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The Effect of Monetary Policy on Bank Wholesale Funding

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Abstract. We study how monetary policy affects the funding composition of the banking sector. When monetary tightening reduces the supply of retail deposits, banks attempt to substitute wholesale funding for deposit outflows to smooth their lending. Because of financial frictions, banks have varying degrees of access to wholesale funding. Therefore, large banks, or those with greater reliance on wholesale funding, increase their wholesale funding more. Consequently, monetary tightening increases both the reliance on and the concentration of wholesale funding within the banking sector. Our findings also suggest that liquidity requirements could bolster monetary policy transmission through the bank lending channel.

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1. Introduction

The recent financial crisis clearly demonstrated the risks of banks being dependent on short-term wholesale funding, as it can critically increase funding liquidity risks during times of market disruption. In response to such concerns, the Basel Committee on Banking Supervision introduced new liquidity regulations, such as the liquidity coverage ratio (LCR) and the net stable funding ratio (NSFR), to contain the excessive reliance on runnable funding in the banking sector. Whereas previous studies have analyzed the risks of relying on wholesale funding during the crisis,[1] what contributed to the rapid development of a reliance on wholesale funding in the banking sector in the run-up to the crisis and how the new liquidity regulations will interact with existing policy measures, particularly monetary policy, remain open questions.

In this paper, we examine the impact of monetary policy on bank funding composition, both in the time dimension and in the cross-sectional dimension. We argue that monetary tightening by central banks contributes to the accumulation of the banking sector's reliance on wholesale funding, as well as systemic imbalances, in that the distribution of the reliance on wholesale funding becomes more concentrated among heavy users or large banks. This implies that during monetary tightening, a financial system could become more vulnerable in terms of funding liquidity risks and potential spillover effects (e.g., fire-sale externalities that increase with the size of a bank). We then discuss the implications of the interaction between the new liquidity regulations and monetary policy, both in terms of systemic stability (focusing on risks) and the monetary policy transmission mechanism (focusing on policy effectiveness).

Bank borrowing can typically be divided into two sources: retail deposits and wholesale funding. Retail deposits, sometimes referred to as core deposits or core funding, represent funding from a bank's traditional and regular customer base in the local geographic market. In contrast, wholesale funding is mostly supplied by other financial intermediaries, such as money market mutual funds, and raised through the money market (e.g., large certificates of deposit, foreign or brokered deposits, and repo funding). Retail deposits have lower funding costs (Berlin and Mester 1999, DeYoung and Rice 2004), have lower interest rate elasticity owing to the transactional or storage (i.e., "monetary") purposes of depositors (Amel and Hannan 1999), and are more sticky with regard to funding liquidity risks and sensitivity to financial market conditions (Flannery and James 1984, Berlin and Mester 1999, Cornett et al. 2011, Choi and Velasquez 2016). Because the retail deposit supply is highly price inelastic, banks often reach out to the wholesale funding market when they wish to expand their lending.

We first discuss the relationship between changes in monetary policy stances and the reliance on wholesale funding in the banking sector by measuring a bank's reliance on wholesale funding as the ratio of total wholesale funding to retail deposits. Previous studies commonly suggest that monetary tightening drains retail deposits from the banking sector (e.g., Bernanke and Blinder 1992, Kashyap and Stein 1995) by decreasing bank reserves, which limits the creation of (reservable) retail deposits. In addition to this transmission channel, we focus on the variation in the depositor's opportunity cost of holding retail deposits, which pay upward-sticky interest, if any at all (Hannan and Berger 1991, Hutchison and Pennacchi 1996, Drechsler et al. 2017).

Because of this upward stickiness, which may be banks' optimal choice, the opportunity cost of such "bank money" for savers increases in the policy rate, which also contributes to the decline in the supply of retail deposits to banks. To replace deposit outflows, banks increase their reliance on alternative funding sources, such as wholesale funding, to smooth their lending. Using quarterly panel data from the Consolidated Financial Statements for Holding Companies (FR Y-9C reports) and the Federal Reserve's Report of Condition and Income (call reports) between 1992 and 2006, we find that changes in banks' reliance on wholesale funding are positively associated with changes in the federal funds rate (FFR); that is, the monetary tightening decreases banks' retail deposits and increases their reliance on wholesale funding.

Next, we analyze the cross-sectional implications of this funding substitution during monetary tightening. Note that banks facing fewer financial frictions in the wholesale funding market would pay less for such funds and thus choose to use more of them and become larger in equilibrium. In response to monetary tightening, which makes retail deposits more costly, banks substitute toward wholesale funding until the marginal cost of wholesale funding is equal to the marginal product from lending. This implies that the banks that are already large and rely more on wholesale funding, as they face fewer financial frictions, will also add more wholesale funding because they face a less steep cost function (i.e., the funding cost increases more slowly as they increase their wholesale borrowing). Our empirical findings support this prediction. We find that when the policy rate increases, banks with larger assets show more active funding substitution, and banks with a greater reliance on wholesale funding show a larger increase in their reliance.

We also confirm that banks with more active funding substitution are less affected by the bank lending channel of monetary policy, as suggested and implicitly assumed by Kashyap and Stein (2000). We use the correlation between the change in the FFR and the change in banks' reliance on wholesale funding to measure the sensitivity of funding substitution to monetary policy. Using this measure, we find that lending by a bank with higher funding substitution sensitivity fluctuates less with changes in the monetary policy stance.

Note that in our empirical specifications, we regress bank-level balance sheet adjustments on changes in the monetary policy stance. Our results may be subject to an identification problem, as the change in unobservable loan demand would be a confounding factor. To mitigate this problem, we first include in our regressions various macro- and bank-level controls that are related to the change in loan demand. Because the change in local economic conditions is an important factor for the change in local loan demand, we also use the subsample of "local" banks that operate predominantly within a single metropolitan statistical area (MSA), with additional MSA-level controls and find that our results are robust.

In addition, we exploit demographic variations in the composition between senior ("old," those aged 65 and over) and nonsenior ("young") depositors across regions to improve the tightness of our identification. Here, our identification strategy focuses on differential demand elasticities of bank money—equivalently, from a bank's perspective, the deposit supply elasticity—across different age cohorts (generations). Based on survey evidence, we claim that the deposit supply of seniors during our sample period, belonging to the G.I. generation and silent generation, is less sensitive to changes in the deposit rate (spread) than that of nonseniors during this period.[2]

By exploiting the difference in the elasticity of deposit supply across the depositor types, we argue that, all else being equal, banks with a more nonsenior deposit base should have a greater decrease in retail deposits during monetary tightening, as nonsenior depositors are more sensitive to changes in the deposit rate. This allows a richer variation in the treatment of the reduction in retail deposits by banks, given the policy rate changes. As a result, banks with a more nonsenior deposit base should increase the use of wholesale funding more.

Using branch-level deposit data from the Federal Deposit Insurance Corporation (FDIC) Summary of Deposits and the county-level age structure from the Census, we construct the fraction of seniors that a local bank would face in its local market. We find that banks with a more nonsenior deposit base experience a larger decrease in their retail deposits and a larger increase in the use of wholesale funding following an increase in the policy rate. To the best of our knowledge, this differential deposit demand elasticity across age groups has not previously been exploited in the literature to identify the effect of monetary policy on banks.

However, changes in local demand could still be a potential confounding factor if the change in local demand differs between young and old groups. We find that banks with a younger deposit base experience a larger decrease in retail deposits following monetary policy tightening, but this greater reduction could be coming from two sources: (1) the deposit supply of nonsenior depositors is more sensitive to rate changes, as we suggest, or (2) local loan demand in regions with more nonsenior residents is more sensitive to policy rate changes, thus reflecting the conventional interest rate channel; that is, loan demand decreases more in response to monetary tightening, and, subsequently, the reduced number of loan originations reduces retail deposits. However, (1) and (2) yield opposite predictions with respect to funding substitution. If the larger reduction in retail deposits reflects loan demand being more sensitive to monetary policy, banks with a younger deposit base would not need to increase their use of wholesale funding. If the larger reduction in retail deposits reflects a more sensitive deposit supply, banks with a younger deposit base should raise more wholesale funding, which we find.

We further exploit the difference in banks' asset size within the age groups to support this argument. If the larger decrease in retail deposits for the nonsenior group is driven primarily by more sensitive local loan demand, financial frictions will matter less, and the difference in funding substitution should be similar across the small and large banks with a younger deposit base. If this is not the case, the funding substitution will be stronger in large banks with a younger deposit base, which is what we find. Thus, this result supports our thesis on the effect of monetary policy on retail deposit supply and the funding composition response, rather than an effect operating through changes in local demand.

The relationship between bank funding composition and monetary policy suggests several novel policy implications. First, a systemic vulnerability could accumulate when central banks attempt to contain excessive credit growth through monetary tightening. In attempting to unwind the tightening effect through the lending channel, banks might increase their reliance on the funding sources that can dry up during a financial crisis. This will be more pronounced in "systemic" banks, which are larger and have higher exposure to liquidity risks, thereby amplifying potential externalities on the entire system. In this case, liquidity requirements could enhance financial stability by imposing additional costs on the substitution of wholesale funding for retail deposits, which would prevent a surge in the reliance on wholesale funding and in funding liquidity risks. Therefore, our study provides a novel perspective on the importance of the interaction between monetary policy and macroprudential regulations.

Our results also suggest that monetary policy could have a more pronounced effect on real output through the bolstered bank lending channel combined with liquidity regulation. Note that regulatory liquidity requirements are more binding for large banks because they usually rely more on wholesale funding. As a result, large banks are at a lower LCR, and the implicit substitution cost between the two funding sources would be higher for large banks. This prediction contrasts with the existing findings in the bank lending channel literature that large banks can easily smooth their lending through better access to alternative funding sources (Kashyap and Stein 2000, Kishan and Opiela 2000, Williams 2016) and dampen any *aggregate* effect through the lending channel (Romer and Romer 1990). Because large banks with binding liquidity requirements might need to reduce their lending in response to monetary tightening, this could decrease aggregate bank credit.

1.1. Related Literature

This study is related to several strands of literature. The bank lending channel literature (e.g., Bernanke and Blinder 1992, Kashyap and Stein 1995, Peek and Rosengren 1995, Kashyap and Stein 2000) analyzes how bank lending responds to monetary policy changes, but most of the empirical analyses in this literature focus on the asset side, whereas our analysis examines the liability side. In these papers, the underlying transmission of monetary policy to banks starts from a quantitative change in central bank reserves due to open market operations, which limits banks' deposit creation and thus credit supply. In our paper, we also focus on the role of retail deposits as "bank money" and changes in depositors' demand as the policy rate varies. We then present an identification strategy based on the variation in depositors' demand elasticities, which affect banks' liability directly, rather than through quantitative changes in reserves. A recent paper by Drechsler et al. (2017) also examines the liability side and proposes a deposit channel of monetary policy that focuses on banks' deposit pricing behaviors across different markets and their implications for monetary transmission. Our paper, on the other hand, focuses on the effect of monetary policy on bank funding composition across heterogeneous banks and its implications for the interaction between monetary policy and liquidity regulation.

Previous studies examine the risks of wholesale funding for banks, particularly the impact of relying on wholesale funding during financial crises (see, e.g., Shin 2009, Ivashina and Scharfstein 2010, Cornett et al. 2011, Gorton and Metrick 2012, Copeland et al. 2014, De Haas and Van Lelyveld 2014, Krishnamurthy et al. 2014, Dagher and Kazimov 2015, Irani and Meisenzahl 2017). However, the mechanism driving this increase in banks' reliance on wholesale funding remains an open question. Here, we present one possible channel through which wholesale funding in the banking sector grows and becomes concentrated among banks with greater externalities. Acharya and Mora (2015) and Egan et al. (2017) examine the substitution between core and noncore funding during bank stress when wholesale funding flows out, and Hahm et al. (2013) study the relationship between noncore funding reliance and financial stability.

This study is also related to the literature analyzing the effect of monetary policy on financial stability and on the interaction between monetary policy and macroprudential regulation. There is an emerging literature on the risk-taking channel of monetary policy (for an overview, see Adrian and Shin 2010, De Nicolò et al. 2010, Borio and Zhu 2012), in which monetary loosening leads to lax lending standards and excessive risk taking (see, e.g., Ioannidou et al. 2009, Peydró and Maddaloni 2011, Jiménez et al. 2014, Dell'Ariccia et al. 2017). Adrian and Shin (2008, 2009) and Dell'Ariccia et al. (2014) analyze the role of monetary policy in financial stability via changes in financial sector leverage, and Allen and Gale (2004) discuss how monetary loosening can lead to an asset price bubble. Whereas these studies focus on financial vulnerabilities accumulated during monetary *loosening*, we focus on the systemic imbalance that could form if central banks attempt to contain the aforementioned vulnerabilities through monetary *tightening*. Landier et al. (2015) examine the asset substitution problem, which is exacerbated during tightening, whereas we focus on the funding side. Maddaloni and Peydro (2013), Stein (2012), and Bech and Keister (2013) examine the interaction between monetary policy and macroprudential regulations, and Kashyap et al. (2014) investigate macroprudential regulation and credit supply.

