose monetary policy regimes.

The prior literature tests for the bank lending channel of monetary policy using bank lending regressions where changes in the federal funds rate are regressed on changes in bank lending (Kashyap and Stein, 1994; Kishan and Opiela, 2000). Our theoretical model suggests that monetary policy transmission depends on both the size of the bank and the monetary policy state in an asymmetric manner. Specifically, our model suggests that large banks are *more* (not less) sensitive to changes in the policy rate in

[3] Alternatively, we can consider a simpler albeit more general setup whereby there is a likelihood that the banks may be hit by a liquidity shock in the interim period and may thus need to resort to external funding to finance such a shock. Both of these interpretations give us the same results.

[4] Fixed-rate commitments imply that these institutions need to generate minimum returns for their investors (to avoid default). These commitments do not imply that their investors receive a constant spread over the risk-free rate.

[5] See Stein (1998) for a model of how informational problems make it difficult for small banks to raise external funding other than insured deposits. Similarly, Disyatat (2011) shows how informational asymmetries give rise to financial frictions, which are reflected in the external finance premium.

[6] OECD (2015) highlights concerns that pension funds and life insurance companies have incentives to reach for yield to match the level of returns promised to their investors.

[7] Put simply, smaller banks command a higher risk premium due to their higher underlying riskiness. Thus, even if policy rates are zero or near-zero, the risk premia for smaller banks will be positive and higher than that of large banks and may not change significantly as policy rates change.

loose monetary states. Our empirical identification strategy rests on extending the standard bank lending regression by introducing a triple interaction of the (1) large bank dummy, (2) a dummy for the loose monetary policy state, and (3) the change in the Fed funds rate. Suppose large banks are indeed *more* sensitive to changes in the Fed funds rate in loose monetary states. In that case, we expect the coefficient on interaction term to be negative, suggesting heightened transmission.

Our empirical tests using a comprehensive sample of 804,216 bank-quarters from 1992 to 2018 obtained from the Federal Reserve Board's Call Reports database are broadly supportive of our model.[8] The 27 year period in our sample consists of both tight (39 quarters) and loose (69 quarters) monetary policy regimes, which allows us to isolate our main effects cleanly. We also include a suite of standard bank-level control variables, controls for the business cycle, four lags of the dependent variable, bank fixed effects, and (in some specifications) time fixed effects.

Across all specifications, we find that the coefficient on the triple interaction is negative and significant. This finding provides large sample evidence that suggests that the bank lending channel maybe active through not just small banks, but also large ones during loose monetary regimes. These results contrast with extant research that claims that large banks are relatively insensitive to monetary policy.

An important consideration for the identification relates to our definition of the monetary policy regime. Our baseline tests consider the boundary between loose and tight monetary policy regimes is given by the equilibrium 4% federal funds rate as per the Taylor rule (Taylor, 1993). Our results are also robust to using a time-varying measure of monetary policy tightness that relaxes the fixed 4% cutoff point. In the alternative definition, we classify monetary policy as relatively tight if the real interest rate is greater than the natural real rate of interest following the Laubach and Williams (2003) model (LW R-star), where the real interest rate is defined as the Fed funds rate minus Core PCE inflation.

Similarly, another consideration for identification relates to the definition of the large bank dummy. It is well-known that the distribution of banks based on size (total assets) in the sample is highly skewed. We define a bank as large if it is in the top 2 percentile of the total asset distribution for that quarter. As an alternative, we use a 1% cutoff or consider a bank as large if it is among the top 25 banks by total assets in the quarter. The top 2% of banks held approximately 82% of total assets in the banking system in 2018-Q4 (in our sample data). The corresponding proportions for the top 1% and top 25 banks are approximately 75% and 64%, respectively. As these alternative definitions focus on even larger banks, we find that our results are stronger using them.

In addition to the gross lending effect, we also examine the sensitivity of the cost of capital for large and small banks to changes in the fed funds rate in relatively loose or tight monetary regimes. Ceteris paribus, our model implies that large banks benefit from a lower cost of capital than small banks due to lower risk from implicit too big to fail subsidies. Large banks may also benefit from lower information asymmetry and better access to capital. We compute the cost of debt capital for each bank-quarter following Dick-Nielsen et al. (2021) [DGT]. We employ a similar triple interaction identification strategy to explain the cost of debt capital in a panel regression with bank and time fixed effects. Consistent with our model, we find that the cost of debt capital for large banks is more sensitive to the Fed funds rate in relatively loose monetary policy states.

The DGT proxy for the cost of debt capital includes all interest payments and all bank debt obligations. Our theoretical model suggests that liquidity shortfalls are funded by external financiers. In practice, emergency funding is more likely to occur via non-deposit sources than via deposits, given the time taken to raise deposit financing. We conduct additional tests that consider the cost of deposit and non-deposit financing separately. While our results hold for both deposit and non-deposit financing, they are stronger for non-deposit financing.

We finally validate our findings using syndicated bank-loan level data from Dealscan to determine the impact of changes in monetary policy on large bank lending decisions. Specifically, we utilize the same triple interaction identification framework to examine determinants of the log loan amount contributed by a bank for the tranche. As banks that participate in syndicated loans are generally large, these tests are biased against finding an effect as the control group consists of larger banks relative to the overall bank population. Once again, we find that the triple interaction is negative and significant, suggesting that large bank lending is more sensitive to changes in the Fed funds rate in relatively loose monetary states.

Overall, our empirical tests support our theoretical model and shed new light on the role of large banks in the transmission of monetary policy.

2. The model

2.1. The basic setup

We consider a three-period model of bank i, where $i = S, B$ denotes the size of the bank, which can be either small (S), or big (B).[9] At $t = 0$, the bank receives deposits D^i from risk-neutral depositors. Each depositor invests 1 unit of their endowment in the bank. The reservation utility of the depositors is given by $\bar{u}$. Hence, to acquire deposits, the bank needs to set the rate of return on deposits, r_D^i, such that depositors receive an expected payoff of at least $\bar{u}$.[10] We assume that depositors are rational and when offered a contract they can ascertain whether r_D^i is high enough to satisfy their investor rationality.[11]

After acquiring deposits, the bank makes investments in projects while setting aside a fraction of the deposits as liquid reserves, R^i. The liquid reserves earn a (gross) rate of return, r_R, which is realized at $t = 2$, where r_R is determined by monetary policy.

The projects either succeed or fail at $t = 2$. The success probability of projects is given by θ, and if projects succeed, they payoff at $t = 2$. The projects not only have a default risk as given by $1 - \theta$ but are also illiquid since they payoff at $t = 2$. On the other hand, investment in reserves, R^i, does not suffer from either default or illiquidity risk. Thus, investment in reserves can be interpreted as an investment in safe assets, whilst investment in projects can be interpreted as an investment in risky assets.

After observing θ, the bank sets the project lending rate, r_L^i, which is the (gross) rate of return on loans. When setting the loan rate the bank takes into account the success probability of

8 We begin our sample in 1992 as a key control variable, credit demand, is only available after 1992.

9 Alternatively, the size of the bank, i, could be a continuous variable such that a higher i denotes a larger bank. The paper's analysis remains the same regardless of whether we treat i as a continuous or a binary variable.

10 We can also model $\bar{u}$ as a function of monetary policy, but it has no bearing on our qualitative results. It is also argued (for instance, by Disyatat, 2011) that many deposit accounts (e.g., checking accounts) are held for transactional purposes and are insensitive to changes in the policy rate. Hence, in our setup $\bar{u}$ is not interest-sensitive, and thus our results are not driven by arguments related to portfolio substitution by depositors.

11 Alternatively, we can assume that the risk premium required to satisfy investor rationality is public information.

the projects, θ, as well as the demand function for loans which is given by $L(r_L^i)$, where $L'(r_L^i) < 0$. Thus, the investment retained in bank reserves is given by:

$$R^i = D^i - L(r_L^i). \tag{1}$$

Let r_m^t denote the monetary policy stance of the central bank at date t, where r_m^t can be interpreted as the yield on Treasury bills at date t. The yield on Treasury Bills is a function of monetary policy whereby a monetary tightening increases r_m^t and a monetary loosening decreases r_m^t. Our principal focus is to analyze the effect of a change in monetary policy stance at $t = 0$ (as denoted by r_m^0) on a bank's portfolio allocation between risky loans and safe reserves. However, this effect will also depend on the monetary policy stance at $t = 1$ (denoted by r_m^1). We thus need to specify the distribution of monetary policy shocks. In particular, we need to specify the extent of persistence of monetary policy as well as the degree of uncertainty at $t = 0$ surrounding the realization of r_m^1. To do so, we pick the following formulation similar to Kashyap and Stein (1995). Once r_m^0 is realized the distribution of r_m^1 is given by

$$r_m^1 = \phi r_m^0 + \gamma \tag{2}$$

where the expected value of γ is zero, i.e. $E[\gamma] = 0$ and the parameter ϕ is a measure of the persistence of monetary policy shocks - the larger is ϕ, the more permanent are monetary policy shocks.[12]

Without loss of generality, we assume that the rate of return on liquid reserves, r_R, is given by r_m^0. This would be the case, for instance, if the bank invested its liquid reserves in Treasury Bills. All our results hold even if r_R is a more general function of r_m^0 and also for the case where $r_R = 1$ which implies that liquid reserves are held as cash.

In the interim period, $t = 1$, similar to Bryant (1980) and Diamond and Dybvig (1983), the bank could experience withdrawals whereby some depositors suffer a liquidity shock and withdraw their endowments. The fraction of depositors who withdraw early is denoted by a random variable, $\tilde{x}$, where $\tilde{x} \in [0, 1]$. The cumulative distribution function and the probability density function are given by $F(\tilde{x})$ and $f(\tilde{x})$, respectively. Each depositor who withdraws in the interim period, $t = 1$, receives back 1 unit of his endowment. Thus, the cumulative withdrawals at $t = 1$ are given by $\tilde{x}D^i$.[13]

The bank faces a liquidity shortfall at $t = 1$ if the total amount of withdrawals, $\tilde{x}D^i$, exceeds the amount of bank reserves, R^i. In this case, the bank needs to raise external financing, Ω^i, where $\Omega^i = \tilde{x}D^i - R^i$, to cover its liquidity shortfall. In our model, the external financing at $t = 1$ takes the form of non-deposit debt securities. Let r_F^i denote the per unit (i.e. per dollar) cost of debt financing at $t = 1$. Thus, the debt issuance cost of covering the liquidity shortfall is $r_F^i \Omega^i$ and it varies with the size of the bank. We assume that the bank also faces a per unit (i.e. per dollar) financing cost, $c(r_F^i)$, where $c'(r_F^i) > 0$, and $c''(r_F^i) < 0$. The financing cost, $c(\cdot)$, could be interpreted as a non-pecuniary cost, and it ensures that the second-order condition (of the bank's problem at $t = 1$) is satisfied.