2. Theoretical Motivation

In this section, we discuss how monetary tightening affects the retail deposit supply to the banking sector, bank funding composition, and bank liquidity ratios (e.g., LCR).

2.1. Retail Deposit Supply and Monetary Policy

Panel (a) of Figure 1 plots the relationship between the year-on-year percentage changes in the aggregate retail deposits of commercial banks and the FFR.[3] A clear negative relationship exists between the two time series—retail deposits in the banking sector tend to decrease during monetary tightening when the FFR increases—as is widely documented in the literature (e.g., Bernanke and Blinder 1992, Kashyap and Stein 1995). Below, we briefly describe some of the channels through which monetary tightening drains retail deposits from the banking sector. We later utilize the "money demand" channel, that is, the second and third channels, for our identification strategy in the empirical analysis.

2.1.1. Decrease in Central Bank Reserves. Monetary tightening reduces central bank reserves through open market operations. This limits the amount of reservable deposits that banks can issue because of reserve requirements (see, e.g., Bernanke and Blinder 1992, Kashyap and Stein 1995), or bank money (demandable deposits) creation more broadly because of liquidity concerns (see, e.g., Stein 1998, Bianchi and Bigio 2014).[4]

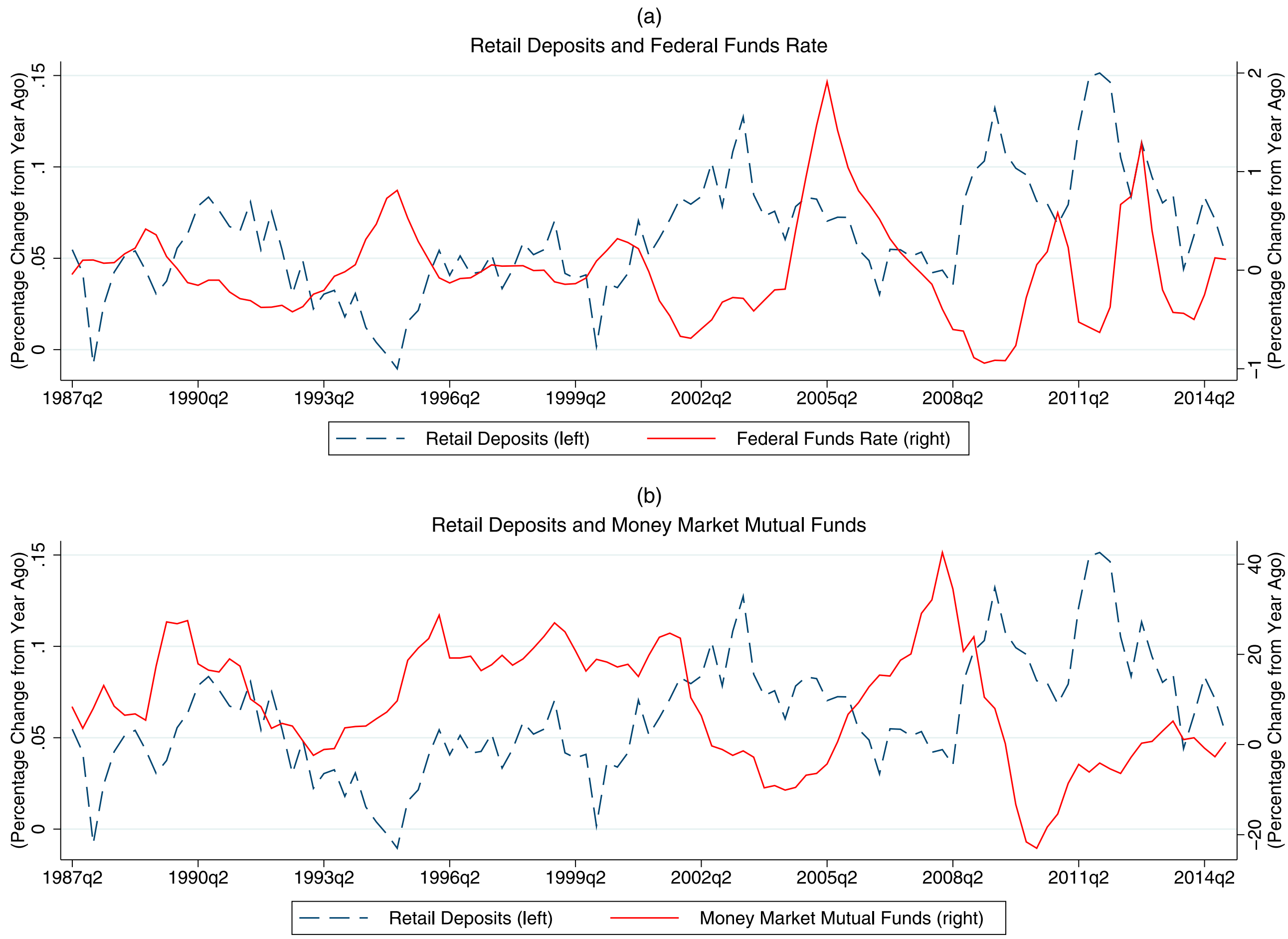
2.1.2. Decrease in Money Demand. Retail depositors save in banks primarily for "monetary" purposes, such as transactions or storage, incurring the cost of a low interest payment. Money demand derives from the agent's portfolio decision between liquid and illiquid assets (Baumol 1952, Tobin 1956). The demand for money decreases when the policy rate increases, because the opportunity cost of holding money increases. Therefore, the demand for bank money also decreases during tightening,[5] which shifts the supply curve of retail deposits to the banking sector upward (Bernanke and Blinder 1988).

2.1.3. Substitution to Alternative Money-Like Assets (e.g., Money Market Funds). The previous channel focuses on switching from a money-like asset to more illiquid nonmoney assets (a decrease in money demand). In addition, financial innovation has introduced alternative money-like assets, which has led to a substitution between different private monies (see, e.g., Nagel 2016, Xiao 2017). For instance, although relatively less convenient and less liquid than bank deposits, money market funds (MMFs) offer such money-like services and provide higher yields than bank deposits.[6] Panel (b) of Figure 1 shows a negative relationship between MMF asset growth and retail deposit growth, especially after the 1990s, when MMFs became popular. Because MMFs offer more market-competitive yields than retail deposits, the yield spread between MMFs and bank deposits increases when the policy rate increases. This leads to a substitution between money-like assets: funds are reallocated from retail deposits to MMFs during tightening, shifting the supply curve of retail deposits to banks upward.[7]

2.2. Bank Funding Substitution and the Liquidity Coverage Ratio

We briefly describe a bank's optimal funding problem and its response to monetary tightening to develop

Figure 1. (Color online) Retail Deposits, Federal Funds Rate, and MMFs



Notes. The figure plots the time series of the change in the federal funds rate, the change in the aggregate amount of retail deposits, and the change in the aggregate amount of money market funds. Panel (a) plots the change in the aggregate amount of retail deposits against a change in the federal funds rate. Panel (b) plots the change in the aggregate amount of money market funds against a change in the aggregate amount of retail deposits.

empirical hypotheses. Our interest lies in comparing the funding composition (i.e., retail versus wholesale funding) across banks facing differential financial frictions. See Online Appendix A for the formal model.

Consider two banks, Bank 1 and Bank 2, which, for simplicity, face identical retail deposit supply and loan demand. Given a loan demand schedule, a bank finances its assets (i.e., loans) from two sources of funding, retail deposits and wholesale funding.[8] The only difference between the two banks is the cost incurred when attracting wholesale funding (reflecting heterogeneous access to money markets). Because of financial frictions such as agency problems, the borrowing cost of wholesale funding increases with the amount of total borrowing, and it increases more rapidly for Bank 2, reflecting the greater financial frictions it faces.

Banks choose the amounts of their retail deposits and wholesale funding to maximize their profits. In equilibrium, the marginal product of lending is equal to the marginal cost of their retail deposits and that of their wholesale funding. As all banks face identical loan demand and retail deposit supply but different costs of wholesale funding, Bank 1, which faces fewer frictions, raises more wholesale funding than Bank 2 to originate more loans.

In equilibrium, Bank 1 is hence more reliant on wholesale funding, defined as the ratio between wholesale funding and retail deposits. This is straightforward because the banks face the same deposit cost functions but different wholesale funding cost functions. Note that this suggests that Bank 1 will have a lower LCR, the ratio of high-quality liquid assets to expected net cash outflows, as retail deposits are assumed to be stickier than wholesale funding under the Basel III assumptions. Here, we obtain the following empirical prediction.

Prediction 1. *Banks facing fewer financial frictions rely more on wholesale funding, and their LCR is lower.*

Now, suppose that the central bank tightens its monetary policy and raises the policy rate. As discussed in the previous subsection and shown in Online Appendix A, this would reduce banks' borrowing of retail deposits. The banks then increase their wholesale funding to maintain their lending, but, again, they do so such that the marginal cost of borrowing and the marginal product of lending are equalized. Here, Bank 1, which faces fewer frictions, will add more wholesale funding because its funding cost rises more slowly. Consequently, banks with better access to wholesale funding can better mitigate a policy shock and smooth lending, as is widely suggested in the bank lending channel literature (e.g., Kashyap and Stein 2000, Kishan and Opiela 2000). We hence make the following prediction on bank funding composition.

Prediction 2. *During monetary tightening,* (i) *banks increase their reliance on wholesale funding,* (ii) *which is more pronounced if they face fewer financial frictions in the funding markets, and* (iii) *banks could better mitigate the impact of monetary policy on their lending by more actively implementing such funding substitution.*

Note that banks that add more wholesale funding—facing fewer financial frictions—are those that already made greater use of wholesale funding prior to the policy change and thus have larger assets. Therefore, as a result of monetary tightening, wholesale funding becomes more concentrated in the banking sector, and we make the following prediction.

Prediction 3. *During monetary tightening, banks that rely more heavily on wholesale funding and/or are larger become more reliant on wholesale funding. Hence, wholesale funding becomes more concentrated in the banking sector.*

Suppose that the private and social costs of wholesale funding deviate because, for example, individual banks do not consider pecuniary externalities through a fire sale of assets (e.g., Lorenzoni 2008, Stein 2012), which becomes more likely as the reliance on wholesale funding increases. This wedge should be greater for larger banks because they impose more externalities on others during fire-sale episodes. Our prediction indicates that this distortion will become greater during monetary tightening, as larger banks add more wholesale funding, which increases their exposure to liquidity risks.

Finally, we discuss the impact of liquidity requirements on the bank lending channel. Because of funding substitution, the LCR of the banks decreases during monetary tightening, owing to an increase in their reliance on flighty wholesale funding. When the introduction of new liquidity requirements imposes a mandatory lower bound on the LCR, this constraint becomes more binding during the tightening period. In addition, the constraint will be more binding for the larger bank (Bank 1) because its LCR is lower, as discussed previously. In this case, because larger banks cannot as easily substitute wholesale funding for their deposit outflows to smooth their lending, we have the following prediction.

Prediction 4. *Liquidity requirements become more binding in the monetary tightening regime, particularly for larger banks. Compared with an economy lacking such requirements, larger banks would reduce their lending by a relatively larger amount in response to monetary tightening.*

This implies that with the introduction of liquidity requirements, monetary tightening could have a greater effect on the lending of larger banks because these requirements increase the implicit cost of funding substitution from retail to wholesale funding. In other words, we could have a more pronounced transmission of monetary policy to aggregate lending through the greater effect on larger banks.

3. Empirical Results

3.1. Data

We collect bank-quarter variables from the first quarter of 1990 (1990Q1) to the fourth quarter of 2006 (2006Q4), using FR Y-9C reports and the Federal Reserve's call reports. We limit our sample to "noncrisis" periods, thereby excluding the savings and loan crisis (before 1990) and the Great Recession (after 2007). This is because bank funding changes for exogenous reasons unrelated to monetary policy during a crisis, such as failures of other institutions, flight to quality, or disruptions in certain money markets. If a bank fulfills the FR Y-9C reporting criteria, we use the bank holding company (BHC)-level variables directly from the FR Y-9C. For banks that do not file an FR Y-9C but have call report item RSSD9348 (RSSD ID of the top holder) populated, we aggregate the bank-level variables by RSSD9348 to construct the BHC-level variables. For banks that neither file an FR Y-9C nor have the RSSD9348 field populated, we use their call report variables and interpret these banks as standalone commercial banks. For simplicity, we refer to both BHCs and commercial banks as banks.

Because we focus on changes in wholesale funding reliance, we eliminate very small banks that tend to rely exclusively on local retail deposits. Specifically, we exclude banks with an average asset size of less than \$10 million, as well as any single-branch banks.[9] We further drop the bank-quarter observations if (1) the bank had more than a 10% change in total assets in a quarter, to control for bank mergers following Campello (2002), or (2) the total deposits to total assets or the total loans to total assets is lower than 25%, to focus on institutions whose main business is commercial banking. We retain the bank-quarter samples with all control variables available. This restricts our sample to 2,161 banks on average in each quarter.

We construct the variables for bank funding composition in the following way. *RD* is the amount of bank retail deposits, calculated by subtracting the wholesale deposits (brokered and foreign deposits, as well as the time deposits over $100,000) from the total deposits.[10] *WSF* is the bank's total wholesale funding, which is the sum of wholesale deposits, federal funds and repo borrowing, and other borrowed money. We then construct the wholesale funding to retail deposits ratio (*WSF to RD* = *WSF*/*RD*), which is our main measure of a bank's reliance on wholesale funding. We winsorize all variables at the 1% and 99% levels, by quarter.

We measure the changes in the monetary policy stance using the quarterly changes in the effective FFR and retrieve the data from the Board of Governors of the Federal Reserve System. We control for bank-level and aggregate-level year-to-year loan growth with a four-quarter lag; hence, the dependent variables start in 1992.

3.2. Summary Statistics

Table 1 reports the summary statistics. The amount of bank retail deposits (*RD*) has a mean of $715 million and a standard deviation (SD) of $6.84 billion. The distribution of *RD* is highly right skewed (skewness of 32.54). Bank wholesale funding (*WSF*) has a mean of $492 million and an SD of $11.8 billion.

Table 1. Summary Statistics

Variables	Obs.	Mean	SD	5th percentile	95th percentile
RD ($ millions)	129,492	715	6,841	24	1,097
WSF ($ millions)	129,492	492	11,800	1.85	391
WSF to RD (%)	129,492	22.30	17.49	4.21	56.52
% Change in RD (%)	129,492	1.21	3.62	−4.49	7.62
% Change in WSF (%)	129,492	4.02	17.60	−19.75	33.99
Change in WSF to RD (%)	129,492	0.32	3.37	−4.87	6.11
Change in RD to TL($t-4$) (%)	129,492	1.04	3.16	−3.97	6.63
Change in WSF to TL($t-4$) (%)	129,492	0.50	2.38	−3.16	4.84
Log *Assets*	129,492	18.90	1.28	17.19	21.15
Capital Ratio (%)	129,492	9.51	2.47	6.34	14.29
Liquid Asset Ratio (%)	129,492	35.77	12.83	16.69	60.05
Securitization (%)	129,492	0.27	0.09	0.13	0.41
RE Loan to Total Loan Ratio (%)	129,492	60.94	17.15	30.11	87.08
CI Loan to Total Loan Ratio (%)	129,492	9.56	11.17	0.00	31.46
Bank-Level Total Loan Growth (%)	129,492	7.81	9.49	−7.47	24.33
Aggregate-Level Total Loan Growth (%)	129,492	9.55	13.96	−12.70	31.07
CP Spread (%)	129,492	0.34	0.18	0.08	0.64
Term Premium (%)	129,492	1.84	0.88	0.55	3.32

Notes. We report the summary statistics of variables that we construct from FR Y9C and call reports. If a bank fulfills the FR Y9C's reporting criteria, we use the BHC-level variables directly from the FR Y9C. For banks that do not file an FR Y9C but have call report item RSSD9348 (RSSD ID of the top holder) populated, we aggregate the bank-level variables by RSSD9348 to construct the BHC-level variables. For banks that do not file an FR Y9C and do not have the RSSD9348 field populated, we use their call report data and interpret these banks as stand-alone commercial banks. We use the Summary of Deposits to restrict our sample to those banks with nonzero deposits other than in the headquarters branch. *RD* is the amount of retail deposit funding, calculated by subtracting wholesale deposits (brokered and foreign deposits as well as time deposits over $100,000) from total deposits. *WSF* is the amount of wholesale funding, which is the sum of wholesale deposits, federal funds, and repo borrowing, and other borrowed money. *WSF to RD* is the wholesale funding to retail deposits ratio (*WSF*/*RD*), which is our main measure for a bank's reliance on wholesale funding. The term *% Change in RD* is the percentage change of a bank's RD from the previous quarter. The term *% Change in WSF* is the percentage change of a bank's WSF from the previous quarter. *Change in WSF to RD* is the change in WSF-to-RD ratio from the previous quarter. *Change in RD to TL*($t-4$) is the change in RD from the previous quarter to the total liabilities of four quarters prior. *Change in WSF to TL*($t-4$) is the change in WSF from the previous quarter to the total liabilities of four quarters prior. Log *Assets* is the log of a bank's assets. *Capital Ratio* is the ratio of a bank's total equity to total assets. *Liquid Asset Ratio* is the ratio of liquid assets (sum of cash, federal funds lending, reverse repo, and securities holdings) to total assets. *RE Loan to Total Loan Ratio* is the ratio of real estate loans to total loans. *CI Loan to Total Loan Ratio* is the ratio of CI loans to total loans. *Bank-Level Total Loan Growth* is the growth rate of total loans of a bank from a year prior. *Aggregate-Level Total Loan Growth* is the growth rate of total loans aggregated for all banks from a year prior. *CP Spread* is the spread between the three-month high-grade commercial paper and the three-month Treasury bill. *Term Premium* is the term premium for a 10-year maturity from the Federal Reserve Bank of New York. *Securitization* is the bank-level measure of securitization activity using Loutskina (2011). The sample period is from 1992 to 2006. We winsorize all variables at the 1% and 99% level by quarter, except *RD* and *WSF*, which we do not use in our regressions. Obs., Observations.

The distribution of *WSF* is also highly right skewed (skewness of 66.77). The ratio of wholesale funding to retail deposits (*WSF to RD*) has a mean of 22.3% and an SD of 17.49%. The distribution of *WSF to RD* is less skewed (skewness of 2.00) than that of *WSF or RD* because we control for the common factors that affect the skewness of *RD* and *WSF* by using the ratio.

We are interested in the change in bank funding composition. The term *% Change in RD* is the quarterly percentage change in a bank's *RD*; this has a mean of 1.21% and an SD of 3.62%. The term *% Change in WSF* is the quarterly percentage change in a bank's *WSF*; this has a mean of 4.02% and an SD of 17.60%. *Change in WSF to RD* is the quarterly change in a bank's *WSF to RD*; this has a mean of 0.32% and an SD of 3.37%. In addition, we construct the quarterly change in *RD* and *WSF*, normalized by the total liabilities (TLs) of four quarters prior. *Change in RD to TL*$(t-4)$ is the change in *RD* from $t-1$ to t normalized by the TL at $(t-4)$, with a mean of 1.04% and an SD of 3.16%. *Change in WSF to TL*$(t-4)$ is defined similarly, with a mean of 0.5% and an SD of 2.38%.

In addition to the bank fixed effects, we include bank-level characteristics and the macro controls in our analysis. The bank-level characteristics are as follows. Log *Assets* is the log of a bank's total assets. *Capital Ratio* is the ratio of a bank's total equity to the total assets; we include it to control for the bank's soundness.[11] *Liquid Asset Ratio* is the ratio of the liquid assets that can be rapidly transformed into cash with minimal impact on the price received (sum of cash, federal funds lending and reverse repo, and securities holdings) to bank assets, and *Securitization* is the measure of loan securitizability, based on Loutskina (2011); these control for the liquidity of a bank's assets. *RE Loan to Total Loan Ratio* is the ratio of real estate loans to total loans, and *CI Loan to Total Loan Ratio* is the ratio of CI loans to total loans; we include them to control for the difference in banks' business models. *Bank-level Total Loan Growth* is the year-to-year growth rate of total bank lending; this controls for the investment opportunity/demand of a bank. We winsorize all variables at the 1% and 99% levels, by quarter.

We use the following macroeconomic controls. *Aggregate-Level Total Loan Growth* is the year-to-year growth rate of aggregate lending by all banks; this controls for the aggregate demand across time. *CP Spread*, based on Gatev and Strahan (2006), is the spread between three-month high-grade commercial paper and the three-month Treasury bill, to capture any flight-to-quality effect. Finally, *Term Premium* is the term premium for a 10-year maturity from the Federal Reserve Bank of New York to control for the slope of the yield curve.

3.3. Wholesale Funding and Liquid Asset Holdings by Bank Size

We begin by establishing stylized facts about the size of banks' assets and balance sheet structures. We examine whether banks' (i) reliance on wholesale funding, (ii) liquid asset holdings, or (iii) decomposition of their wholesale funding is related to their asset size.

We first analyze the relationship between *WSF to RD* and log *Assets* using the bank-level time-series average of *WSF to RD* and log *Assets*. Regressing the former on the latter, we find a strong positive relationship between the two, with a t-statistic of 30.04. As previously discussed, banks that have better access to market funding will choose to raise more wholesale funding and become larger. A very large asset size itself can improve banks' market access because it leads to better diversification and monitoring incentives (Diamond 1984), less severe adverse selection problems (Stein 1998), or more transparency and implicit government guarantees (Park and Pennacchi 2008). If we interpret large banks as the banks facing fewer financial frictions, this evidence supports Prediction 1.

We similarly analyze the relationship between *Liquid Asset Ratio* and log *Assets* using their bank-level time-series average. Regressing the former on the latter, we find a strong negative relationship, with a t-statistic of −10.36. Larger banks hold fewer liquid assets, which is intuitive because they can tap into wholesale funding markets to meet their liquidity demand instead of hoarding more liquid asset buffers. Very large banks perceived as safe havens tend to experience deposit inflows during market disruptions (Gatev and Strahan 2006, Pennacchi 2006), which also incentivizes them to hoard fewer liquid assets ex ante.

Table 2 presents the decomposition of bank wholesale funding by bank asset size. Panel A decomposes banks into three size-groups: the top 1%, top 2%–5%, and bottom 95%, as in Kashyap and Stein (2000). The ratio of wholesale funding to total liabilities is lower for smaller banks, and the majority of their wholesale funding consists of large time deposits (greater than $100,000). Larger banks are more reliant on wholesale funding and use more foreign deposits, federal funds and repo borrowing, and other borrowed money such as commercial paper. This pattern is very monotonic in bank asset size, as can be seen in Panel B, where we present the statistics by decile.

3.4. The Change in Banks' Funding Composition

We next estimate the response in banks' funding composition to the changes in the monetary policy stance. From Prediction 2, we expect that during monetary tightening (loosening), (i) banks' retail deposits will decrease (increase) and (ii) banks' wholesale

Table 2. Summary Statistics on the Decomposition of Bank Wholesale Funding by Bank Asset Size

			Fraction in total liabilities (%)					
				Decomposition of wholesale funding				
	Total assets ($ millions)	Total liabilities ($ millions)	Wholesale funding	Time deposit (>$100,000)	Brokered deposit (<$100,000)	Foreign deposits	Fed. funds/repo	Other borrowed money
Panel A: Top 1%, top 2%–5%, and bottom 95% by bank asset size								
Bottom 95%	231.69	209.57	16.16	11.27	0.24	0.03	1.42	3.11
Top 2%–5%	5,463.77	4,964.53	26.09	11.50	0.34	1.46	6.72	5.91
Top 1%	103,189.50	94,475.25	33.45	7.25	0.14	7.04	8.24	10.77
Panel B: Decile groups by asset size								
1/10	33.14	29.86	11.95	9.69	0.23	0.00	0.61	1.41
2/10	58.51	52.70	14.38	11.03	0.24	0.00	0.79	2.31
3/10	82.71	74.47	15.09	11.33	0.24	0.09	0.89	2.53
4/10	108.18	97.41	15.36	11.67	0.21	0.04	1.07	2.36
5/10	138.16	124.42	15.96	11.85	0.19	0.01	1.15	2.65
6/10	177.64	160.23	16.41	11.38	0.23	0.01	1.44	3.25
7/10	230.81	208.56	16.66	11.27	0.24	0.02	1.52	3.49
8/10	318.12	288.38	18.00	11.78	0.22	0.02	1.72	4.09
9/10	514.15	465.83	18.98	11.36	0.35	0.01	2.43	4.67
10/10	12,983.89	11,867.37	24.42	11.03	0.30	1.39	5.40	6.16

Notes. We report the summary statistics of wholesale funding composition by bank asset size. Panel A reports wholesale funding compositions by the asset size of banks following Kashyap and Stein (2000). The bottom 95% banks are the banks with assets less than the 95th percentile in the distribution of bank asset size. The top 1% banks are banks with assets greater than the 99th percentile. The rest are top 2%–5% banks. We report average total assets in millions, average total liabilities, and average fraction of wholesale funding in banks' total liabilities. By decomposing wholesale funding, we report the average fraction of time deposits (greater than $100,000), brokered deposits (less than $100,000), foreign deposits, federal fund borrowing and repos, and other borrowed money in banks' total liabilities. Panel B reports wholesale funding composition by the decile groups of banks by their asset size.

funding will increase (decrease), (iii) so the banks increase (decrease) their reliance on wholesale funding.