Finally, at $t = 2$ the bank either fails or succeeds and the payoffs are divided amongst the parties according to contractual terms. With probability θ bank i succeeds and can repay the debt borrowed at $t = 1$ to cover any liquidity shortages. However, if a large bank fails, then with probability β, it is bailed out by the regulator.[14] Thus, the success probability of a large bank paying its debt is $\theta + (1 - \theta)\beta$, which is greater than the success probability of a small bank since $\beta > 0$.[15] Let ρ^i denote the probability that bank i will repay its debt. Thus ρ^i is given by:

$$\rho^i = \begin{cases} \theta & \text{for } i = S \\ \theta + (1 - \theta)\beta & \text{for } i = B \end{cases} \tag{3}$$

The sequence of events is summarized in the timeline in Fig. 1.

2.2. Financiers

The bank "*financiers*" face an opportunity cost of r_m^1 at $t = 1$ since they can make an investment in Treasury Bills and earn the corresponding yield. Thus, the bank needs to ensure that, on average, it pays a return of at least r_m^1 on the debt securities that it issues at $t = 1$. Furthermore, as OECD (2015) and Rajan (2006) noted, many institutions, like insurance companies, pension funds, endowments, etc., have fixed-rate commitments whereby they need to earn a rate of return on their investments greater than a certain threshold to avoid a default on their contracts. Suppose the fixed-rate commitments of the financier are given by $\digamma$.

The financier can lend to either small banks or large banks. The small bank gives a gross return of r_F^S with probability ρ^S, where ρ^S is the probability that the small bank will repay its debt. The large bank gives a gross return of r_F^B with probability ρ^B, where ρ^B is the probability that the large bank will repay its debt. The small banks are riskier since they face a lower likelihood of a bailout and thus have to compensate investors for the higher risk. This implies that the gross return offered by the small bank is higher than that offered by large banks, but the probability of default is also higher. More formally, $r_F^S > r_F^B$ but $\rho^S < \rho^B$. If the bank fails and is not bailed out, the return to financiers is zero. Overall, investment in the small bank has a higher expected return, i.e., $\rho^S r_F^S > \rho^B r_F^B$, but there is also a higher probability of failure.

In the event of failure, the financiers default on their fixed-rate commitments and face a cost, K, that is increasing in $\digamma$.[16] We assume that the cost function, $K(\digamma)$, satisfies the usual conditions whereby K is increasing in $\digamma$ and is a convex function of $\digamma$, i.e. $K'(\digamma) > 0$ and $K''(\digamma) > 0$.

Assuming risk neutrality, the problem of the financier is to choose the asset type so as to maximize its expected profit. Thus, the financier solves the following problem:

$$\max_{i=B,S} U = \rho^i \left(r_F^i - \digamma\right) - (1 - \rho^i) K(\digamma) \tag{4}$$

In other words, the financier chooses the riskiness of the asset portfolio so as to maximize the expected return from the investments minus the expected cost in the event of failure. We can then prove the following proposition:

Proposition 1. *The financier will invest in the small bank, if and only if its fixed-rate liability commitments, $\digamma$, exceed a certain threshold, $\digamma^*$, where*

$$\digamma^* = K(\digamma^*) - \frac{\left(\rho^S r_F^S > \rho^B r_F^B\right)}{\rho^B - \rho^S}. \tag{5}$$

[12] We choose this formulation for its simplicity. However, any other distribution of r_m^1 gives us similar results.

[13] As in Allen and Gale (1998), we could have assumed that the fraction of depositors who run correlates with asset quality news. Alternatively, we can simply assume that the bank suffers a liquidity shock at $t = 1$, which must be financed.

[14] More generally, we can alternatively assume that the small bank is bailed out with probability α such that $\alpha < \beta$.

[15] Apart from a large bank being "too big to fail" there may be other reasons why a larger bank is more likely to repay its debt. For instance, the asymmetry of information between a large bank and outsiders may be lower relative to the case of a small bank because of which a large bank may have access to a larger pool of liquidity.

[16] Schmeiser and Wagner (2015) observed that from the late 1980s through the 2000s, many life insurer defaults occurred when they could not meet their guaranteed commitments.

Table 1
Summary Statistics The table provides descriptive statistics for the data used in our main tests, sourced from the U.S. Federal Reserve Call Report database in Panel A. The sample period extends from 1992 to 2018 and consists of 804,216 bank-quarter observations. Total assets are Call Report variable code RCFD2170, total loans are RCFD2122, deposits are RCFD 2200. Bank Liquidity is defined following Kashyap, Rajan, and Stein (2002) as the sum of RCFD1350, RCFD1754, and RCFD1773. Non-performing loans (NPL) is defined as the sum of RCFD1407 and RCFD1403. All bank-specific controls are scaled by bank total assets. GDP growth (GDP), core inflation (CPILFESL), and credit demand (DRSDCILM) are taken from the St. Louis Feds FRED database as of the beginning of the quarter. Panel B presents the average bank size and the percentage of aggregate total assets held for various size groups examined in the study.

Panel A: Summary Statistics

Variable	N	Mean	Standard Deviation	Q1	Median	Q3
Total Loans	804,216	716140	12489643	27854	65376	163468
Log Loans	804,216	11	1.4	10	11	12
δ Log Loans	804,216	0.02	0.064	-0.088	0.016	0.043
Fed Funds Rate	804,216	0.029	0.022	0.0038	0.03	0.053
Deposits/Assets	804,216	0.84	0.088	0.81	0.86	0.89
Liquidity/Assets	804,216	0.27	0.16	0.15	0.25	0.36
Equity/Assets	804,216	0.11	0.034	0.084	0.098	0.12
NPL/Assets	804,214	0.008	0.012	0.0013	0.0042	0.0099
Credit Demand	804,216	1.5	26	-11	1.8	19
GDP Growth	804,216	0.011	0.0063	0.0089	0.012	0.015
Core Inflation	804,216	0.022	0.0054	0.019	0.022	0.026

Panel B: Bank size distribution

Bank size group	Average total assets ($ million)	Percentage of aggregate total assets
Top 25 banks	244,086	60.5%
Top 1% banks	94,683	73.5%
Top 2% banks	51,261	79.8%
Bottom 98% banks	251	20.2%

Table 2
Bank Size and the Transmission of Monetary Policy In this table we study the relation between the change in bank lending (δ log total loans) and changes in the Fed funds rate for large and small banks under loose and tight regimes. Large banks are defined as those having assets in the top 2% in the quarter. In the baseline test, we define loose monetary policy periods when the Fed funds rate is less than or equal to 4%. The highlighted row indicates the main object of interest, the triple interaction between large bank, loose monetary state, and the change in the fed funds rate. All models include 4 lags of the dependent variable and bank fixed effects. Model 1 presents the baseline effects without bank controls. Model 2 adds bank controls: deposits, liquidity, equity, and non-performing loans (NPL) scaled by total assets. Model 3 additionally saturates the specification with time fixed effects (quarter-year dummies). Standard errors are clustered at the bank level.

VARIABLES	Model 1	Model 2	Model 3
δ Fedfunds Rate	-0.163***	-0.200***	
	(0.0114)	(0.0119)	
Large Bank (Top 2%)	-0.0332***	-0.0276***	-0.0272***
	(0.00275)	(0.00289)	(0.00290)
Large Bank (Top 2%) $\times$ δ Fedfunds Rate	0.451***	0.398***	0.387***
	(0.0883)	(0.0900)	(0.0895)
Loose Dummy	-0.00798***	-0.00280***	
	(0.000181)	(0.000199)	
Loose Dummy $\times$ δ Fedfunds Rate	0.210***	0.0503***	
	(0.0133)	(0.0145)	
Large Bank $\times$ Loose Dummy	0.0110***	0.00702***	0.00645***
	(0.00150)	(0.00160)	(0.00161)
Large Bank $\times$ Loose Dummy $\times$ δ Fedfunds Rate	-0.227**	-0.257**	-0.259**
	(0.104)	(0.106)	(0.106)
Deposits/Assets		0.0302***	0.0365***
		(0.00306)	(0.00328)
Liquidity/Assets		0.0506***	0.0525***
		(0.00130)	(0.00145)
Equity/Assets		0.149***	0.158***
		(0.00772)	(0.00786)
NPL/Assets		-0.779***	-0.730***
		(0.0111)	(0.0114)
Credit Demand		0.000116***	
		(3.73e-06)	
GDP Growth		0.0206	
		(0.0132)	
Inflation		0.0680***	
		(0.0171)	
Constant	0.0185***	-0.0346***	-0.0413***
	(0.000176)	(0.00280)	(0.00311)
Lag Dependent Variable	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes
Time Fixed Effects (Year-Quarter)	No	No	Yes
Observations	804,216	804,216	804,216
Adjusted R-squared	0.116	0.141	0.157

Robust Clustered standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 3
Alternative Definition of the Monetary Policy Regime In this table we repeat the test presented in Table 2 with an alternative definition of the monetary policy regime that relaxes the fixed 4% cutoff point. We classify monetary policy as relatively tight if the real interest rate is greater than natural real rate of interest following the Laubach-Williams (2003) model (LW R*), where the real interest rate is defined as the Fed funds rate minus Core PCE inflation. Monetary policy is defined as relatively loose otherwise. The dependent variable continues to be the change in bank lending (δ log total loans), and large banks are defined as those having assets in the top 2% in the quarter. The highlighted row indicates the main object of interest, the triple interaction between large bank, relatively loose monetary state, and the change in the fed funds rate. All models include 4 lags of the dependent variable and bank fixed effects. Model 1 presents the baseline effects without bank controls. Model 2 adds bank controls: deposits, liquidity, equity, and non-performing loans (NPL) scaled by total assets. Model 3 additionally saturates the specification with time fixed effects (quarter-year dummies). Standard errors are clustered at the bank level.