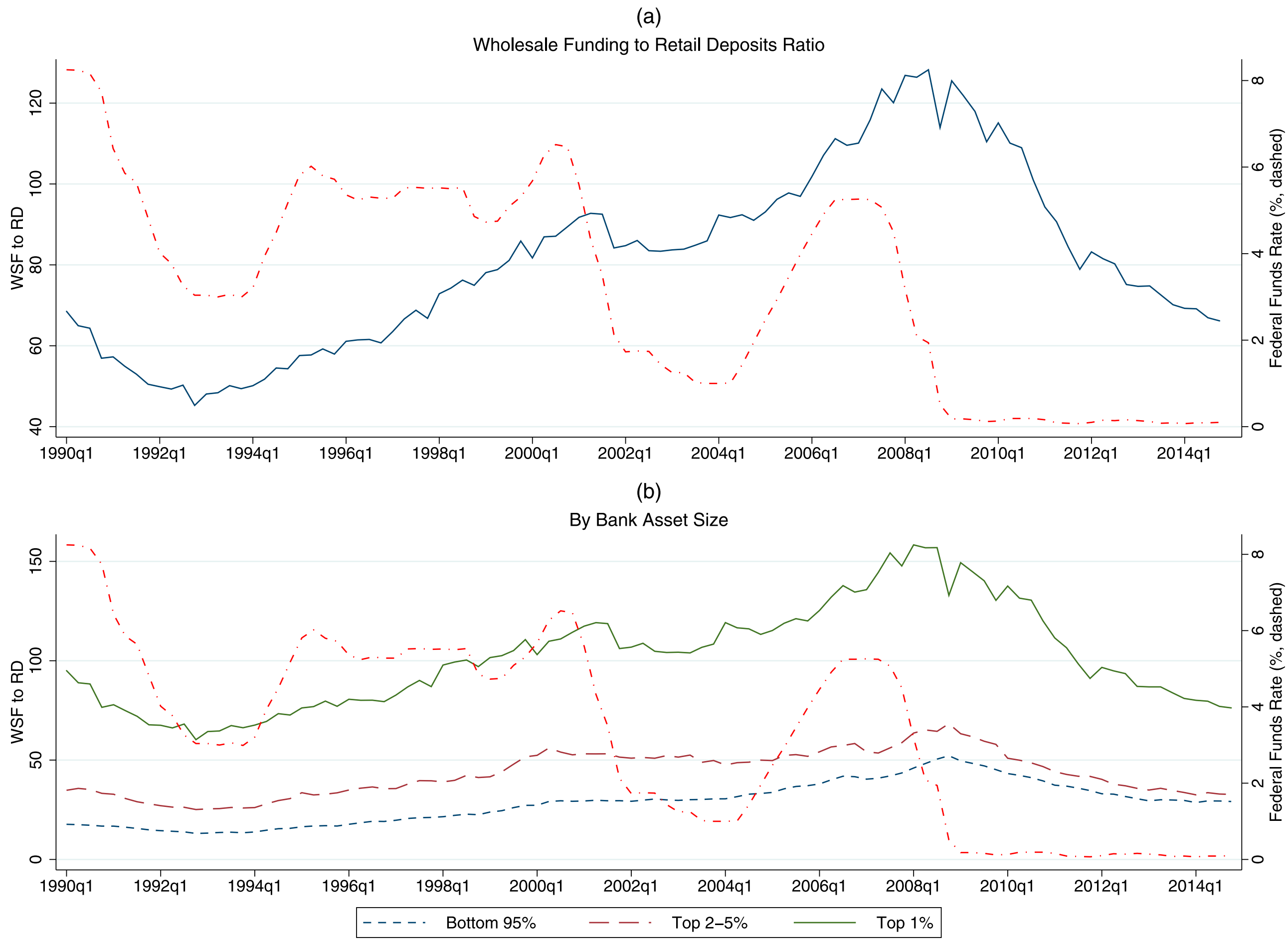
Figure 2 shows the time series of *WSF to RD*, our measure of reliance on wholesale funding, along with the FFR from 1990 to 2014. Panel (a) reports the aggregate *WSF to RD* ratio, which is the ratio of aggregate wholesale funding to aggregate retail deposits, using the FR Y-9C. Overall, we observe a positive association between the policy rate and the U.S. banking sector's reliance on wholesale funding.[12] The periods 1990–1992 and 2001–2004 showed a slight decline in the reliance on wholesale funding, which coincide with periods of declining interest rates.

Note that there was a general upward trend in the reliance on wholesale funding in the run-up to the recent financial crisis, followed by a downtrend.[13] Although a detailed analysis of these longer term trends is beyond the scope of this paper, this uptrend may primarily reflect the consolidation of the U.S. banking industry; the number of commercial banks in the United States decreased from approximately 12,500 at the beginning of 1990 to 5,600 at the end of 2014 according to the Federal Financial Institutions Examination Council (2019), whereas the aggregate assets of all commercial banks nearly quintupled over the same period. As discussed previously, larger banks generally have better access to wholesale funding markets (Diamond 1984, Stein 1998, Park and Pennacchi 2008). Another potential determinant is financial innovations that reduce information or agency frictions to help banks attract wholesale funds. This trend reversed circa 2008, and the ratio in 2014 fell to levels last seen in 1996. This reversal may reflect disruptions in money markets during the crisis that lead to investors' flight to safety into the protected banking sector (Gatev and Strahan 2006, Pennacchi 2006), as well as the increase in aggregate deposits due to the prolonged monetary stimulus.

Panel (b) of Figure 2 reports the time series of *WSF to RD* separately for the three size groups, the top 1%, top 2%–5%, and bottom 95%, following Kashyap and Stein (2000). Note that the general levels of wholesale funding reliance are higher for the larger banks. Furthermore, the positive comovement of wholesale funding reliance and the FFR is more pronounced for the large banks, suggesting more active adjustment in their funding composition as the policy rate changes. We next examine this relationship in greater detail.

3.4.1. Baseline Result. Table 3 reports the panel regression results of the changes in the banks' funding composition on the changes in the FFR.[14] We use the distributed-lag model (i.e., that of Kashyap and Stein 2000) to incorporate the lagged effect of FFR on the

Figure 2. (Color online) Wholesale Funding to Retail Deposits Ratio



Notes. The figure plots the time series of the wholesale funding to retail deposits ratio (*WSF to RD*). Panel (a) plots the aggregate WSF to RD, which we calculate by aggregating retail deposits and wholesale funding, by quarter, for all banks. The solid line plots the aggregate WSF to RD, and the dotted dashed line plots the federal funds rate quarterly from 1990 to 2014. Panel (b) plots the aggregate WSF to RD of the banks by their asset sizes in our sample quarterly from 1990 to 2014 with the federal funds rate. Following Kashyap and Stein (2000), the solid line plots the aggregate WSF to RD of the banks with top 1% asset size, and the dashed lines plot the aggregate WSF to RD of the banks in the top 2%–5% of asset size (longer dashes) and the aggregate WSF to RD of the banks in the bottom 95% of asset size (shorter dashes).

banks' funding composition. The regression specification is as follows:

$$Y_{it} = \alpha_i + \alpha_q + \sum_{j=1}^{4} \beta_j \cdot \textit{Change in FFR}_{t-j} + \gamma \cdot X_{t-4} + \delta \cdot X_{i,t-4} + \epsilon_{i,t}, \quad (1)$$

where we include bank fixed effects and quarter-of-year fixed effects to account for seasonality. The term X_t denotes two macroeconomic controls, *CP Spread* and *Term Premium*. Previous studies (e.g., Gatev and Strahan 2006, Pennacchi 2006) suggest that investors' funds flow into the protected banking sector during flight-to-safety episodes. If retail deposits increased during the recession because of this effect while the central bank simultaneously reduced the policy rate, we would have a negative relationship between retail deposit growth and the policy rate that was not driven by monetary policy. We mitigate this effect by (i) excluding the crisis periods and (ii) adding *CP Spread* to directly account for the money market stress following Gatev and Strahan (2006). The term $X_{i,t}$ denotes six bank-specific control variables. Log *Assets* and *Capital Ratio* control for bank size and soundness, respectively, and both of them also affect banks' access to funding markets. *RE Loan to Total Loan Ratio* and *CI Loan to Total Loan Ratio* control for bank business models.[15] The bank lending channel literature suggests that banks can mitigate the impact of monetary policy if they own highly liquid assets (Kashyap and Stein 2000, Kishan and Opiela 2000) or their loans can be easily securitized (Loutskina 2011). *Liquid Asset Ratio* controls for the liquidity of bank assets excluding loans, and *Securitization* controls for the liquidity of a bank's loan portfolio. To capture the changes in loan demand, we further include total loan growth at both the bank and aggregate levels.

Table 3. Banks' Funding Composition and the Federal Funds Rate

Variables	(1) *% Change in RD*	(2) *% Change in WSF*	(3) *Change in WSF to RD*	(4) *Change in RD to TL(t − 4)*	(5) *Change in WSF to TL(t − 4)*
Change in FFR (*t* − 1 to *t*)	−0.864***	1.255*	0.446***	−0.748***	0.204**
	(−4.04)	(1.95)	(3.50)	(−3.83)	(2.22)
Change in FFR (*t* − 2 to *t* − 1)	0.158	2.231***	0.198	0.111	0.241**
	(0.58)	(2.92)	(1.41)	(0.45)	(2.54)
Change in FFR (*t* − 3 to *t* − 2)	0.413	−0.220	0.017	0.404	0.011
	(1.50)	(−0.26)	(0.11)	(1.57)	(0.11)
Change in FFR (*t* − 4 to *t* −3)	−0.407*	0.768	0.075	−0.380*	0.026
	(−1.86)	(1.21)	(0.65)	(−1.86)	(0.31)
Sum of effects	−0.70***	4.03***	0.74***	−0.61***	0.48***
	(−4.71)	(7.65)	(7.54)	(−4.43)	(7.05)
Log *Assets* (*t* − 4)	−0.481***	−3.951***	−0.213**	−0.657***	−0.215***
	(−3.46)	(−10.98)	(−2.18)	(−5.01)	(−3.10)
Capital Ratio (*t* − 4)	0.045**	0.505***	0.081***	0.049***	0.077***
	(2.64)	(7.46)	(4.48)	(3.28)	(6.93)
RE Loan to Total Loan Ratio (*t* − 4)	0.003	−0.006	−0.0002	0.003	0.001
	(1.29)	(−0.58)	(−0.14)	(1.17)	(0.49)
CI Loan to Total Loan Ratio (*t* − 4)	0.004	0.001	−0.002	0.004	0.001
	(1.02)	(0.08)	− 0.52)	(0.92)	(0.54)
Liquid Asset Ratio (*t* − 4)	−0.010**	0.0411**	−0.002	−0.011***	−0.004*
	(−2.41)	(2.39)	(−0.79)	(−3.07)	(−1.71)
Securitization (*t* − 4)	0.732	1.979	0.199	0.812	0.523
	(0.68)	(0.58)	(0.23)	(0.84)	(1.00)
Bank-Level Total Loan Growth (*t* − 4)	0.018***	0.031***	0.001	0.016***	0.005***
	(7.94)	(2.87)	(0.31)	(8.19)	(4.04)
CP Spread (*t* − 4)	−0.042	−1.736	0.060	−0.049	−0.010
	(−0.11)	(−1.18)	(0.17)	(−0.14)	(−0.04)
Term Premium (*t* − 4)	−0.010	−1.293***	−0.210***	−0.011	−0.195***
	− 0.09)	(−5.16)	(−2.90)	− 0.12)	(−4.60)
Aggregate-Level Total Loan Growth (*t* − 4)	−0.011***	0.020*	0.006**	−0.010**	0.003*
	(−2.69)	(1.83)	(2.61)	(−2.60)	(1.91)
Observations	129,492	129,492	129,492	129,492	129,492
R^2	0.113	0.048	0.059	0.119	0.069
Bank FEs and quarter-of-year FEs	Yes	Yes	Yes	Yes	Yes

Notes. We report the panel regression estimates of the relationship between the change in a bank's funding composition and the change in the FFR. We use bank-quarter observations from 1992 to 2006. The dependent variables are the percentage change in the retail deposits of a bank (% *Change in RD*) in column (1), the percentage change in the wholesale funding of a bank (% *Change in WSF*) in column (2), the change in wholesale funding to retail deposits ratio (*Change in WSF to RD*) in column (3), the change in RD from the previous quarter to the total liabilities of four quarters prior (*Change in RD to TL*(*t* − 4)) in column (4), and the change in WSF from the previous quarter to the total liabilities of four quarters prior (*Change in WSF to TL*(*t* − 4)) in column (5). The independent variables include four lags of the change in the FFR, log *Assets* (the log of bank's asset size), *Capital Ratio* (the ratio of the bank's equity to the bank's assets), *Securitization* (the bank-level measure of securitization activity using Loutskina (2011)), *RE Loan to Total Loan Ratio* (the fraction of real estate loans in the bank's total loans), *CI Loan to Total Loan Ratio* (the fraction of CI loans in the bank's total loans), *Liquid Asset Ratio* (the ratio of liquid assets to the bank's total assets), *Bank-Level Total Loan Growth* (the growth rate of the bank's total lending from the previous quarter), *CP Spread* (the spread between the three-month high grade commercial paper and the three-month Treasury bill), *Term Premium* (the term premium for a 10-year maturity from the Federal Reserve Bank of New York), and *Aggregate-Level Total Loan Growth* (the growth rate of the total lending of all banks from the previous quarter). We use four-quarter-lagged bank characteristics and macro variables in our analysis. We include bank fixed effects (FEs) and quarter-of-year fixed effects (for seasonality). We report the sum of the estimates of the lagged FFR and the *t*-statistics of the sum. The table reports point estimates with *t*-statistics in parentheses. All standard errors are clustered at the year-quarter level.
*10% statistical significance; **5% statistical significance; ***1% statistical significance.