VARIABLES	Model 1	Model 2	Model 3
δ Fedfunds Rate	-0.150***	-0.201***	
	(0.0125)	(0.0130)	
Large Bank (Top 2%)	-0.0365***	-0.0304***	-0.0297***
	(0.00286)	(0.00298)	(0.00299)
Large Bank (Top 2%) $\times$ δ Fedfunds Rate	0.460***	0.453***	0.440***
	(0.0963)	(0.0974)	(0.0970)
Relatively Loose Dummy	-0.00632***	-0.00111***	
	(0.000181)	(0.000198)	
Relatively Loose Dummy $\times$ δ Fedfunds Rate	0.237***	0.0876***	
	(0.0141)	(0.0158)	
Large Bank $\times$ Relatively Loose Dummy	0.0142***	0.0101***	0.00942***
	(0.00159)	(0.00165)	(0.00166)
Large Bank $\times$ Relatively Loose Dummy $\times$ δ Fedfunds Rate	-0.221**	-0.290***	-0.289***
	(0.103)	(0.105)	(0.105)
Deposits/Assets		0.0295***	0.0363***
		(0.00305)	(0.00329)
Liquidity/Assets		0.0517***	0.0524***
		(0.00130)	(0.00145)
Equity/Assets		0.147***	0.157***
		(0.00771)	(0.00787)
NPL/Assets		-0.779***	-0.730***
		(0.0111)	(0.0114)
Credit Demand		0.000113***	
		(3.77e-06)	
GDP Growth		0.0268**	
		(0.0135)	
Inflation		0.126***	
		(0.0171)	
Constant	0.0177***	-0.0363***	-0.0410***
	(0.000182)	(0.00281)	(0.00312)
Lag Dependent Variable	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes
Time Fixed Effects (Year-Quarter)	No	No	Yes
Observations	804,216	804,216	804,216
Adjusted R-squared	0.115	0.141	0.157

Proposition 1 says that financiers self-select the size of the bank for investment purposes. The financier with high enough fixed-rate commitments will invest in smaller banks. In comparison, the financier with relatively lower fixed-rate commitments will choose to invest in larger banks. Intuitively, funds that have promised their investors higher fixed-rate commitments are riskier and thus need to reach for yield to fulfill their contracts. On the other hand, safer funds have lower fixed-rate commitments and prefer to invest in larger banks.

The minimum return demanded by financiers is such that the financier earns an expected profit of at least zero ex ante. This ensures that ex ante, the financier would be able to service its fixed-rate commitments. Let $\underline{r_F^i}$ denote the minimum return demanded by the financier from bank i and let F^j denote the fixed-rate commitment of fund j for $j = h, l$, where $F^j = F^h$ if $F > F^*$ and $F^j = F^l$ if $F \leq F^*$. In other words, F^h denotes the relatively high fixed rate commitments of the financier which lends to the small bank, while F^l denotes the relatively lower fixed rate commitments of the financier which lends to the large bank. We can then prove the following proposition.

Proposition 2. *The minimum return requirement of the financier, which lends to the small bank is given by*

$$\underline{r_F^S} = \frac{\rho^S F^h + \left(1 - \rho^S\right) K\left(F^h\right)}{\rho^S}, \tag{6}$$

while the minimum return requirement of the financier who lends to the large bank is given by

$$\underline{r_F^B} = \frac{\rho^B F^l + \left(1 - \rho^B\right) K\left(F^l\right)}{\rho^B}. \tag{7}$$

We then have the following corollary to Proposition 2.

Corollary 1. *Since $\rho^S > \rho^B$ and $F^h > F^l$, the minimum return requirement demanded by the financier is higher for the small bank relative to the large bank. More formally, $\underline{r_F^S} > \underline{r_F^B}$.*

The intuition behind the above corollary is as follows. The financier who lends to the small bank has higher fixed rate commitments and faces a higher probability of default from the small bank. It follows that the minimum return requirement from lending to the small bank is higher than that for the large bank.

2.3. The bank's problem

At $t = 0$, a bank makes its portfolio choice by setting the lending rate, r_L^i, and allocating funds to bank reserves, R^i, after taking into account the expected cost of its liquidity shortfall at $t = 1$.[17]

[17] Note that setting the lending rate, r_L^i, is equivalent to choosing a loan volume $L\left(r_L^i\right)$ given the one to one mapping from the lending rate to loan volume as determined by the downward sloping loan demand function $L\left(r_L^i\right)$.

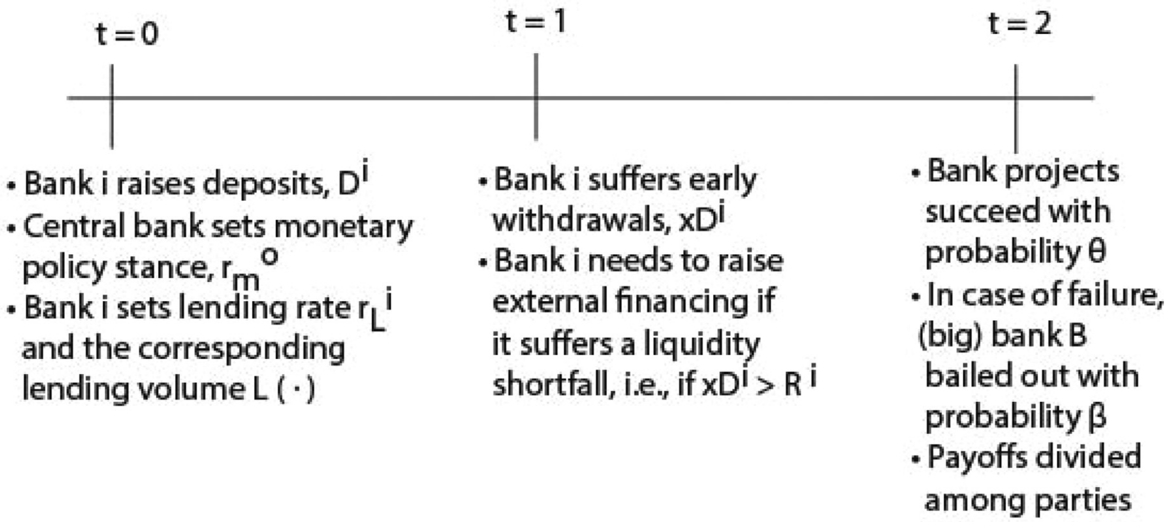

Fig. 1. Model timeline.

To analyze how a bank's portfolio choice is affected by central bank's monetary policy stance we need to solve the model backwards. We first solve the bank's problem in the interim period, whereby it may need to raise external financing to cover any liquidity shortfalls. Subsequently, we solve the bank's optimal portfolio allocation problem by taking into account the expected cost of raising finance to cover any liquidity shortfalls.

2.3.1. The bank's problem at $t = 1$

In the interim period, $t = 1$, if a bank faces a liquidity shortfall, Ω^i, then it solves the following problem:

$$\min_{r_F^i} r_F^i \Omega^i + c\left(r_F^i\right)\Omega^i \tag{8}$$

subject to

$$\rho^i r_F^i \Omega^i \geq r_m^1 \Omega^i \tag{9}$$

and

$$r_F^i \geq \underline{r}_F^i. \tag{10}$$

The above problem says that a bank chooses its per unit cost of financing, r_F^i, to minimize its total cost of liquidity shortfalls subject to two constraints. Constraint (9) is the participation constraint of the financier. It says that the financier must at least receive on average, the opportunity cost of funds as given by the return on Treasury Bills. Constraint (10) is the minimum return requirement which says that the return to the financier must exceed a threshold $\underline{r}_F^i$, where $\underline{r}_F^i$ is given by Proposition 2. In short, a bank sets r_F^i so as to minimize its cost of financing subject to the financier's participation constraint and the financier's minimum return requirement.[18]

We can then prove the following proposition.

Proposition 3. *The per unit (i.e. dollar) cost of financing the liquidity shortfall, $\left(\tilde{x}D^i - R^i\right)$, at $t = 1$ for a small bank, is given by*

$$r_F^S = \max\left(\frac{r_m^1}{\theta}, \underline{r}_F^s\right), \tag{11}$$

where $\underline{r}_F^s$ is given by Eq. (6). The per unit (i.e. dollar) cost of financing the liquidity shortfall, $\left(\tilde{x}D^i - R^i\right)$, at $t = 1$ for a big bank is given by

$$r_F^B = \max\left(\frac{r_m^1}{\theta + (1-\theta)\beta}, \underline{r}_F^B\right). \tag{12}$$

where $\underline{r}_F^B$ is given by Eq. (7).Since $\beta > 0$ and $\underline{r}_F^S > \underline{r}_F^B$, it follows that $r_F^S > r_F^B$.

Proposition 3 says that the cost of financing any liquidity shortfalls is the higher of the opportunity cost of funds (as determined by monetary policy) or the minimum return requirement adjusted for risk.[19] Intuitively, the financiers always need to earn on average, at least their opportunity cost of funds as reflected by the return on Treasury Bills, where the latter is a function of monetary policy. However, if the interest rates set by the central bank are very low (for instance close to zero percent), the financiers will want to meet at least their minimum return requirement. In the latter case, where the central bank adopts a loose or an ultra-loose monetary policy, the cost of financing will be given by the minimum return requirement of financiers after adjusting for risk.

Furthermore, Proposition 3 says that the cost of financing is higher for small banks relative to larger banks. This is because the larger banks have a higher likelihood of repaying their debts as they are more likely to be bailed out if they are unable to service their financial obligations.

2.3.2. The bank's problem at $t = 0$

At $t = 0$, the bank chooses its portfolio to solve the following problem:

$$\max_{r_L^i, r_D^i, R^i} \Pi^i = \pi^i - \theta\left(\hat{r}_F^i + \hat{c}\left(r_F^i\right)\right) E\left[\max\left(\tilde{x}D^i - R^i, 0\right)\right] \tag{13}$$

subject to

$$E(\tilde{x}) + (1 - E(\tilde{x}))\left[\theta r_D^i + (1-\theta)\frac{r_R E\left[\max\left(R^i - \tilde{x}D^i, 0\right)\right]}{(1 - E(\tilde{x}))D^i}\right] \geq \bar{u} \tag{14}$$

[18] Alternatively, we could have considered the case where the financier has monopolistic power so that it sets r_F^i to maximize its expected utility subject to the bank's participation constraint and the financier's minimum return requirement. In either case, the qualitative results remain unchanged.

[19] This is consistent with the findings of Adrian and Shin (2008; 2009). They document that the cost of funding is tightly related to the short term interest rates and in particular to the federal funds target rate.

and

$$L\left(r_L^i\right) + R^i = D^i \tag{15}$$

where $E(\cdot)$ is the expectations operator over the distribution of $\tilde{x}$; $\hat{r}_F^i$ and $\hat{c}\left(r_F^i\right)$ are the expected values of r_F^i and $c(\cdot)$ respectively over the range of values of r_m^1; and π^i is given by

$$\pi^i = \theta\left\{r_L^i L\left(r_L^i\right) - r_D^i D^i(1 - E(\tilde{x})) + r_R E\left[\max\left(R^i - \tilde{x}D^i, 0\right)\right]\right\}. \tag{16}$$

Eq. (16) represents the expected profit of the bank, excluding the cost of any liquidity shortfalls. With probability $(1-\theta)$, bank profits are zero since the bank fails and its projects are unsuccessful. With probability θ, the bank does not fail, in which case the bank's expected profit is given by the expected return from the loans $[r_L^i L\left(r_L^i\right)]$ minus the expected cost of deposits $(r_D^i D^i[1 - E(\tilde{x})])$ plus the expected value of net reserve holdings at the end of the period (which is given by the last term of the equation). The last term of Eq. () represents the expected cost of financing any liquidity shortfalls in the interim period, which is given by the likelihood of repaying the debt, θ, multiplied by the expected cost of financing liquidity shortfalls, if any which is given by $\left(\hat{r}_F^i + \hat{c}\left(r_F^i\right)\right)E\left[\max\left(\tilde{x}D^i - R^i, 0\right)\right]$.[20] Thus, Π^i as represented by Eq. (13) is the expected net profit of the bank. Expression (14) represents the participation constraint of depositors. With probability $E(\tilde{x})$, a depositor withdraws his funds early, in which case he receives a payoff of one. With a probability of $(1 - E(\tilde{x}))$, the depositor does not experience a liquidity shock, in which case he receives a promised payment of r_D^i if the bank does not fail (which is with probability θ). In case of a bank failure (which happens with probability $1-\theta$), any surplus bank reserves are divided amongst the depositors who did not run. Thus expression (14) says that the depositors must, on average, receive at least their reservation utility. Eq. (15) is the budget constraint of the bank, and it simply represents the balance sheet identity of the bank, i.e. the sum of loan volume and bank reserves must equal the total deposits received by the bank.