We use four-quarter-lagged bank-level characteristics and macro controls in our analysis to mitigate simultaneity problems.

Column (1) of Table 3 reports the regression result of the percentage changes in banks' retail deposits (% *Change in RD*) on the changes in the FFR. The four lags of the quarterly changes in the FFR are our main independent variables. The sum of the effects of the lagged FFR changes ($\Sigma_{j=1}^{4}\beta_j$) is −0.70, with a *t*-statistic of −4.71.[16] An increase in the FFR decreases banks' retail deposits, and this relationship is statistically significant. In terms of economic significance, a 1 SD increase in the *Change in FFR* in the previous year entails a 9% of 1 SD reduction in the % *Change in RD*.

Column (2) reports the regression result of the percentage changes in banks' wholesale funding (*% Change in WSF*) on the changes in the FFR with the same specification as in column (1). We find that an increase in the FFR increases banks' wholesale funding amount and that this relationship is statistically significant. It is also economically significant given that a 1 SD increase in the *Change in FFR* results in a 10% of 1 SD increase in the *% Change in WSF*.

Column (3) reports the regression result of the changes in banks' reliance on wholesale funding (*Change in WSF to RD*) on the changes in the FFR. We find a statistically significant increase in the reliance on wholesale funding with an increase in the FFR. The result is expected from the previous two columns because RD decreases and WSF increases with the FFR. The economic significance of the result is 10%.

Note that the *% Change in RD* and the *% Change in WSF* in columns (1) and (2), respectively, are highly affected by their denominators, that is, the levels of *RD* or *WSF* in the previous quarter. We thus rerun the regressions with the change in *RD* or *WSF* normalized by the total liabilities of four quarters prior, which provides us with a better idea of the compositional changes in funding. Column (4) reports the result of the change in banks' retail deposits normalized by the total liabilities of four quarters prior (*Change in RD to TL*$(t-4)$) on the changes in the FFR. Similar to the result in column (1), the banks' retail deposits (relative to the total liabilities one year ago) decrease with the increase in the FFR. Column (5) reports the result for the change in banks' wholesale funding normalized by the total liabilities of four quarters prior (*Change in WSF to TL*$(t-4)$) on the changes in the FFR. Similar to the result in column (2), banks' wholesale funding (relative to the total liabilities four quarters prior) increases with the increase in the FFR.

Table 4 reports the results in Table 3 by bank size. As suggested in Predictions 2 and 3, we expect to find greater funding substitution in large banks than in small banks. Following Kashyap and Stein (2000), we define large banks as banks with an asset size above the 95th percentile of the bank asset distribution; the rest are defined as small banks. We define the *Large Bank* dummy as 1 if a bank is large and 0 otherwise. In our sample, there are 2,054 small banks and 108 large banks on average in a given year-quarter.

The regression specification is as follows:

$$Y_{it} = \alpha_i + \alpha_q + \sum_{j=1}^{4} \theta_j \cdot \mathit{Change\ in\ FFR}_{t-j} \cdot \mathit{Large\ Bank}_{i,t-4} + \psi \cdot \mathit{Large\ Bank}_{i,t-4} + \sum_{j=1}^{4} \beta_j \cdot \mathit{Change\ in\ FFR}_{t-j} + \gamma \cdot X_{t-4} + \delta \cdot X_{i,t-4} + \epsilon_{i,t}, \quad (2)$$

where our main variable of interest is the interaction between the changes in the FFR and the *Large Bank* dummy. The regression specifications are the same as in Table 3; we do not report the controls in Table 4 for brevity.[17]

Column (3) of Table 4 reports the estimation result for the changes in banks' reliance on wholesale funding (*Change in WSF to RD*) on the changes in the FFR by bank size. First, the sum of the effects of the lagged FFR changes ($\Sigma_{j=1}^{4}\beta_j$) is 0.69, with a t-statistic of 7.10. This is similar to column (3) of Table 3. Moreover, the sum of the effects of the interactions ($\Sigma_{j=1}^{4}\theta_j$) is also significantly positive (0.96), with a t-statistic of 4.23. The economically significance is large at 13%; compared with the small banks (with an economic significance of 9%), a 1 SD increase in the *Change in FFR* yields an increase of an additional 13% of 1 SD of the *Change in WSF to RD* in the large banks. This indicates that the large banks experience a greater increase in their reliance on wholesale funding during monetary tightening, which supports our Predictions 2 and 3.

To be consistent with Table 3, columns (1) and (2) report the estimation results for the changes in banks' retail deposits and wholesale funding on the changes in the FFR by bank size. However, as discussed above, the *% Change in RD* and the *% Change in WSF* are highly affected by the levels of *RD* and *WSF*, respectively, in the previous quarter. In this sense, the comparison of the estimated coefficients across the bank-size groups here could be less informative because, for instance, larger banks rely more on wholesale funding to begin with and thus have larger denominators (*WSF*) for *% Change in WSF*.

Therefore, as in Table 3, we rerun the regressions with the changes in *RD* or *WSF* that are normalized by the total liabilities of four quarters prior. Columns (4) and (5) report the regression results of the *Change in RD to TL*$(t-4)$ and the *Change in WSF to TL*$(t-4)$ on the changes in the FFR. First, the sum of the effects of the lagged FFR changes ($\Sigma_{j=1}^{4}\beta_j$) is significantly negative for *Change in RD to TL*$(t-4)$ and positive for *Change in WSF to TL*$(t-4)$. This is very similar to columns (4) and (5) in Table 3.

Note that we have different results for the coefficients for the interaction terms ($\Sigma_{j=1}^{4}\theta_j$) in columns (4) and (5). For the compositional changes in retail deposits (*Change in RD to TL*$(t-4)$) in column (4), the sum of the coefficients ($\Sigma_{j=1}^{4}\theta_j$) is not statistically significant. This indicates that the decrease in retail deposits as a share of total liabilities during monetary tightening is similar across the bank size groups. However, the sum of the coefficients is statistically significant for the *Change in WSF to TL*$(t-4)$ in column (5), with a t-statistic of 2.41, and its economic significance is 5% (1 SD of the *Change in FFR* (0.45) × 0.28/1 SD

Table 4. Banks' Funding Composition and the Federal Funds Rate by Bank Size

Variables	(1) *% Change in RD*	(2) *% Change in WSF*	(3) *Change in WSF to RD*	(4) *Change in RD to TL(t − 4)*	(5) *Change in WSF to TL(t − 4)*
Change in FFR (*t* − 1 to t)	−0.857***	1.266*	0.407***	−0.753***	0.193**
	(−4.05)	(1.94)	(3.22)	(−3.86)	(2.12)
Change in FFR (*t* − 2 to *t* − 1)	0.139	2.197***	0.192	0.103	0.223**
	(0.52)	(2.83)	(1.39)	(0.42)	(2.42)
Change in FFR (*t* − 3 to *t* − 2)	0.417	−0.204	0.025	0.406	0.019
	(1.55)	(−0.24)	(0.16)	(1.59)	(0.19)
Change in FFR (*t* − 4 to *t* − 3)	−0.389*	0.822	0.065	−0.369*	0.033
	(−1.82)	(1.28)	(0.58)	(−1.83)	(0.42)
Sum of effects	−0.69***	4.08***	0.69***	−0.61***	0.47***
	(−4.65)	(7.55)	(7.10)	(−4.46)	(6.94)
Large Bank	−0.314	0.313	0.219	−0.168	−0.067
	(−1.62)	(0.60)	(1.04)	(−1.10)	(−0.59)
Large Bank × *Change in FFR* (*t* − 1 to *t*)	−0.133	−0.225	0.776***	0.105	0.217
	(−0.49)	(−0.36)	(2.74)	(0.60)	(1.60)
Large Bank × *Change in FFR* (*t* − 2 to *t* − 1)	0.397	0.674	0.125	0.188	0.374*
	(1.11)	(0.82)	(0.28)	(0.79)	(1.88)
Large Bank × *Change in FFR* (*t* − 3 to *t* − 2)	−0.105	−0.327	−0.134	−0.0481	−0.159
	(−0.35)	(−0.39)	(−0.34)	(−0.26)	(−0.73)
Large Bank × *Change in FFR* (*t* − 4 to *t* − 3)	−0.380*	−1.094	0.197	−0.217	−0.152
	(−1.77)	(−1.63)	(0.70)	(−1.55)	(−1.02)
Sum of effects	−0.22	−0.97	0.96***	0.03	0.28**
	(−1.12)	(−1.64)	(4.23)	(0.24)	(2.41)
Observations	129,492	129,492	129,492	129,492	129,492
R^2	0.113	0.048	0.060	0.119	0.069
Bank FEs and quarter-of-year FEs	Yes	Yes	Yes	Yes	Yes
Bank-level controls	Yes	Yes	Yes	Yes	Yes
Macro controls	Yes	Yes	Yes	Yes	Yes

Notes. We report the panel regression estimates of the relationship between the change in banks' funding composition and the change in the federal funds rate by bank size. The dependent variables are the percentage change in the retail deposits of a bank (*% Change in RD*) in column (1), the percentage change in the wholesale funding of a bank (*% Change in WSF*) in column (2), the change in the wholesale funding to retail deposits ratio (*Change in WSF to RD*) in column (3), the change in RD from the previous quarter to the total liabilities of four quarters prior (*Change in RD to TL*(*t* − 4)) in column (4), and the change in WSF from the previous quarter to the total liabilities of four quarters prior (*Change in WSF to TL*(*t* − 4)) in column (5). Following Kashyap and Stein (2000), we define large banks as banks with an asset size above the 95th percentile in the banks' asset distribution and the rest as small banks. We define the *Large Bank* dummy as 1 if a bank is large and 0 otherwise. Our main variable of interest is the interaction between the federal funds rate and the *Large Bank* dummy. Other independent variables include bank-level controls (*RE Loan to Total Loan Ratio*, *CI Loan to Total Loan Ratio*, log *Assets*, *Capital Ratio*, *Bank-Level Total Loan Growth*, *Liquid Asset Ratio*, *Securitization*) and macro controls (*CP Spread*, *Term Premium*, *Aggregate-Level Total Loan Growth*). We use four-quarter-lagged bank characteristics and macro variables in our analysis. For brevity, we do not report the controls in the table. We also include bank fixed effects and quarter-of-year fixed effects (for seasonality). We report the sums of the estimates of the lagged FFR and the interaction terms with the *t*-statistics of the sums. The table reports point estimates with *t*-statistics in parentheses. All standard errors are clustered at the year-quarter level.
*10% statistical significance; **5% statistical significance; ***1% statistical significance.

of the *Change in WSF to TL*(*t* − 4) (2.38) = 5%); that is, compared with the small banks (with an economic significance of 9%), a 1 SD increase in the *Change in FFR* yields an additional 5% of 1 SD increase in *Change in WSF to TL*(*t* − 4) for the large banks. This indicates that the large banks experience a greater increase in their wholesale funding (relative to the level of total liabilities) during monetary tightening, which again supports our Predictions 2 and 3.[18]

3.4.2. Potential Endogeneity due to the Loan Demand Effect. One of the main identification problems is that the changes in demand for bank loans can be confounded: any relationship between bank funding composition and the change in the FFR could emerge and not be reflective of the policy impact, but, rather, the change in local loan demand. For instance, the increase in wholesale funding following monetary tightening might simply reflect stronger loan demand, although this would not explain the decrease in retail deposits—which should be increasing in loan originations—during the same period.

To mitigate the impact of the potential change in loan demand, we control for bank-level total loan growth, aggregate-level loan growth, and term spreads in our baseline regression. We further implement the following robustness analysis of our results: for the cross-sectional difference in local loan demand and the local business cycle, we control for MSA characteristics such as population, income per capita, and the unemployment rate. We restrict our sample to the local banks that operate mainly in a single MSA, so that our MSA-level controls can better capture the economic environment faced by banks. Using the Summary of Deposits, we define local banks as banks with more than 70% of their deposits on average from one MSA. Local banks are smaller, less levered, have more liquid assets, and rely more on retail deposits and less on wholesale funding.[19] This restricts our sample size to 86,060.

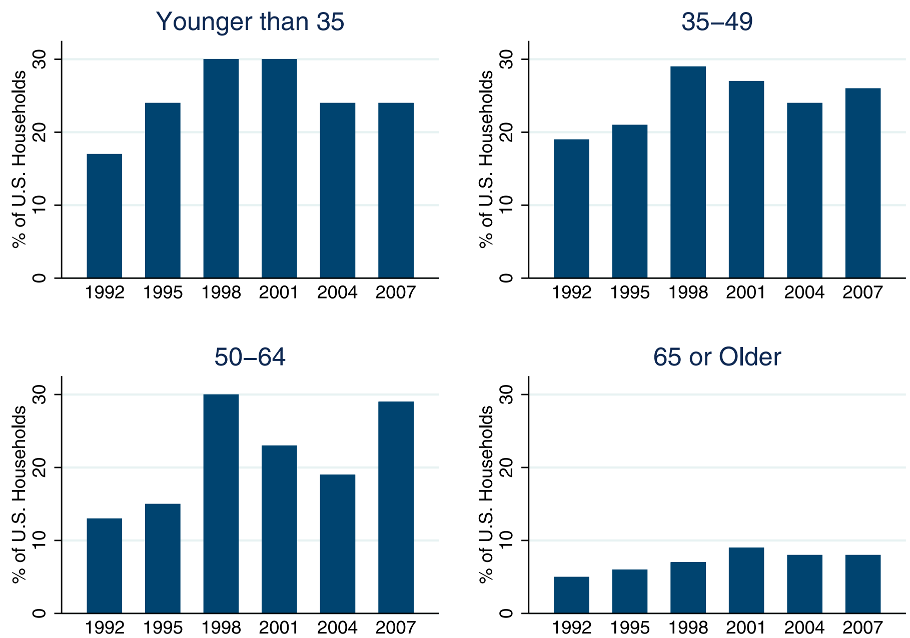
We reestimate Table 3 using the sample of local banks with the additional controls for MSA characteristics.[20] We find that these MSA variables indeed reflect the local business cycle. A higher unemployment rate is negatively associated with changes in retail deposits, wholesale funding, and the wholesale funding to retail deposits ratio, whereas higher income is positively associated with the changes in retail deposits. The main results remain similar to the previous ones in Table 3.

3.4.3. The Difference in the Impact of Monetary Policy by Local Age Demographics. We next exploit demographic variation across regions to improve the tightness of our identification. Specifically, we compare banks facing different retail deposit supply elasticities to control for common shocks to loan demand and isolate the effect of monetary policy on bank liabilities.[21]

Becker (2007) suggests that areas populated with more seniors (referring to that part of the population aged 65 and over) tend to have more deposits in banks and uses this demographic characteristic as an instrument for the deposit supply *level* to the banking sector. We instead use this regional demographic variation as a measure of the deposit supply *sensitivity* to the policy rate change.[22]

Seniors in our sample period of 1992–2006 belong to the silent and G.I. generations, born before 1945. Previous studies widely document that savers in this cohort have a different attitude toward financial risks and investment compared with the following cohorts, including the baby boomers (born between 1946 and 1964) and those in Generation X (born between 1965 and 1980), which belong to the nonsenior group in our sample period. For instance, based on the 1999 Michigan Surveys of Consumers, Kiser (2002a, b) indicates that seniors belonging to these generations are less likely to switch their banks, and the high switching costs may decrease price sensitivity of deposit supply.[23] Examining households' attitudes toward investment and financial risks, Investment Company Institute (2006) factbook reports that as of 2005, more than 50% of those in the age groups of 35 to 44, 45 to 54, and 55 to 64 own mutual funds, whereas this ratio falls to 37% for those 65 or older.[24] Figure 3, based on Investment Company Institute (2010),

Figure 3. (Color online) Risk-Taking Behavior by Age



Notes. The figure reports the willingness to take above-average or substantial investment risk by age. We plot the percentage of U.S. households by age of head of household from Investment Company Institute (2010). For each age group, we report the fraction for 1992, 1995, 1998, 2001, 2004, and 2007.

compares investment risk appetites for the U.S. households across different age groups, which clearly suggest that seniors during our sample period are less willing to take financial risks.[25]

We further examine the Survey of Consumer Finances (SCF) administered between 1992 and 2006 to confirm this argument. Table 5 examines households' reasons for choosing their banks. Those belonging to the silent and G.I. generations (born between 1901 and 1945), referred to as seniors, tend to choose their banks based on location (column (1)) and long-term relationships (column (6)), which suggests that these households have higher switching costs. On the other hand, they tend to care less about fees or minimum balance requirements (column (3)), indicating lower price sensitivity. Table 6 examines savers' risk attitudes and whether they own certain types of financial assets. A larger fraction of seniors responded that they would not take any financial risks (column (1)), although this tendency is less pronounced for more educated seniors (column (2)). They also tend to have invested more in retail deposits (checking, savings, time deposits, and money market deposit accounts (MMDAs)) but less in MMFs or risky assets, particularly if they did not receive a higher education.

These results suggest that seniors in our sample period save their funds more as retail deposits and that their deposit demand is less sensitive to changes in yields. As shown in the model in Online Appendix A, this results in differential changes in retail deposits across banks during monetary tightening—those with a deposit base of mostly price-sensitive nonseniors would have a greater decrease in retail deposits and thus a larger increase in their reliance on wholesale funding.[26]

Using the annual population estimates from the Census, we first compute the fraction of the population who are older than 65 for all U.S. counties.[27]

Table 5. Choice of Financial Institutions by Seniors

Variables	(1) Location	(2) Many services	(3) Low fee and min balance	(4) Safety and absence of risk	(5) Personal relationship	(6) Long-term relationship	(7) Friend/family recommendation	(8) Through school/work
Senior	0.131***	0.036	−0.188***	−0.007	−0.079*	0.153***	−0.199***	−0.019
	(5.80)	(1.25)	(−6.01)	(−0.14)	(−1.85)	(2.94)	(−4.68)	(−0.24)
Marginal effects	[0.13]	[0.04]	[−0.19]	[−0.01]	[−0.08]	[0.15]	[−0.20]	[−0.02]
High Education	−0.006	−0.019	0.145***	0.027	0.018	−0.077	0.048	−0.092
	(−0.29)	(−0.83)	(5.35)	(0.62)	(0.49)	(−1.40)	(1.04)	(−1.51)
Log *Net Worth*	0.013**	0.058***	−0.021***	0.076***	0.041***	0.032**	−0.025**	−0.021*
	(2.30)	(8.73)	(−3.09)	(5.60)	(3.74)	(2.47)	(−1.99)	(−1.74)
Log *Income*	0.071***	0.053***	0.019	−0.019	0.082***	0.014	−0.059**	0.218***
	(5.52)	(2.93)	(1.24)	(−0.74)	(3.50)	(0.47)	(−2.19)	(5.79)
Male	0.028	−0.057	−0.034	−0.017	−0.066	−0.298***	−0.170***	0.030
	(1.13)	(−1.61)	(−0.88)	(−0.25)	(−1.30)	(−3.62)	(−3.11)	(0.43)
Married	−0.081***	0.107***	0.097***	−0.017	0.024	0.254***	0.018	−0.150**
	(−3.32)	(3.25)	(3.03)	(−0.29)	(0.50)	(3.31)	(0.31)	(−2.22)
Have Kid	−0.022	−0.009	−0.011	−0.093*	−0.103***	−0.139***	−0.081**	0.155***
	(−1.19)	(−0.42)	(−0.42)	(−1.86)	(−3.13)	(−2.76)	(−2.28)	(2.87)
Working	−0.038	0.030	0.238***	−0.206***	−0.052	−0.042	−0.039	0.096
	(−1.40)	(1.05)	(7.04)	(−4.12)	(−1.15)	(−0.71)	(−0.70)	(1.06)
Race (*White*)	−0.075	0.101**	0.070	−0.034	0.202**	−0.053	−0.023	0.100
	(−1.62)	(2.08)	(1.30)	(−0.29)	(2.07)	(−0.36)	(−0.25)	(0.50)
Race (*Black*)	−0.196***	0.061	−0.113*	0.066	−0.227*	0.022	−0.137	0.287
	(−3.64)	(1.10)	(−1.85)	(0.48)	(−1.94)	(0.14)	(−1.22)	(1.37)
Race (*Hispanic*)	−0.195***	−0.082	−0.110	0.241*	−0.084	−0.195	−0.222*	0.009
	(−3.84)	(−1.64)	(−1.52)	(1.79)	(−0.70)	(−1.08)	(−1.75)	(0.04)
Observations	98,455	98,455	98,455	98,455	98,455	98,455	98,455	98,455
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes. The table reports the probit estimates of the determinants for seniors' choice of financial institutions for the main checking account using the SCF between 1992 and 2006. The dependent variables are indicator variables equal to 1 if they were important factors for a household when deciding which financial institution to open a main checking account with. The main independent variable is *Senior,* which is a dummy variable that equals to 1 for households who were born between 1901 and 1945, following Strauss and Howe (1992), for the definition of the silent and G.I. generations. Other household controls include *High Education*, which is an indicator that equals 1 if the head of household has more than a bachelor's degree, log *Net Worth*, log *Income*, and dummies for *Male*, *Married*, *Have Kid*, *Working*, and *Race*. We include survey year fixed effects. The average marginal effect is in brackets. The table reports point estimates with *t*-statistic in parentheses. Because of the multiple imputation process (five implicates to generate a distribution for the imputed values) for missing values in the SCF, standard errors are based on weighted data and are adjusted for the multiple implicates.

*10% statistical significance; **5% statistical significance; ***1% statistical significance.

Table 6. Choice of Financial Portfolio by Seniors

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Risk attitude		Have asset							
Variables	No financial risk		Checking and savings, CD		MMDA		MMF		Risky assets	
Senior	0.164***	0.187***	0.015***	0.028***	0.011*	0.012*	−0.002	−0.010**	−0.035***	−0.046***
	(23.22)	(21.05)	(3.55)	(5.63)	(1.72)	(1.90)	(−0.45)	(−2.38)	(−4.25)	(−5.85)
Senior × *High Education*		−0.072***		−0.042***		−0.004		0.027***		0.033**
		(−5.39)		(−6.07)		(−0.32)		(2.98)		(2.34)
High Education	−0.125***	−0.099***	0.003	0.017***	0.052***	0.053***	0.066***	0.056***	0.140***	0.129***
	(−17.44)	(−11.53)	(0.78)	(4.30)	(7.97)	(6.71)	(12.55)	(11.39)	(19.10)	(15.50)
Log *Net Worth*	−0.037***	−0.037***	0.012***	0.012***	0.036***	0.036***	0.020***	0.020***	0.065***	0.065***
	(−16.01)	(−16.15)	(7.44)	(7.35)	(27.75)	(27.69)	(21.19)	(21.28)	(40.51)	(40.75)
Log *Income*	−0.098***	−0.098***	0.043***	0.043***	0.044***	0.044***	0.028***	0.027***	0.083***	0.082***
	(−21.02)	(−20.96)	(10.61)	(10.63)	(14.75)	(14.71)	(10.15)	(9.97)	(21.05)	(20.93)
Male	−0.096***	−0.094***	−0.040***	−0.039***	−0.033***	−0.032***	−0.021***	−0.022***	−0.018**	−0.019**
	(−9.83)	(−9.56)	(−6.31)	(−6.12)	(−3.90)	(−3.87)	(−3.67)	(−3.83)	(−2.20)	(−2.31)
Married	0.081***	0.080***	0.009	0.008	0.006	0.006	−0.001	−0.0003	−0.016*	−0.015*
	(9.18)	(9.04)	(1.61)	(1.49)	(0.76)	(0.75)	(−0.15)	(−0.06)	(−1.84)	(−1.78)
Have Kid	0.042***	0.044***	−0.013***	−0.013***	−0.035***	−0.035***	−0.012***	−0.012***	−0.034***	−0.035***
	(6.88)	(7.06)	(−3.20)	(−3.01)	(−5.79)	(−5.79)	(−3.23)	(−3.36)	(−5.63)	(−5.76)
Working	−0.106***	−0.103***	0.012**	0.014**	−0.037***	−0.037***	−0.020***	−0.021***	−0.045***	−0.047***
	(−12.92)	(−12.48)	(2.01)	(2.33)	(−4.99)	(−4.93)	(−4.00)	(−4.31)	(−6.11)	(−6.37)
Race (*White*)	−0.062***	−0.061***	0.018*	0.019*	0.001	0.002	0.024***	0.024***	0.039***	0.039***
	(−4.34)	(−4.25)	(1.67)	(1.72)	(0.14)	(0.15)	(3.47)	(3.42)	(3.35)	(3.34)
Race (*Black*)	−0.010	−0.008	−0.067***	−0.066***	−0.022*	−0.022*	0.008	0.008	−0.024*	−0.025*
	(−0.50)	(−0.41)	(−4.91)	(−4.82)	(−1.84)	(−1.83)	(1.15)	(1.06)	(−1.79)	(−1.86)
Race (*Hispanic*)	0.081***	0.084***	−0.110***	−0.108***	0.007	0.007	0.009	0.008	−0.049***	−0.050***
	(4.52)	(4.76)	(−8.08)	(−7.92)	(0.55)	(0.57)	(1.30)	(1.10)	(−3.46)	(−3.62)
Observations	98,455	98,455	98,455	98,455	98,455	98,455	98,455	98,455	98,455	98,455
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes. The table reports panel regression estimates of the portfolio choice of senior households. The dependent variable in columns (1) and (2) is an indicator for the willingness to take financial risks in the SCF. The indicator equals 1 if the household would not take any financial risks. The main independent variable is *Senior*. Column (2) additionally includes the interaction term between *Senior* and the *High Education* dummy. The dependent variable is an indicator variable for having a checking account, savings account, or CD in columns (3) and (4), an indicator for having an MMDA in columns (5) and (6), an indicator for having an MMF account in columns (7) and (8), an indicator for having risky assets such as stocks, bonds, and non–money market mutual funds in columns (9) and (10). The table reports point estimates with *t*-statistic in parentheses. Because of the multiple imputation process (five implicates to generate a distribution for the imputed values) for missing values in the SCF, standard errors are based on weighted data and are adjusted for the multiple implicates.