Thus the above program says that the bank chooses its lending rate, deposit rate and the level of reserves to maximize its expected profit, π^i, net of the expected cost of financing any liquidity shortfalls in the interim period and subject to the participation constraint of the depositors given by expression (14) and the budget constraint given by Eq. (15). The results from solving the bank's optimization problem are summarized by Proposition 4.

Proposition 4. *The optimal gross lending rate for bank i is given by*

$$r_L^{i*} = \frac{r_R \Pr\left(\tilde{x}D^i < R^{i*}\right) + \theta\left(\hat{r}_F^i + \hat{c}(\cdot)\right)\Pr\left(\tilde{x}D^i \geq R^{i*}\right)}{\theta\left(1 - \frac{1}{\eta_L^i}\right)}, \tag{17}$$

where $\eta_L^i = -r_L^i L'\left(r_L^i\right)/L\left(r_L^i\right) > 0$ *is the elasticity of the demand for loans. The optimal gross deposit rate is given by*

$$r_D^{i*} = \frac{(\bar{u} - E(\tilde{x}))D^i - (1-\theta)r_R E\left[\max\left(R^{i*} - \tilde{x}D^i, 0\right)\right]}{\theta(1 - E(\tilde{x}))D^i}. \tag{18}$$

And the optimal level of reserves is given by

$$R^{i*} = D^i - L\left(r_L^{i*}\right). \tag{19}$$

Similar to Acharya and Naqvi (2012; 2019) and Prisman et al. (1986), the above proposition implies that as the elasticity of demand for loans decreases, the lending rate increases. This increases the spread between the lending rate and the deposit rate ceteris paribus. In the above problem, the bank has monopoly power and thus sets the choices variables to maximize its expected profits. Nevertheless, it can be shown that all our results also hold for the case where the banks act competitively.

2.4. Impact of monetary policy on a bank's portfolio

Having solved the bank's portfolio choice problem, we can now do comparative statics with respect to monetary policy to analyze the responsiveness of the portfolios of small versus big banks to changes in the monetary stance of the central bank. We will show that the sensitivity of bank portfolios to monetary policy is contingent on the underlying monetary policy regime. To facilitate the discussion, we define different monetary policy regimes as follows.

Definition 1. At $t = 0$, we have a "tight monetary policy regime" as long as the expected Treasury yield at $t = 1$ conditional on current monetary policy, i.e., $\hat{r}_m^1 \equiv E\left[r_m^1 | r_m^o\right]$, exceeds the minimum return requirement of small banks, $\underline{r_F^S}$. Given the distribution of r_m^1 as defined in Eq. (2), this will be the case as long as $r_m^o > \underline{r_F^S}/\phi$.

Definition 2. At $t = 0$, we have a "loose monetary policy regime" as long as the expected Treasury yield at $t = 1$ conditional on current monetary policy, i.e., $\hat{r}_m^1$ is equal to or lower than the minimum return requirement of small banks, $\underline{r_F^S}$. Given the distribution of r_m^1 this will be the case as long as $r_m^o \leq \underline{r_F^S}/\phi$.

We can then prove the following lemma.

Lemma 1. *Under a tight monetary policy regime, i.e., for* $r_m^o > \underline{r_F^S}/\phi$, *the sensitivity of a bank's expected cost of financing (liquidity shortfalls) with respect to the monetary policy at* $t = 0$ *(i.e.* $d\hat{r}_F^i/dr_m^o$*) is given by* ϕ/ρ^i, *where* ϕ/ρ^i *is the ratio of the persistence of monetary policy to the likelihood that a bank will not default on any borrowings it might make to cover liquidity shortfalls.*

Lemma 1 says that the sensitivity of a bank's portfolio with respect to the current monetary policy is higher the higher is the persistence of monetary policy and the higher the default risk of the bank. The intuition behind Lemma 1 is as follows. If the persistence of monetary policy is high then the current monetary policy will have a bigger impact on the Treasury yields at $t = 1$. Hence, the expected cost of financing any liquidity shortfalls at $t = 1$ will be more sensitive to the current state of monetary policy. Furthermore, from Proposition 3, we know that for high enough Treasury yields the cost of financing is given by Treasury yields scaled by risk. Hence for any change in Treasury yields, the impact on the cost of financing will be bigger the higher is the default risk.

Next, taking the derivative of the lending rate, r_L^{i*}, with respect to the monetary policy stance at $t = 0$, r_m^o, we can prove the following proposition.

Proposition 5. *Under a tight monetary policy regime, such that,* $r_m^o > \underline{r_F^S}/\phi$, *for any given reserve to deposit ratio,* R^{i*}/D^i, *a small bank's portfolio is more sensitive to any changes in monetary policy relative to a big bank, i.e.,*

$$\frac{dr_L^{S*}}{dr_m^o} > \frac{dr_L^{B*}}{dr_m^o} \text{ for } r_m^o > \underline{r_F^S}/\phi. \tag{20}$$

Under a loose monetary policy regime, such that, $r_m^o \leq \underline{r_F^S}/\phi$, *for any given reserve to deposit ratio,* R^{i*}/D^i *, a big bank's portfolio is at least as sensitive or more sensitive to any changes in monetary policy relative to a small bank, i.e.,*

$$\frac{dr_L^{B*}}{dr_m^o} \geq \frac{dr_L^{S*}}{dr_m^o} \text{ for } r_m^o \leq \underline{r_F^S}/\phi. \tag{21}$$

[20] The implicit assumption is that if a big bank fails and is bailed out by the regulator, then the bail-out cost is covered by the regulator, given that the bank is insolvent with probability $1-\theta$. Thus the last term in expression (13) gives the expected cost of external financing. Our qualitative results are independent of this assumption and can be derived under alternative formulations.

The above proposition says that under a tight monetary policy regime (such that the policy rate is high enough) a small bank's portfolio is more responsive to changes in monetary policy as compared to that of a large bank. On the other hand, under a loose monetary policy regime (such that the policy rate is low enough), a large bank's portfolio is at least as or more responsive to changes in monetary policy compared to that of a small bank.

The intuition for this result is as follows. In our setup, monetary policy affects banks' portfolios primarily in two ways. First, monetary policy by influencing the yields of T-bills affects the rate of return on reserves. A monetary tightening increases r_R and hence encourages banks to hold more reserves and reduce lending. Conversely, a monetary loosening by lowering r_R encourages bank lending. Since both large and small banks can "park" their reserves in T-bills, they face the same return on reserves and thus, the impact of monetary policy on bank lending via its effect on r_R is the same for both large and small banks.

Second, and more importantly, monetary policy affects a bank's portfolio via its effect on the cost of financing. A contractionary monetary policy increases a bank's cost of financing any liquidity shortfalls. This, in turn, encourages banks to set higher lending rates to internalize the higher cost of financing any potential liquidity shortfalls. Higher lending rates reduce the demand for loans. Thus by increasing lending rates, a bank decreases its risky loan volume and increases its reserves by holding safer assets. Conversely, a loose monetary policy reduces the cost of financing and thereby encourages banks to increase lending. As we explain below the impact of monetary policy on the cost of financing is generally different for large versus small banks. Consequently, any change in monetary policy has an asymmetric effect on the portfolios of large versus small banks.

Hence, the sensitivity of a bank's portfolio choice with respect to monetary policy is tantamount to the sensitivity of the bank's cost of financing with respect to monetary policy.

We know from Proposition 3 that a bank's cost of financing is given by the yield on Treasury Bills adjusted for risk as long as the yield on Treasury Bills exceeds the minimum return requirement of financiers. More specifically, a bank's cost of financing any liquidity shortfall, r^i_F, is given by r^1_m/ρ^i as long as $r^1_m/\rho^i \geq \underline{r}^i_F$. Given the distribution of r^1_m the expected value of r^1_m at $t = 0$ conditional on r^o_m is given by ϕr^o_m. Hence for a tight enough monetary policy regime (in the range $\phi r^o_m > \underline{r}^S_F$ or $r^o_m > \underline{r}^S_F/\phi$) a bank's expected cost of financing is given by the opportunity cost of funds (as reflected by Treasury yields) scaled by risk. Since smaller banks have a lower likelihood of being bailed out (and are thus riskier), their cost of financing any liquidity shortfalls is higher than that of large banks.

Furthermore, from Lemma 1, we know that as long as $r^o_m > \underline{r}^S_F/\phi$ the sensitivity of the cost of financing (liquidity shortfalls) with respect to monetary policy at $t = 0$ is given by ϕ/ρ^i, which is the ratio of the persistence of monetary policy to the likelihood that a bank will not default on any borrowings it might make to cover liquidity shortfalls. Since smaller banks are less likely to be bailed out, they have higher default risk. Thus, it follows that a smaller bank's cost of financing and hence its portfolio choice is more sensitive to any changes in monetary policy than that of large banks. In other words, under a tight monetary policy regime, any changes in monetary policy have a larger impact on the portfolio allocations of smaller banks relative to large banks.

On the other hand, under a loose monetary policy regime, whereby $r^o_m \leq \underline{r}^S_F/\phi$, the expected cost of financing for a small bank is given by $\underline{r}^S_F$. Thus, in this regime, the small bank's cost of financing does not fluctuate with changes in monetary policy. Intuitively, as interest rates fall, the cost of financing also decreases. But for low enough interest rates, the cost of financing hits a lower bound due to the financier's minimum return requirement and any further reduction in interest rates do not impact the bank's cost of financing. However, as long as $r^o_m > \underline{r}^B_F/\phi$, the large bank's cost of financing is given by r^1_m/ρ^i, and thus any changes in Treasury yields have an impact on the cost of financing for a large bank, and consequently, in this range, the large bank's portfolio allocations are more sensitive to changes in monetary policy.