*10% statistical significance; **5% statistical significance; ***1% statistical significance.

Using the FDIC Summary of Deposits data on banks' branch-level deposit distributions, we then calculate the deposit-weighted fraction of seniors for each bank. This serves as a proxy for the fraction of seniors that a bank faces in its local deposit markets.[28] Note that as a bank operates in a greater number of counties, the proxy becomes a noisier measure of the demographic characteristics of a bank's deposit base. We therefore begin our analysis by restricting the sample to local banks, which are the banks with more than 70% of deposits on average from one MSA, and we add MSA-level economic controls. This restricts our sample size to 86,048.

We first test whether the banks with a young deposit base experience larger retail deposit outflows than banks with an old deposit base when monetary policy tightens. The regression specification is as follows:

$$Y_{it} = \alpha_i + \alpha_q + \sum_{j=1}^{4} \theta_j \cdot Change\ in\ FFR_{t-j} \cdot Young_{i,t-4} + \psi \cdot Young_{i,t-4} + \sum_{j=1}^{4} \beta_j \cdot Change\ in\ FFR_{t-j} + \gamma \cdot X_{t-4} + \delta \cdot X_{i,t-4} + \epsilon_{i,t}, \tag{3}$$

where the *Young* dummy equals 1 if the average deposit-weighted fraction of seniors of a bank is below the median and 0 otherwise. Our main variable of interest is the interaction between the changes in the FFR and the *Young* dummy. The regression controls also include MSA characteristics capturing local economic conditions.

Table 7. The Difference in the Sensitivity of Funding Composition by the Deposit Base of Local Banks

Variables	(1) *% Change in RD*	(2) *% Change in WSF*	(3) *Change in WSF to RD*	(4) *Change in RD to TL*($t-4$)	(5) *Change in WSF to TL*($t-4$)
Change in FFR ($t-1$ to t)	−0.820***	1.364*	0.437***	−0.720***	0.209**
	(−3.67)	(1.83)	(3.30)	(−3.48)	(2.21)
Change in FFR ($t-2$ to $t-1$)	0.147	2.076**	0.166	0.115	0.205**
	(0.53)	(2.30)	(1.14)	(0.45)	(2.27)
Change in FFR ($t-3$ to $t-2$)	0.370	−0.576	−0.081	0.363	−0.074
	(1.41)	(−0.65)	(−0.50)	(1.45)	(−0.69)
Change in FFR ($t-4$ to $t-3$)	−0.372*	0.433	0.016	−0.370*	−0.006
	(−1.71)	(0.62)	(0.13)	(−1.80)	(−0.07)
Sum of effects	−0.67***	3.30***	0.54***	−0.61***	0.33***
	(−4.31)	(6.36)	(4.99)	(−4.27)	(4.82)
Young	0.054	0.461	0.055	0.064	0.066
	(0.62)	(1.65)	(0.82)	(0.81)	(1.43)
Young × *Change in FFR* ($t-1$ to t)	−0.195*	−0.298	0.042	−0.164*	−0.002
	(−1.95)	(−0.48)	(0.49)	(−1.80)	(−0.03)
Young × *Change in FFR* ($t-2$ to $t-1$)	0.067	−0.062	0.060	0.057	0.050
	(0.42)	(−0.09)	(0.54)	(0.39)	(0.66)
Young × *Change in FFR* ($t-3$ to $t-2$)	0.090	0.804	0.119	0.070	0.118
	(0.68)	(1.31)	(1.13)	(0.57)	(1.57)
Young × *Change in FFR* ($t-4$ to $t-3$)	−0.259**	0.427	0.092	−0.203*	0.014
	(−2.21)	(0.78)	(0.94)	(−1.96)	(0.21)
Sum of effects	−0.30***	0.87*	0.31***	−0.24***	0.18***
	(−3.02)	(1.86)	(4.24)	(−2.72)	(3.47)
Observations	86,048	86,048	86,048	86,048	86,048
R^2	0.110	0.050	0.057	0.117	0.070
Bank FEs and quarter-of-year FEs	Yes	Yes	Yes	Yes	Yes
Bank-level controls	Yes	Yes	Yes	Yes	Yes
Macro controls	Yes	Yes	Yes	Yes	Yes
MSA-level controls	Yes	Yes	Yes	Yes	Yes

Notes. We report the panel regression estimates of the relationship between the change in banks' funding composition and the change in the federal funds rate, by the deposit base of local banks. We restrict our sample to local banks, which are the banks with more than 70% of deposits on average from one MSA. The dependent variables are the percentage change in the retail deposits of a bank (*% Change in RD*) in column (1), the percentage change in the wholesale funding of a bank (*% Change in WSF*) in column (2), the change in the wholesale funding to retail deposits ratio (*Change in WSF to RD*) in column (3), the change in RD from the previous quarter to the total liabilities of four quarters prior (*Change in RD to TL*($t-4$)) in column (4), and the change in WSF from the previous quarter to the total liabilities of four quarters prior (*Change in WSF to TL*($t-4$)) in column (5). Using the county-level fraction of seniors (whose age is above 65) from the Census, we construct the deposit-weighted fraction of seniors for each local bank. *Young* dummy is 1 if the average deposit-weighted fraction of seniors of a bank is below the median and is 0 otherwise. Our main variable of interest is the interaction between the federal funds rate and the *Young* dummy. Other independent variables include bank-level controls (*RE Loan to Total Loan Ratio*, *CI Loan to Total Loan Ratio*, log *Assets*, *Capital Ratio*, *Bank-Level Total Loan Growth*, *Liquid Asset Ratio*, *Securitization*), macro controls (*CP Spread*, *Term Premium*, *Aggregate-Level Total Loan Growth*), and MSA-level controls (log *Population*, *Income Per Capita*, *Unemployment Rate*). We use four-quarter-lagged bank characteristics, macro variables, and MSA-level controls in our analysis. For brevity, we do not report the controls in the table. We also include bank fixed effects (FEs) and quarter-of-year fixed effects (for seasonality). We report the sums of the estimates of the lagged FFR (sum of effects) and the interaction terms with the *t*-statistic of the sums. The table reports point estimates with *t*-statistics in parentheses. All standard errors are clustered at the year-quarter level.

*10% statistical significance; **5% statistical significance; ***1% statistical significance.

In columns (1)–(5) of Table 7, the sum of the effects of the lagged FFR changes ($\Sigma_{j=1}^{4}\beta_j$) is negative for *% Change in RD*, positive for *% Change in WSF*, positive for *Change in WSF to RD*, negative for *Change in RD to TL*($t-4$), and positive for *Change in WSF to TL*($t-4$). They all are statistically and economically significant and very similar to those in Table 3.

Moreover, we find stronger effects in *% Change in RD* for the banks with a young deposit base, as predicted. In column (1), the sum of the effects of the interactions ($\Sigma_{j=1}^{4}\theta_j$) is negative for *% Change in RD*; that is, the banks with a young deposit base show higher sensitivity in RD to the changes in the FFR. This allows for richer variation in the treatment of the reduction in RD by banks, given the same changes in the FFR. We find that banks with a greater treatment of the reduction in RD also increase their reliance on wholesale funding. In columns (2) and (3), the sum of the effects of the interactions ($\Sigma_{j=1}^{4}\theta_j$) is positive for both *% Change in WSF* and *Change in WSF to RD*. The results are statistically and economically significant. They are also robust to the consideration of changes in *RD* or *WSF* that are normalized by the total liabilities of four quarters prior. In columns (4) and (5), the sum of the effects of the interactions is negative for *Change in RD to TL*$(t-4)$ and positive for *Change in WSF to TL*$(t-4)$.

In sum, our empirical results suggest that the impact of monetary tightening on banks' funding composition differs depending on the demographics of banks' deposit bases. Banks with a young deposit base would experience a greater decrease in retail deposits, which are associated with their greater increase in reliance on wholesale funding. This finding supports our hypothesis that changes in the FFR would lead to funding substitution by banks.

Recall that our identification strategy assumes (a) differential deposit supply elasticities and (b) identical loan demand responses to monetary policy across regions. However, the difference in the response of retail deposits with respect to banks' deposit bases could still be a product of the difference in omitted characteristics, particularly differential demand responses violating the second identification assumption. The banks with a young deposit base may experience a larger decrease in retail deposits because (1) the deposit supply of young depositors is more sensitive to the changes in policy rates (and thus, the banks raised fewer such deposits) or (2) the loan demand of young residents is more sensitive to changes in policy rates (the typical interest rate channel).[29] For instance, nonseniors' demand could be affected more if they have a larger amount of debt with floating interest rates (Di Maggio et al. 2017).

We address this concern as follows. Note that we have the opposite predictions on funding substitution between the two cases. If the larger decrease in retail deposits for banks with a young deposit base reflected more sensitive loan demand for young residents to monetary policy, the banks would not require more wholesale funding to substitute for these funds. On the other hand, if the larger decrease for these banks instead reflected a more elastic deposit supply for young depositors, the banks would more actively seek to increase wholesale funding. Our findings in Table 7 that indicate a stronger effect of wholesale funding substitution in banks with a young deposit base support the second argument.

We further exploit the difference in banks' asset sizes within the age demographic groups to support this claim. In our baseline result in Section 3.4.1, we find that large banks are more likely to substitute wholesale funding for retail deposit outflows, as they face fewer financial frictions. Our conjecture is that financial frictions would matter more in a region with greater retail deposit outflows (i.e., a young deposit base) because in those regions, the incentives to pursue funding substitution would be greater. Thus, we test whether the difference in funding substitution activity (in response to a change in the monetary stance) across the bank size groups is larger when facing a younger deposit base with greater deposit outflows. We should observe the opposite result if this greater deposit decline is driven primarily by more sensitive local demand, as explained above.

Table 8 reports the regression results by bank size and banks' deposit base groups. As in Table 7, the sample in this analysis is restricted to local banks, which are banks with more than 70% of deposits on average from one MSA, and includes MSA-level economic controls. Columns (1) and (2) report the results on *Change in WSF to RD*. Column (1) shows the results for the banks with an old deposit base, and column (2) shows the results for the banks with a young deposit base. The young group consists of banks with an average deposit-weighted fraction of seniors below the median, and the old group contains the rest. As in Table 7, when the FFR increases, we find that the sum of the effects of the lagged FFR changes is positive and significant; that is, the banks' reliance on wholesale funding increases in both groups, and the increase is larger in the young group. We then interact the changes in the FFR with the *Large Bank* dummy. *Large Bank* dummy equals 1 for banks with an assets in the top 5% and 0 otherwise. We find additional sensitivity of reliance on wholesale funding to the change in the FFR in the large bank group, but it is significant only for banks with a young deposit base. The difference between the two sums of effects of the interaction terms, $1.81 - 0.33 = 1.48$, is statistically significant, with a t-statistic of 2.81.