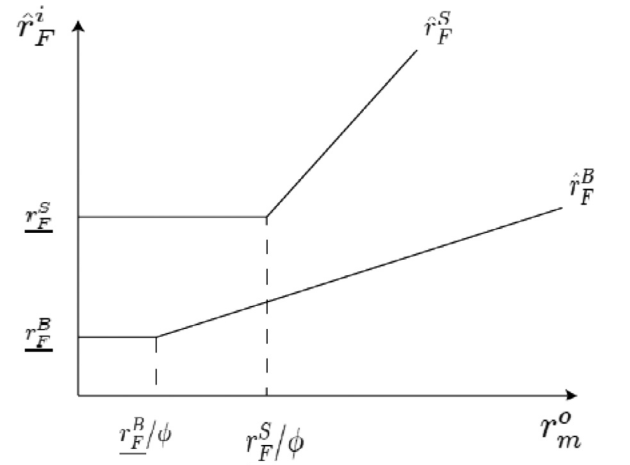

Fig. 2. The dynamics of the expected cost of financing liquidity shortfalls with respect to monetary policy.

The relationship between the expected cost of financing liquidity shortfalls ($\hat{r}^i_F$) and monetary policy (r^o_m) can be depicted by the $\hat{r}^i_F$ schedules as illustrated in Fig. 2. As can be seen in the figure, under a tight monetary policy regime (when $r^o_m > \underline{r}^S_F/\phi$) the expected cost of financing for small banks, $\hat{r}^S_F$, is more sensitive to any changes in monetary policy as compared to that of bigger banks (since the $\hat{r}^S_F$ schedule has a steeper slope compared to the $\hat{r}^B_F$ schedule). However, under a loose monetary policy regime (when $r^o_m \leq \underline{r}^S_F/\phi$) the expected cost of financing for big banks, $\hat{r}^B_F$, is as or more sensitive to any changes in monetary policy relative to small banks.

It should be noted that the expected cost of financing schedules, $\hat{r}^i_F$, in Fig. 2 are drawn for a given level of risk. Any change in the riskiness of banks causes a shift in the $\hat{r}^i_F$ schedule, whereas a change in monetary policy ceteris paribus causes a movement along the $\hat{r}^i_F$ schedules. The change in the expected cost of financing in response to a change in monetary policy affects the lending rates and subsequently the portfolio allocations of banks, as summarized in Proposition 5.

In summary, the main empirical implication of our model is that monetary policy shocks have an asymmetric impact on bank lending: under a tight monetary policy regime (such that $r^o_m > \underline{r}^S_F/\phi$), small banks are more sensitive to any monetary policy shocks whereas under a relatively loose monetary policy regime (such that $r^o_m \leq \underline{r}^S_F/\phi$) large banks are as or more responsive to any underlying monetary policy shocks. In the next section, we conduct empirical tests using a comprehensive sample of banks in the U.S. from 1992 to 2018 to test this hypothesis.

3. Empirical identification strategy

Prior empirical work suggests that large bank lending is less sensitive to changes in the Fed funds rate, raising concerns about the effectiveness of the bank lending channel of monetary policy. Specifically, researchers conduct bank lending regressions where the change in log total loans for each bank is the dependent variable, and the change in the monetary policy rate (the Fed funds

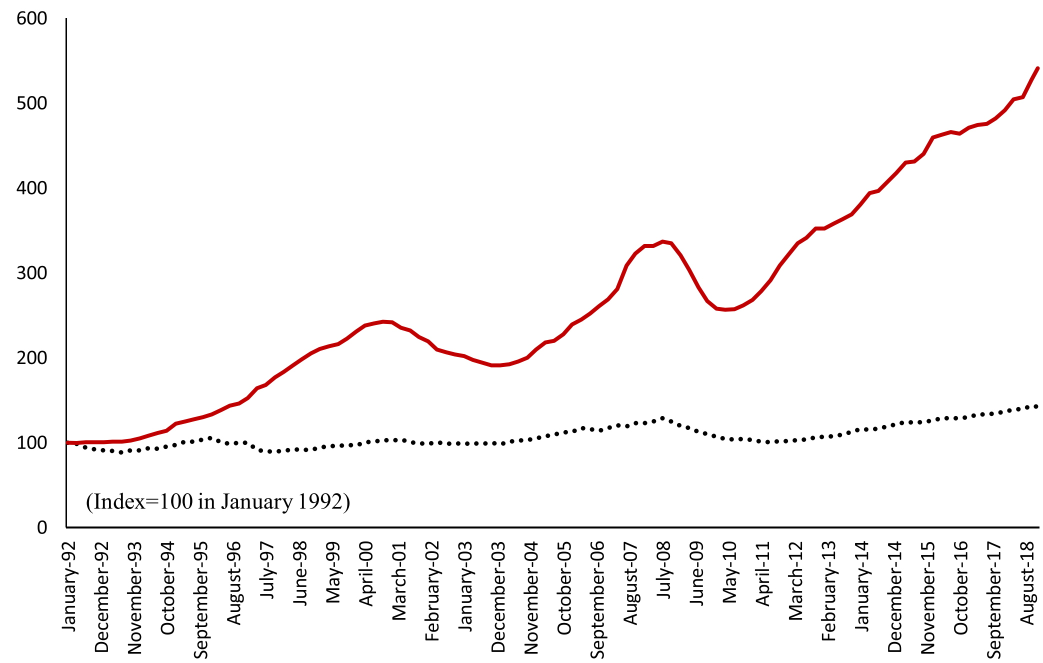

Fig. 3. Total Interest Earning Assets (Loans). This figure shows the growth in total loans for the top 100 banks versus banks not in the top 100 tracked by the Federal Reserve. The time series presented are in the form of an index and are standardized to 100 in January 1992 (the start date of our sample). While growth for large banks may have come from acquisitions or through organic means, taken together, these statistics suggest that large banks have become larger and more important over time. As large banks are responsible for a significant proportion of total lending in the economy, this provides further motivation to revisit the evidence related to bank lending channel for large banks.

rate) is the key independent variable (Arce et al., 2021; Andrade et al., 2018; Kashyap and Stein, 1995), amongst many others. These regressions control for bank characteristics such as deposits, liquidity, equity, and bad debt levels (relative to assets), controls for the business cycle such as GDP growth and inflation, lags of the dependent variable, and often bank and/or time fixed effects.

Our theoretical model suggests that the transmission of monetary policy via large and small banks is more nuanced and may depend on the monetary policy regime. Our empirical identification adapts the standard bank lending regression from the prior literature to account for this asymmetry. Specifically, we introduce a triple interaction of the (1) large bank dummy, (2) a dummy for the loose monetary policy state, and (3) the change in the Fed funds rate. Suppose large banks are indeed more sensitive to changes in the Fed funds rate in loose monetary states. In that case, we expect the coefficient on interaction term to be negative, suggesting heightened transmission (i.e., increases in the policy rate result in greater decreases in bank lending for large banks when the monetary policy regime is loose).

Our theoretical model also suggests that large bank cost of capital is more sensitive to policy rates in loose monetary regimes. We employ a similar triple interaction setup to test the cost of capital channel in a pooled panel regression with bank and time fixed effects. In these tests, the bank's cost of debt capital is the dependent variable and the triple interaction of the large bank dummy, a dummy for the loose monetary policy state, and the Fed funds rate is included as independent variables along with a standard set of control variables. If our hypothesis is true, we expect the coefficient on the triple interaction term to be positive and significant.

The triple interaction setup provides several advantages. First, the triple interaction is a direct test of the asymmetry implied by our theoretical model. Second, unlike group by-regressions, the triple interaction allows us to capture variation across all banks for cleaner identification. Finally, as the triple interaction is a simple modification to the standard specification, it makes results easier to interpret in the context of the extant literature.

An important element of the triple interaction that relates to our theoretical model is the classification of the monetary policy regime as loose or tight. In the following subsection, we discuss two alternate proxies that we use to determine the monetary policy regime.

3.1. Monetary policy regimes

We define monetary policy as tight when the Fed funds rate is greater than 4% and loose when it is less than or equal to 4%. We use the 4% threshold as it corresponds to the nominal funds rate equilibrium level as per the Taylor rule.[21] Specifically, according to the Taylor rule, the FOMC's target for the Fed funds rate is given by the following formula:

$$r = p + 0.5y + 0.5(p - 2) + 2 \tag{22}$$

where r is the Fed funds rate, p is the inflation rate, and y is the output gap or the percent deviation of real GDP from its target. Simplifying, the Taylor rule says that when inflation is at its target rate of 2% (i.e. $p = 2$) and the output gap is zero ($y = 0$), the Fed funds rate should be 4% (i.e. $p + 2$).

This classification of loose or tight regimes is based on a *fixed* threshold given by the Taylor rule. We relax this assumption and allow for a time-varying threshold based on the actual state of the economy. Specifically, our alternative classification of the monetary policy regime is based on the Laubach and Williams (2003) estimate of the natural rate of interest (r-star). The natural rate of interest is the real short-term interest rate when economic output is equal to its potential and inflation is stable. We classify the monetary policy regime as being relatively tight if the real interest rate is greater than the natural real rate of interest, where the real interest rate is measured as the nominal Fed funds rate minus Core PCE inflation. On the other hand, monetary policy is classified as

[21] See Taylor (1993) and Bernanke (2015).

relatively loose when the real interest rate is less than the natural real rate of interest.

4. Empirical analysis

4.1. Data

The empirical tests in this paper are based on bank balance sheet data from the Fed's quarterly Call Reports. Our sample consists of 804,216 bank quarters from 1992-Q1 to 2018-Q4.[22] The Call Reports database is based on regulatory filings made to the Federal Reserve and is thus comprehensive in its coverage of US banks. It is also used extensively in the prior literature Kashyap and Stein (1995; 2000), Loutskina (2011), Cetorelli and Goldberg (2012).

4.2. Summary statistics

Table 1 provides summary statistics for our sample, including mean, standard deviation, 25th percentile (Q1), median, and 75th percentile (Q3) distributional statistics. The average bank in the sample held $716 million in total loans. The median total loans, however, is much smaller at $65 million. This striking difference points to the significant skewness in bank size in the economy. The average bank deposits to assets ratio is 0.84, while the bank equity to assets ratio is 0.11 in our overall sample. Non-performing loans as a proportion of assets average around 0.8%, with a median of 0.42%.

Table 1 Panel B presents the average bank size and the percentage of aggregate total assets held for various size groups examined in the study. These include our proxy for large banks (banks in the top 2% of the total asset distribution) and small banks (banks in the bottom 98% of the total asset distribution). Panel B also presents statistics for two alternative proxies for our large bank identifier used in the prior literature (banks in the top 1% and top 25 banks based on total assets). We find that approximately 79.8% of total assets in our sample are held by the top 2% banks, 73.5% by the top 1% banks, and 60.5% by the top 25 banks. Small banks (in the bottom 98%) hold only 20.2% of aggregate total assets. The average bank size in the top 2% of the distribution is approximately 204 times larger than the average bank size in the top decile. Going further, this skewness can also be observed at the top percentile of the bank distribution.

Fig. 3 shows the growth in total loans for the top 100 banks versus banks not in the top 100 tracked by the Federal Reserve. The time series presented are in the form of an index and are standardized to 100 in January 1992 (the start date of our sample). While growth for large banks may have come from acquisitions or through organic means, taken together, these statistics suggest that large banks have become larger and more important over time. As large banks are responsible for a significant proportion of total lending in the economy, this provides further motivation to revisit the evidence related to bank lending channel for large banks.

4.3. Main results

Standard bank lending regressions study the relation between the changes in bank lending and changes in the Fed funds rate. To understand monetary policy transmission under loose and tight regimes for large and small banks, we present results from our triple interaction specification described in Section 3. We include four lagged dependent terms to account for the autocorrelation in residuals given the persistence in lending policy from quarter to quarter and bank fixed effects in all models. In addition, regressions control for cross-sectional differences in bank characteristics as changes in the macroeconomic environment to mitigate relevant identification concerns.

Jiménez et al. (2012) show that bank sensitivity to monetary policy is stronger for banks with lower capital or liquidity ratios. Banks also differ in the structure of their liabilities (deposits) and the quality of their risk assets (loan book) (Arce et al., 2021; Andrade et al., 2018). Their studies motivate the inclusion of controls related to deposits, liquidity, equity, and non-performing loans (all scaled by lag total assets).

We control for aggregate credit demand using survey responses from Fed's Senior Loan Officer Opinion Survey on Bank Lending Practices (Altavilla et al., 2021; Andrade et al., 2018).[23] In addition, we include controls for GDP growth and inflation following Kashyap and Stein (2000).

In our baseline specification, we define large banks as those having assets in the top 2% at the beginning of the quarter. We define the monetary policy state as tight if interest rates are about 4% and loose otherwise. Table 2 presents three specifications with our main object of interest – a triple interaction between large bank dummy, loose monetary state, and the change in the Fed funds rate (shaded in gray). Models 1 and 2 present the baseline effects without and with bank controls. As GDP growth, inflation, and credit demand may not be sufficient to control for the business cycle perfectly, Model 3 additionally saturates the specification with time fixed effects (quarter-year dummies) following Jiménez et al. (2012). Clustered standard errors at the bank-level are presented in parentheses below the coefficients.

Consistent with our theoretical model, we find that the coefficient on the triple interaction is negative and significant, suggesting that large banks are more sensitive to changes in the Fed funds rate in loose monetary states. This finding has important implications for our understanding of the "bank lending" channel. It provides large sample evidence that suggests that banks are affected by the Fed's monetary policy asymmetrically in different states of the world.

Unlike small bank sensitivity to monetary policy, which comes about as a result of financing constraints, large bank sensitivity in loose regimes is a result of incentives and not of constraints. Large banks can choose to be insensitive to monetary policy and not take advantage of the lower cost of capital, but it is not value-maximizing for them to do so. Thus, large banks "can have their cake and eat it too" in the sense that they are less affected by monetary policy when the monetary regime is tight due to their ability to raise external finance, but can take advantage of an implicit external subsidy that reduces their cost of capital when the regime is loose.

Our theoretical model claims differential sensitivity to monetary policy based on bank size and the monetary policy regime. In the following subsections, we study whether our results are robust to alternative definitions of both of these key variables.

4.3.1. Alternative definitions of the monetary policy regime

Our baseline specification assumes a fixed cutoff of 4% to identify loose and tight monetary regimes. The 4% cutoff is based on the nominal Fed funds equilibrium based on the Taylor rule assuming a 2% inflation target. As an alternative to the fixed cutoff,

[22] The sample period in Kashyap and Stein (2000) extends from 1976-Q1 to 1993-Q2, while in Cetorelli and Goldberg (2012), the sample starts in 1980-Q1 and ends in 2005-Q4. Thus, unlike Kashyap and Stein (1995,2000) or Cetorelli and Goldberg (2012), our analysis also includes the period following the financial crisis of 2008 characterized by historically low policy rates.

[23] Our baseline analysis maybe subject to endogenous bank-firm matching as we control aggregate credit demand rather than bank-specific credit demand (due to lack of data). In Section 4.5 (Robustness: Evidence from syndicated loans), we exploit bank-firm loan level data and the Khwaja and Mian (2008) methodology to show that our results are not driven by endogenous bank-firm matching.

Table 4
Alternative Definition of Bank Size In this table we test robustness of our result for alternative definitions of the bank size. We define large banks alternatively as (1) those with the top 1% of assets in the quarter, and as (2) those that rank in the top 25 by total assets in the quarter. Models 1 and 3 present results for the first definition, and Models 2 and 4 present results for the second definition. Models 1 and 2 present presents using the fixed 4% classification for the monetary policy regime, while Models 3 and 4 present results for the relative classification introduced in Table 3. The highlighted row indicates the main object of interest, the triple interaction between large bank, relatively loose monetary state, and the change in the fed funds rate. All models include 4 lags of the dependent variable, bank control variables, and bank and time fixed effects. Standard errors are clustered at the bank level.

VARIABLES	Model 1	Model 2	Model 3	Model 4
Large Bank Indicator	Top 1%	Top 1%	Top 25	Top 25
Monetary Regime Classification	Fixed 4%	Relative Fixed 4%	Relative	
Large Bank (Top 1%) $\times$ Loose Dummy $\times$ δ Fedfunds Rate	-0.337***			
	(0.0879)			
Large Bank (Top 1%) $\times$ Relatively Loose Dummy $\times$ δ Fedfunds Rate		-0.297***		
		(0.0781)		
Large Bank (Top 25) $\times$ Loose Dummy $\times$ δ Fedfunds Rate			-0.461***	
			(0.109)	
Large Bank (Top 25) $\times$ Relatively Loose Dummy $\times$ δ Fedfunds Rate				-0.399***
				(0.114)
Large Bank (Top 1%)	-0.0133***	-0.0178***		
	(0.00280)	(0.00291)		
Large Bank (Top 1%) $\times$ δ Fedfunds Rate	0.410***	0.457***		
	(0.0668)	(0.0667)		
Large Bank (Top 1%) $\times$ Loose Dummy	0.00618***			
	(0.00147)			
Large Bank (Top 25)			-0.00409	-0.00882***
			(0.00282)	(0.00308)
Large Bank (Top 25) $\times$ δ Fedfunds Rate			0.463***	0.507***
			(0.0962)	(0.105)
Large Bank (Top 25) $\times$ Loose Dummy			0.00391*	
			(0.00205)	
Large Bank (Top 1%) $\times$ Relatively Loose Dummy		0.0124***		
		(0.00145)		
Large Bank (Top 25) $\times$ Relatively Loose Dummy				0.0107***
				(0.00212)
Deposits/Assets	0.0377***	0.0373***	0.0382***	0.0380***
	(0.00332)	(0.00333)	(0.00332)	(0.00332)
Liquidity/Assets	0.0522***	0.0521***	0.0522***	0.0521***
	(0.00145)	(0.00145)	(0.00145)	(0.00145)
Equity/Assets	0.158***	0.157***	0.159***	0.158***
	(0.00785)	(0.00786)	(0.00784)	(0.00784)
NPL/Assets	-0.731***	-0.731***	-0.731***	-0.731***
	(0.0114)	(0.0114)	(0.0114)	(0.0114)
Constant	-0.0426***	-0.0421***	-0.0431***	-0.0429***
	(0.00315)	(0.00315)	(0.00314)	(0.00314)
Lag Dependent Variable	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	Yes
Time Fixed Effects (Year-Quarter)	Yes	Yes	Yes	Yes
Observations	804,216	804,216	804,216	804,216
Adjusted R-squared	0.157	0.157	0.157	0.157

we create a monetary policy regime classification rule based on the Laubach and Williams (2003) estimate of the natural real rate of interest (r-star) obtained from the Federal Reserve. This alternative definition classifies the monetary policy regime as relatively tight if the real interest rate is greater than the natural real rate of interest, and loose otherwise.

Table 3 replicates the main results presented earlier using this alternative definition. Similar to Table 2, Models 1 and 2 present the baseline effects without and with bank controls, while Model 3 additionally includes time fixed effects (quarter-year dummies). We find that the coefficient on the triple interaction is negative and significant, suggesting that our findings are robust to this alternative proxy for the monetary policy state.

An advantage of this definition is that it relaxes the fixed 4% cutoff by adopting a time-varying baseline threshold based on the natural real rate of interest (which itself is based on the underlying state of the macroeconomy). In practice, however, we find that monetary regime classification based on the fixed 4% cutoff from the Taylor rule and the time-varying classification based on the natural real rate of interest are highly correlated in the data. Strikingly, between 1992-Q1 and 2018-Q4 (our sample period), the two proxies agree on the classification of the monetary policy state (loose or tight) in approximately 94% of cases (101/108 quarters).

4.3.2. Alternative definitions of bank size

What constitutes a large bank? Our baseline analysis considers a bank as large if it is in the top 2% of the total asset distribution. The theoretical wedge in the cost of capital between large and small banks in our paper is driven by differences in ex-ante bailout probabilities. The prior literature studying bank lending uses alternative definitions that focus on the largest banks in the size distribution. For example, Kashyap and Stein (2000) define banks as large if they are in the top 1% (99th percentile) of the total asset distribution, while Acharya and Mora (2015) classify as large the top 25 banks based on total assets following the Federal Reserve's H.8 classification.

We test whether our findings are robust to these alternative definitions of bank size. Table 4 presents four models. Models 1 and 2 present results using the Kashyap and Stein (2000) top 1% size definition, while Models 3 and 4 present results using the Fed H.8 classification scheme of the top 25 banks followed by Acharya and Mora (2015). For each definition, we present two models for alternative definitions for the monetary policy regime discussed in the previous section.

We find that the coefficient on the triple interaction has a greater magnitude and significance as these alternative measures focus on the largest banks in the size distribution. This size-effect

Table 5
Bank Size and Cost of Debt Capital This table presents the relationship between the cost of bank debt capital and the Fed funds rate the under relatively loose and tight monetary policy regimes for large and small banks. We proxy for the cost of debt capital for banks following Dick-Nielsen, Gyntelberg, and Thimsen (2021) as $r_{i,t} = \frac{\sigma_{k=1}^{4} Interest_{i,t+k}}{\frac{1}{4}\sigma_{j=0}^{3} Debt_{,t+j}}$, where i and t denote the bank and quarter respectively. Interest refers to the total interest expense, while Debt refers to total debt obligations. Model 1 presents the results for the broad proxy for the cost of debt. We extend the proxy to compute the cost of deposit and non-deposit financing separately in Models 2 and 3. The cost of deposit financing is defined similarly, where the numerator is the interest paid on total deposits, and the denominator is total deposits. Non-deposit interest payments are defined as the difference between total interest payments and interest paid on deposits. Non-deposit liabilities are defined as the difference between total liabilities and total deposits. All models include bank fixed effects, bank control variables, and time fixed effects. Standard errors are clustered at the bank level.

VARIABLES	(1) Cost of Debt Capital	(2) Cost of Deposit Financing	(3) Cost of Non-Deposit Financing
Large Bank (Top 2%)	0.00743***	0.00313***	0.119***
	(0.000785)	(0.000953)	(0.00640)
Large Bank (Top 2%) × Fedfunds Rate	-0.159***	-0.0787***	-2.074***
	(0.0120)	(0.0153)	(0.127)
Large Bank (Top 2%) × Relatively Loose Dummy	-0.00835***	-0.00403***	-0.0994***
	(0.000691)	(0.000985)	(0.00652)
Large Bank (Top 2%) × Relatively Loose Dummy × Fedfunds Rate	0.134***	0.0611***	2.290***
	(0.0147)	(0.0197)	(0.136)
Deposits/Assets	-0.0109***	-0.00322***	0.00113
	(0.000581)	(0.000902)	(0.00246)
Liquidity/Assets	-0.00543***	-0.00537***	-0.00399**
	(0.000252)	(0.000280)	(0.00198)
Equity/Assets	-0.0225***	-0.0126***	-0.0177**
	(0.00115)	(0.00156)	(0.00705)
NPL/Assets	-0.0119***	-0.0112***	0.0299**
	(0.00159)	(0.00180)	(0.0129)
Constant	0.0366***	0.0283***	0.0391***
	(0.000535)	(0.000845)	(0.00235)
Bank Fixed Effects	Yes	Yes	Yes
Time Fixed Effects (Year-Quarter)	Yes	Yes	Yes
Observations	764,797	764,793	470,918
Adjusted R-squared	0.947	0.923	0.465

is consistent with theory as the largest banks are likely to have higher ex-ante bailout probabilities. These results provide additional robustness that top banks are more sensitive to changes in monetary policy in loose monetary policy states.

4.4. Bank size and the cost of debt capital

Our theoretical model rests on the cost of capital channel to produce differences in incentives and ability for large and small banks. In this section, we test whether small banks' and large banks' cost of capital are sensitive to the Fed funds rate *differently* in loose and tight monetary regimes. We infer the bank-specific cost of debt capital for each quarter following the imputation procedure outlined in Dick-Nielsen et al. (2021). The procedure produces a forward-looking cost of debt capital defined as the total interest paid over the next four quarters divided by the average total debt obligations at the beginning of each quarter.

Table 5 tests the sensitivity of the cost of debt capital for large and small banks to changes in the Fed funds rate in relatively loose or tight monetary regimes. We employ a similar triple interaction identification strategy to explain the cost of debt capital in a panel regression with bank and time fixed effects. We expect the coefficient of the triple interaction to be positive since the dependent variable is now the cost of capital. Consistent with our model, we find that the cost of debt capital for large banks is more sensitive to the Fed funds rate in relatively loose monetary policy states.

The Dick-Nielsen et al. (2021) proxy for the cost of debt capital provides a proxy for the aggregate cost of a bank's debt that includes all interest payments and debt obligations of the bank. However, bank funding costs from depositors may differ from funding raised via non-deposit sources. In practice, emergency funding in instances of liquidity shortfalls is more likely to occur via non-deposit sources than via deposits, given the time taken to raise deposit financing. This is consistent with our theoretical model where external financiers fund liquidity shortfalls.

We conduct additional tests that consider the cost of deposit and non-deposit financing separately. We define the cost of deposit financing as the interest paid on total deposits for the next four quarters scaled by average total deposits at the beginning of the quarter. We define the cost of non-deposit financing similarly as non-deposit interest payments for the next four quarters scaled by average non-deposit liabilities at the beginning of the quarter.

While our results hold for both deposit and non-deposit financing, they are stronger for non-deposit financing.

4.5. Robustness: evidence from syndicated loans

An important element of our theoretical model relates to the variation in the bank's lending supply. In practice, firms may not be randomly assigned to banks. For example, large banks may work with large borrowers and small banks with smaller and riskier ones. At the same time, firms may borrow from more than one bank at the same time. In this section, we exploit cross-bank size variation to test whether large bank participation is sensitive to monetary policy differently in relatively loose versus tight monetary regimes. In doing so, we aim to show that our results are not driven by endogenous bank-firm matching.

Bank-firm level analysis was made popular by the seminal work on cross-bank liquidity variation in Khwaja and Mian (2008) and has been extended significantly in the recent literature by the use of credit registers (Andrade et al., 2018; Jiménez et al., 2012; Garcia-Posada and Marchetti, 2016; Carpinelli and Crosignani, 2017; Jasova et al., 2018) or syndicated loans (Heider et al., 2019).[24]

[24] As credit register data for the United States is unavailable to us, our analysis rests on bank-firm level syndicated loan participation data from Dealscan. We ac-

Table 6
Evidence from Syndicated Loans In this table, we use loan participation data from Dealscan to test whether large bank participation in the syndicated loan market is sensitive to monetary policy differently in relatively loose versus tight regimes. The dependent variable in these regressions is the log lender amount where the lender amount is equal to the total tranche amount x the lender share. The key independent variable is a triple interaction between the large bank dummy (Top 2%), the monetary policy state (based on relative actual and the natural real rate of interest) and the Fed funds rate. We present three specifications that all include bank, firm, time, and firm*time interaction fixed effects. Model 1 presents the baseline model without bank, firm, or loan level controls. Model 2 adds bank controls, while Model 3 additionally adds loan level controls and fixed effects for loan type and purpose. Firm and bank data is obtained from Compustat, while loan data is from Dealscan. Standard errors are clustered at the bank level.

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3
Large Bank (Top 2%)	-0.040	-0.087	-0.125
	(0.100)	(0.099)	(0.109)
Large Bank (Top 2%) × Fedfunds Rate	0.723	1.172	1.801
	(1.703)	(1.785)	(1.960)
Large Bank (Top 2%) × Relatively Loose Dummy	0.241**	0.235**	0.271**
	(0.108)	(0.111)	(0.119)
Large Bank (Top 2%) × Relatively Loose Dummy × Fedfunds Rate	-4.615***	-5.715***	-6.135***
	(1.710)	(2.120)	(2.247)
Deposits/Assets		-0.402***	-0.332**
		(0.128)	(0.126)
Equity/Assets		-0.803**	-0.926
		(0.831)	(0.861)
Liquidity/Assets		-0.829**	-0.810***
		(0.326)	(0.283)
NPL/Assets		9.915***	10.35***
		(1.852)	(1.728)
Log Maturity			0.178***
			(0.012)
Log Number of Lenders			0.032
			(0.049)
Secured Loan Dummy			0.290***
			(0.041)
Constant	3.044***	3.416***	2.575***
	(0.023)	(0.081)	(0.150)
Bank Controls	No	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes
Firm*Time Fixed Effects	Yes	Yes	Yes
Loan Level Controls	No	No	Yes
Loan Type and Loan Purpose Fixed Effects	No	No	Yes
Observations	82,407	69,288	63,398
Adjusted R-squared	0.696	0.702	0.717

Our analysis, presented in Table 6, rests on the use of bank-firm loan level syndicated loan participation data from Dealscan. As each loan can have multiple bank participants, any given loan generates multiple observations in the sample with banks of varying size. This setting allows us to examine lending supply variation by banks of different sizes after controlling for the bank, firm-time, and loan-level fixed effects. The dependent variable in our analysis is the log lender amount, where the lender amount is equal to the total tranche amount x the lender share. The key independent variable follows our principal identification strategy and includes a triple interaction between the large bank dummy (Top 2%), the monetary policy state (based on relative actual and the natural real rate of interest) and the Fed funds rate. We merge Dealscan with bank fundamental data using the Dealscan lender link file (Schwert, 2018), and firm fundamental data using the Dealscan-Compustat link file (Chava and Roberts, 2008).

We present three specifications that all include bank and firm-time fixed effects with standard errors clustered at the bank level.[25] Model 1 presents the baseline model without bank or loan level controls. Model 2 introduces bank level controls including deposits, liquidity, equity, and non-performing loans (NPL) scaled by total assets. Model 3 additionally adds loan level controls and fixed effects for loan type and purpose. We include the number of lenders as all else equal, more participants would result in smaller dollar lending amounts by individual banks. Even though the sample sizes vary due to data availability across the three specifications, we find that the triple interaction is negative and significant at the 1% level. Our results, using bank-firm loan level data, confirm that large bank lending is more sensitive to the Fed funds rate when monetary policy is loose.

5. Conclusion

In the seminal Kashyap and Stein (1995) model, small banks are more sensitive than large banks to monetary tightening because they face a higher cost of raising non-deposit external financing. Thus, a monetary contraction results in small banks cutting lending more than large banks, while a monetary loosening enables small banks to lend more easily as financial constraints are lowered by a rise in reserves. Our results under tight monetary policy regimes are similar to those in extant research: small bank portfolios are more sensitive to monetary policy relative to large banks. However, specific to our model we show that this relation is reversed under loose monetary policy regimes. This counter-intuitive implication of our model occurs because monetary policy affects bank lending behavior and risk-taking by changing small and large

knowledge that banks and firms participating in the syndicated loan market tend to be larger, and thus not representative of the overall distribution of banks and firms in the economy. However, to the extent that bank and firm size are highly skewed even in the top decile, our cross-bank tests face a higher 'bar' as the control group for the largest (top 2%) banks are other relatively large banks participating in the syndicated loan market.

[25] We do not include firm-specific or macroeconomic controls as they are redundant given firm-time fixed effects.

bank costs of financing differentially. Unconditionally, a loose monetary policy lowers the bank's cost of financing and encourages banks to make riskier investments. However, banks face a lower bound for the cost of financing. Furthermore, the cost of financing for large banks has a "lower lower-bound" than small banks as large banks not only have lower information asymmetries than small banks, but they can also benefit from implicit too-big-to-fail subsidies. We show that this wedge between large and small bank financing costs at the lower bound flips the monetary transmission mechanism in the economy in loose monetary regimes and show that in such cases, the bank lending channel is mainly driven by large bank action. This is in contrast to tighter regimes where large bank behavior continues to be less sensitive to monetary policy.

Our empirical tests support our hypothesis. We find that controlling for bank risk, bank liquidity, and the macroeconomic environment, the lending of small banks is more sensitive to monetary policy shocks relative to that of large banks under a tight monetary policy regime. However, under a loose monetary policy regime, large bank lending is significantly more responsive to monetary policy shocks relative to small bank lending.

The asymmetric impact of monetary policy on bank lending opens up further avenues for research. For instance, in an era of low interest rates, will monetary policy have a bigger impact on the output of states (or countries) whose banking sector is dominated by large banks relative to those states (or countries) with a more competitive banking structure? On the other hand, in a tight monetary regime, will the output of geographical regions characterized by a competitive banking sector be more responsive to monetary policy? In short, the differential regional effects of monetary policy may be contingent on whether the underlying monetary regime is tight or loose. We leave these questions for future research.

CRediT authorship contribution statement

Hassan Naqvi: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Raunaq Pungaliya:** Conceptualization, Methodology, Software, Data curation, Writing – original draft, Writing – review & editing.

Appendix A. Proofs

Proof of Proposition 1. The financier will choose a risky asset portfolio and hence invest in the small bank, if and only if the expected return from doing so exceeds the expected return from choosing a safer asset portfolio by investing in the large bank. Hence, the financier will lend to the small bank if and only if:

$$\rho^S\left(r_F^S - F\right) - (1-\rho^S)K(F) > \rho^B\left(r_F^B - F\right) - (1-\rho^B)K(F)$$

This will be the case if and only if

$$F > F^*$$

where

$$F^* = K(F^*) - \frac{\left(\rho^S r_F^S > \rho^B r_F^B\right)}{\rho^B - \rho^S}.$$

Q.E.D.

Proof of Proposition 2. The expected return of the financier from lending to bank i is given by:

$$U\left(r_F^i\right) = \rho^i\left(r_F^i - F\right) - (1-\rho^i)K(F) \tag{A.1}$$

The minimum return requirement of the financier is such that the expected return of the financier is at least equal to zero. More formally, $\underline{r_F^i}$ solves:

$$U\left(r_F^i\right)|_{r_F^i = \underline{r_F^i}} = 0 \tag{A.2}$$

Thus, $\underline{r_F^i}$ is such that it solves:

$$\rho^i\left(\underline{r_F^i} - F^j\right) - (1-\rho^i)K\left(F^j\right) = 0 \tag{A.3}$$

where from Proposition 1 it follows that $j = h$ for $i = S$ and $j = l$ for $i = B$. Solving for $\underline{r_F^i}$ $i = S, B$ and $j = h, l$ from Eq. (A.3) we get Eqs. (6) and (7). Q.E.D.

Proof of Proposition 3. The bank's minimization problem can be rephrased as a maximization problem if we maximize the negative of expression (8) subject to constraints (9) and (10). The Lagrangian for this problem is as follows:

$$-r_F^i\Omega^i - c(\cdot)\Omega^i + \lambda_1\Omega^i\left[\rho^i r_F^i - r_m^1\right] + \lambda_2\left[r_F^i - \underline{r_F^i}\right] \tag{A.4}$$

where λ_1 and λ_2 are the Lagrange multipliers for constraints (9) and (10), respectively. Taking the derivative of the Lagrangian with respect to r_F^i and simplifying, we get the following first order condition (FOC):

$$-1 - c'(\cdot) + \lambda_1\rho^i + \lambda_2 = 0. \tag{A.5}$$

Since $c'(\cdot) > 0$, it follows that at least one of the constraints is binding and thus, either $\lambda_1 > 0$ or $\lambda_2 > 0$ or both the multipliers are positive. If $r_m^1 > \underline{r_F^i}$ then it follows that if the second constraint is binding (i.e. $r_F^i = \underline{r_F^i}$) then $r_F^i < r_m^1/\rho^i$, and hence the first constraint is not satisfied. Thus, by contradiction, if $r_m^1 > \underline{r_F^i}$ then the second constraint is not binding and thus the first constraint is binding, in which case $r_F^i = r_m^1/\rho^i > \underline{r_F^i}$. Using similar reasoning, if $r_m^1 < \underline{r_F^i}$ then the second constraint binds, but the first constraint does not bind and thus $r_F^i = \underline{r_F^i} > r_m^1/\rho^i$. Finally, if $r_m^1/\rho^i = \underline{r_F^i}$ then both the constraints bind and $r_F^i = r_m^1/\rho^i = \underline{r_F^i}$. Hence, it follows that

$$r_F^i = \max\left(\frac{r_m^1}{\rho^i}, \underline{r_F^i}\right). \tag{A.6}$$

from which we get Eqs. (11) and (12). Q.E.D.

Proof of Proposition 4. The participation constraint of bank i is binding because otherwise the bank can increase its expected profits by slightly reducing r_D^i. Thus, r_D^{i*} is given by the solution to

$$E(\tilde{x}) + (1 - E(\tilde{x}))\left[\theta r_D^i + (1-\theta)\frac{r_R E\left[\max\left(R^i - \tilde{x}D^i, 0\right)\right]}{(1-E(\tilde{x}))D^i}\right] = \bar{u}. \tag{A.7}$$

Solving for r_D^{i*} results in Eq. (18).

We can then substitute r_D^{i*} in the bank's objective function and, hence, r_L^{i*} is the solution to the following unconstrained maximization problem:

$$\max_{r_L^{i*}}\ \Pi^i = \theta\left\{r_L^i L\left(r_L^i\right) - r_D^{i*}D^i(1-E(\tilde{x})) + r_R E\left[\max\left(R^i - \tilde{x}D^i, 0\right)\right]\right\} \tag{A.8}$$
$$-\theta\left(\hat{r}_F^i + \hat{c}\left(r_F^i\right)\right)E\left[\max\left(\tilde{x}D^i - R^i, 0\right)\right].$$

Assuming that Π^i is quasiconcave in r_L^i and substituting the budget constraint Eq. (15), $R^i = D^i - L\left(r_L^i\right)$, into the bank's objective function, the maximum is characterized by the following first-order condition (FOC):

$$\frac{\partial\Pi^i}{\partial r_L^i} = \theta L\left(r_L^i\right) - \theta r_R \Pr\left[\tilde{x}D^i < R^i\right]L'\left(r_L^i\right) + \theta r_L^i L'\left(r_L^i\right)$$
$$-\theta\left(\hat{r}_F^i + \hat{c}\left(r_F^i\right)\right)\Pr\left[\tilde{x}D^i \geq R^i\right]L'\left(r_L^i\right) - \theta D^i(1-E(\tilde{x}))\frac{\partial r_D^{i*}}{\partial r_L^i} = 0. \tag{A.9}$$

Noting that $\partial r_D^{i*}/\partial r_L^i = (1-\theta)\Pr\left[\tilde{x}D^i < R^i\right]L'\left(r_L^i\right)/\theta D^i(1-E(\tilde{x}))$ and solving for r_L^i after some simplification results in Eq. ():

$$r_L^{i*} = \frac{r_R}{\theta} - \frac{L\left(r_L^i\right)}{L'\left(r_L^i\right)} + \frac{\left(\theta\left(\hat{r}_F^i + \hat{c}\left(r_F^i\right)\right) - r_R\right)\Pr\left(\tilde{x}D^i \geq R^{i*}\right)}{\theta}. \tag{A.10}$$

Substituting $\eta_L^i = -r_L^i L'(r_L^i)/L(r_L^i)$ in Eq. (A.10) we get Eq. (). Thus the optimal reserve level is given by $R^{i*} = D^i - L(r_L^{i*})$. Q.E.D.

Proof of Lemma 1. Define $\hat{r}_m^1 \equiv E\left[r_m^1 | r_m^o\right]$. Then from Eq. (2) we have

$$\hat{r}_m^1 = \phi r_m^o. \tag{A.11}$$

From Eq. (A.6) it follows that

$$\hat{r}_F^i = \begin{cases} \phi r_m^o/\rho^i & \text{if } \frac{\hat{r}_m^1}{\rho^i} > \underline{r}_F^i \\ \hat{r}_F^i & \text{otherwise} \end{cases}. \tag{A.12}$$

Then taking the derivative of $\hat{r}_F^i$ with respect to r_m^o we get

$$\frac{d\hat{r}_F^i}{dr_m^o} = \begin{cases} \phi/\rho^i & \text{if } \frac{\hat{r}_m^1}{\rho^i} > \underline{r}_F^i \\ 0 & \text{otherwise} \end{cases}. \tag{A.13}$$

Thus $d\hat{r}_F^i/dr_m^o = \phi/\rho^i$ for $\hat{r}_m^1 > \rho^i \underline{r}_F^i$. This is always the case under a tight monetary policy regime since $\hat{r}_m^1 = \phi r_m^o$, $\rho^i \in (0,1)$ and $\underline{r}_F^S > \underline{r}_F^B$ Q.E.D.

Proof of Proposition 5. To prove the proposition, we first note that

$$\frac{dr_L^{i*}}{dr_m^o} = \frac{dr_R}{dr_m^o}\cdot\frac{dr_L^{i*}}{dr_R} + \frac{d\hat{r}_F^i}{dr_m^o}\cdot\frac{dr_L^{i*}}{d\hat{r}_F^i} \tag{A.14}$$

where $dr_R/dr_m^o = 1$ since $r_R = r_m^o$ and from Eq. () $dr_L^{i*}/dr_R = \Pr\left(\tilde{x}D^i < R^{i*}\right)/\theta$ for both $i = S$ and $i = B$. Furthermore, $dr_L^{*i}/d\hat{r}_F^i$ from Eq. (A.10) is given by

$$\frac{dr_L^{i*}}{d\hat{r}_F^i} = \Pr\left(xD^i \geq R^{i*}\right). \tag{A.15}$$

Then, for any given reserve-deposit ratio $dr_L^{S*}/dr_m^o > dr_L^{B*}/dr_m^o$ if and only if $d\hat{r}_F^S/dr_m^o > d\hat{r}_F^B/dr_m^o$ while $dr_L^{S*}/dr_m^o < dr_L^{B*}/dr_m^o$ if and only if $d\hat{r}_F^S/dr_m^o > d\hat{r}_F^B/dr_m^o$.

From Eq. (A.13), it follows that

$$\frac{d\hat{r}_F^S}{dr_m^o} > \frac{d\hat{r}_F^B}{dr_m^o} \text{ if } \hat{r}_m^1 > \rho^S \underline{r}_F^S, \tag{A.16}$$

since

$$\frac{\phi}{\rho^S} > \frac{\phi}{\rho^B}$$

given that from Eq. (3) $\rho^S < \rho^B$ as $\beta > 0$.

Given that $\underline{r}_F^S > \underline{r}_F^B$ it follows that

$$\frac{d\hat{r}_F^B}{dr_m^o} > \frac{d\hat{r}_F^S}{dr_m^o} \text{ if } \rho^B \underline{r}_F^B < \hat{r}_m^1 < \rho^S \underline{r}_F^S, \tag{A.17}$$

since $d\hat{r}_F^S/dr_m^o = 0$ for $\hat{r}_m^1 < \rho^S \underline{r}_F^S$ while $d\hat{r}_F^B/dr_m^o = \phi/\rho^B > 0$ for $\rho^B \underline{r}_F^B < \hat{r}_m^1$.

Finally, from Eq. (A.13), we have

$$\frac{d\hat{r}_F^B}{dr_m^o} = \frac{d\hat{r}_F^S}{dr_m^o} = 0 \text{ if } \hat{r}_m^1 < \rho^B \underline{r}_F^B \tag{A.18}$$

which proves all the scenarios summarized in Proposition 5. Q.E.D.

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