Columns (3)–(6) report the results on *Change in RD to TL*$(t-4)$ and *Change in WSF to TL*$(t-4)$. We again confirm that the higher sensitivity of the reliance on wholesale funding to the change in the FFR in the young group comes from the larger decrease in RD and the larger increase in WSF. Moreover, the additional sensitivity associated with the large bank group comes from the additional decrease in RD and additional increase in WSF among the large bank group. In sum, the results in Tables 7 and 8 support our hypothesis on banks' *active* funding substitution as the FFR changes.[30]

Last, we examine whether other regional differences result in the differential responses we documented previously. We find that young MSAs are more populated, with slightly fewer married residents; slightly more educated; and less competitive in terms of the deposit share Herfindahl–Hirschman Index.[31] Theoretically, it is possible that the larger decrease in retail deposits at the young MSAs during monetary tightening may reflect the regional differences in education levels (that are independent of the age structure) or market competition. However, we do not observe the differential changes in retail deposits

Table 8. The Difference in the Sensitivity of Funding Composition by the Deposit Base and the Size of Local Banks

	Change in WSF to RD		*Change in RD to TL(t − 4)*		*Change in WSF to TL(t − 4)*	
	Old	Young	Old	Young	Old	Young
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Change in FFR ($t-1$ to t)	0.418***	0.433***	−0.642***	−0.961***	0.203**	0.187*
	(2.98)	(3.16)	(−3.24)	(−4.36)	(2.10)	(1.90)
Change in FFR ($t-2$ to $t-1$)	0.144	0.274*	0.117	0.168	0.195**	0.268**
	(0.96)	(1.72)	(0.48)	(0.61)	(2.08)	(2.52)
Change in FFR ($t-3$ to $t-2$)	−0.038	−0.027	0.292	0.498	−0.043	0.008
	(−0.23)	(−0.15)	(1.20)	(1.60)	(−0.39)	(0.06)
Change in FFR ($t-4$ to $t-3$)	0.033	0.087	−0.335*	−0.582**	0.002	0.012
	(0.26)	(0.67)	(−1.72)	(−2.42)	(0.02)	(0.12)
Sum of effects	0.56***	0.77***	−0.57***	−0.88***	0.36***	0.48***
	(4.63)	(7.80)	(−3.94)	(−5.49)	(4.68)	(7.27)
Large Bank	0.296	0.534*	−0.141	−0.243	−0.016	0.024
	(0.66)	(1.79)	(−0.51)	(−1.00)	(−0.06)	(0.14)
Large Bank × *Change in FFR* ($t-1$ to t)	−0.422	1.441***	0.985**	0.208	−0.226	0.483**
	(−0.76)	(3.19)	(2.51)	(1.13)	(−0.66)	(2.56)
Large Bank × *Change in FFR* ($t-2$ to $t-1$)	0.446	−0.875	−0.680*	0.092	0.273	−0.192
	(0.71)	(−1.23)	(−1.74)	(0.30)	(0.72)	(−0.72)
Large Bank × *Change in FFR* ($t-3$ to $t-2$)	0.313	0.763	−0.184	−0.363	0.155	0.242
	(0.47)	(1.23)	(−0.42)	(−1.46)	(0.36)	(0.77)
Large Bank × *Change in FFR* ($t-4$ to $t-3$)	−0.004	0.479	0.032	−0.301*	−0.131	−0.103
	(−0.01)	(1.03)	(0.10)	(−1.69)	(−0.34)	(−0.48)
Sum of effects	0.33	1.81***	0.15	−0.37***	0.07	0.43***
	(0.63)	(6.41)	(0.47)	(−2.83)	(0.23)	(2.86)
Observations	37,437	48,611	37,437	48,611	37,437	48,611
R^2	0.054	0.069	0.116	0.124	0.063	0.084
Bank FEs and quarter-of-year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Bank-level controls	Yes	Yes	Yes	Yes	Yes	Yes
Macro controls	Yes	Yes	Yes	Yes	Yes	Yes
MSA-level controls	Yes	Yes	Yes	Yes	Yes	Yes

Notes. We report the panel regression estimates of the relationship between the change in banks' funding composition and the change in the federal funds rate, by the deposit base of local banks and by bank size. We restrict our sample to local banks, which are banks with more than 70% of deposits on average from one MSA. The dependent variables are the change in wholesale funding to retail deposits ratio (*Change in WSF to RD*) in columns (1) and (2), the change in RD from the previous quarter to the total liabilities of four quarters prior (*Change in RD to TL*($t-4$)) in columns (3) and (4), and the change in WSF from the previous quarter to the total liabilities of four quarters prior (*Change in WSF to TL*($t-4$)) in columns (5) and (6). Using the county-level fraction of seniors (whose age is above 65) from the Census, we construct the deposit-weighted fraction of seniors for each local bank. We split the banks into two subgroups: the group of banks with an old deposit base and the group of banks with a young deposit base. Banks in the young deposit base group are banks with an average deposit-weighted fraction of seniors below median. The rest are in the old deposit base group. Columns (1), (3), and (5) report the results of the banks in the old deposit base group, and columns (2), (4), and (6) report the results of the banks in the young deposit base group. We define large banks as banks with an asset size above the 95th percentile in the banks' asset distribution and the rest as small banks. We define the *Large Bank* dummy as 1 if a bank is large and 0 otherwise. Our main variable of interest is the interaction between the federal funds rate and the *Large Bank* dummy. Other independent variables include bank-level controls (*RE Loan to Total Loan Ratio*, *CI Loan to Total Loan Ratio*, log *Assets*, *Capital Ratio*, *Bank-Level Total Loan Growth*, *Liquid Asset Ratio*, *Securitization*), macro controls (*CP Spread*, *Term Premium*, *Aggregate-Level Total Loan Growth*), and MSA-level controls (log *Population*, *Income Per Capita*, *Unemployment Rate*). We use four-quarter-lagged bank characteristics, macro variables, and MSA-level controls in our analysis. For brevity, we do not report the controls in the table. We also include bank fixed effects (FEs) and quarter-of-year fixed effects (for seasonality). We report the sums of the estimates of the lagged FFR and the interaction terms with the *t*-statistic of the sums. The table reports point estimates with *t*-statistics in parentheses. All standard errors are clustered at the year-quarter level.

*10% statistical significance; **5% statistical significance; ***1% statistical significance.

in response to the policy rate change when we sort the banks by these regional characteristics.[32]

3.5. The Effect of Bank Funding Sensitivity on Bank Lending

Prediction 2 suggests that if banks can replace deposit outflows with wholesale funding, they can mitigate the policy effect on the lending channel. We here evaluate the role of banks' funding substitution on the impact of monetary policy on bank lending growth.

We conduct a two-stage estimation following Kashyap and Stein (2000). For each quarter, we construct a bank-level measure of the sensitivity of funding composition to monetary policy. To measure sensitivity, we calculate the correlation between the quarterly changes in the FFR and the quarterly changes in banks' reliance on wholesale funding measured by *WSF to RD*. We interpret the higher correlation as a sign of more active funding substitution at the bank level in response to the changes in the monetary policy stance. We create two versions of the measure by quarter by bank: (1) past five years' correlation of the quarterly change in the FFR and the quarterly change in banks' wholesale funding reliance and (2) the past three years' correlation of the quarterly change in the FFR and the quarterly change in banks' wholesale funding reliance.

Using these measures ($B_{i,t}$), we run the following first-stage regression by quarter:

$$dlogTotalLoan_{i,t} = \alpha + \sum_{j=1}^{3} \delta_{j,t} \cdot dlogTotalLoan_{i,t-j} + \beta_t \cdot B_{i,t-4} + \epsilon_{i,t},$$

where β_t captures the cross-sectional effect of the sensitivity of banks' funding composition on bank lending growth in that quarter, which is expected to be positive.

In the second stage, we regress β_t on the four lags of quarterly changes in the FFR. We expect the sum of the coefficients to be positive and significant; that is, in the tightening regime, we expect that β_t will be higher. This implies that the ability to flexibly adjust funding composition will be more effective in smoothing bank lending when the FFR increases.

Table 9 reports the second-stage regression results. Column (1) reports the result using a five-year window to measure the sensitivity of banks' funding composition. We find significantly positive effects in the sum of the coefficients, as expected. When the FFR increases by 100 basis points over the past year, the result shows that β_t will increase by 0.0041. For a "sensitive" bank, with B_{it} = 35.63%, and an "insensitive" bank, with B_{it} = −19.99%, which are the numbers corresponding to the 90th and 10th percentiles of the distribution for banks in the fourth quarter of 2006, respectively, this translates to a 0.23% larger increase in bank-level total loan growth (0.3563 – (−0.1999) * 0.0041 = 0.0023) for the sensitive banks. This is approximately 3% of the average bank-level total loan growth in Table 1. Note, however, that these numbers are suggestive at best because we do not isolate the effects of other liquidity management techniques that banks use to mitigate the impact of monetary policy, such as liquidity hoarding (Kashyap and Stein 2000, Kishan and Opiela 2000) or securitization (Loutskina and Strahan 2009, Loutskina 2011). Column (2) reports the results using a three-year window to measure the sensitivity of banks' funding composition. We obtain a result similar to that in the previous column.

Table 9. The Impact of Monetary Policy on Banks' Total Lending through the Sensitivity of Funding Composition

	The effect of bank funding sensitivity on bank lending (β_t)	
Variables	(1)	(2)
Change in FFR (*t* − 1 to *t*)	0.0017	0.0018
	(0.82)	(0.96)
Change in FFR (*t* − 2 to *t* − 1)	−0.0010	−0.0022
	(−0.31)	(−1.02)
Change in FFR (*t* − 3 to *t* − 2)	−0.0003	−0.0015
	(−0.13)	(−0.68)
Change in FFR (*t* − 4 to *t* − 3)	0.0038*	0.0044**
	(1.89)	(2.47)
Sum of effects	0.0041***	0.0026**
	(2.56)	(2.17)
Linear Time Trend	7.84e-05	5.28e-05*
	(1.42)	(1.82)
Observations	44	52

Notes. We report the time series regression estimates of the relationship between the change in the FFR and the banks' total lending through the sensitivity of funding composition. We follow the two-stage regression in Kashyap and Stein (2000). The dependent variables are the regression coefficients from the first stage regression (β_t), where we estimate, quarter by quarter, the effect of banks' sensitivity of funding composition on banks' total lending. We construct the measures of banks' sensitivity of funding composition to monetary policy in two different ways: (1) the correlation between the quarterly change in WSF to RD and the quarterly change in FFR using the past five years of the sample and (2) the correlation as in (1) only with three years of sample. For each quarter, we first run the following regression:

$$dlogTotalLoan_{i,t} = \alpha + \sum_{j=1}^{3} \delta_{j,t} \cdot dlogTotalLoan_{i,t-j} + \beta_t \cdot B_{i,t-4} + \epsilon_{i,t},$$

where $B_{i,t}$ is the measure of banks' funding composition sensitivity. Columns (1) and (2) report the second-stage results, where the dependent variables are $\{\beta_t\}$ from the first-stage with the respective measures of banks' funding composition sensitivity ((1) and (2) above). The independent variables are four lags of the change in the FFR, quarter fixed effects, and a linear time trend. Column (1) is from 1996 to 2006, and column (2) is from 1994 to 2006. We report the sum of the estimates of the lagged FFR and the *t*-statistic of the sum. The table reports point estimates with *t*-statistics in parentheses. We report the Newey–West standard error with four lags.

*10% statistical significance; **5% statistical significance; ***1% statistical significance.

3.6. Concentration of Wholesale Funding

Prediction 3 suggests that banks with a greater reliance on wholesale funding will increase their wholesale funding by a greater amount during monetary tightening; that is, during a tightening regime, wholesale funding can be more concentrated among its heavy users. In this section, we test whether the effect of monetary policy on banks' funding composition differs by a bank's preexisting level of reliance on wholesale funding.

In Figure 4, we first show the time series of the distribution of wholesale funding in the U.S. banking sector from 1990 to 2014. For each quarter, we compute the distance between the 90th percentile and the 10th percentile in the distribution of banks' reliance on wholesale funding (*WSF to RD*). We plot the distance with historical FFRs. The solid line depicts the distance, and the dashed line plots the FFR. We find that the distance and the FFR comove, except during the financial crisis from 2007 to 2009; that is, during monetary tightening, the distance widens, indicating the polarization of reliance on wholesale funding. However, the distance narrows during monetary loosening.

Table 10 reports the panel regression results for tests of the heterogeneity in the effect of monetary policy on banks' funding substitution by banks' preexisting level of reliance on wholesale funding. The regression specification is similar to that reported in Table 3 and is as follows:

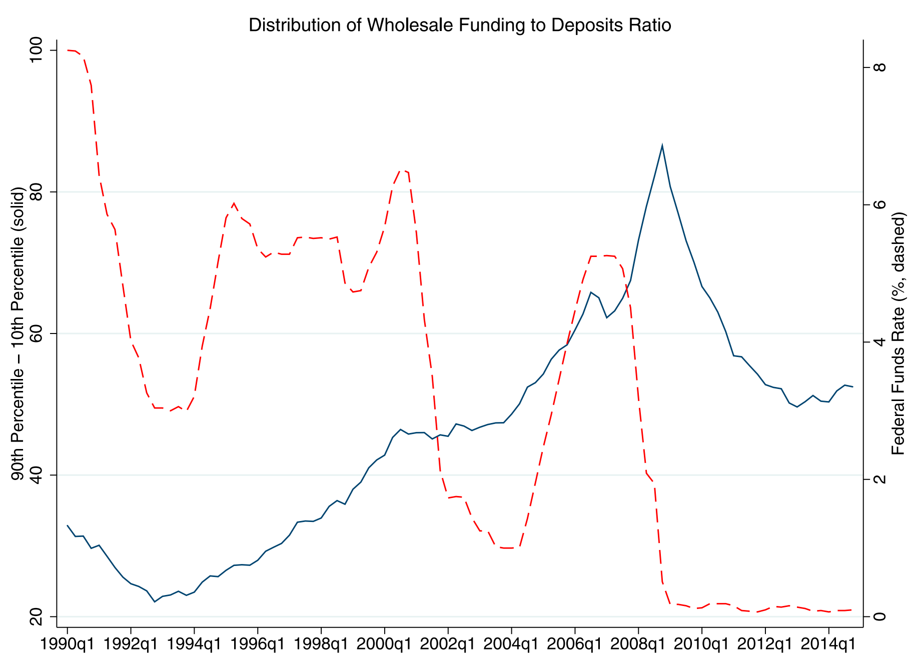
$$\begin{aligned}
&\textit{Change in WSF to RD}_{it} \\
&= \alpha_i + \alpha_q + \sum_{j=1}^{4} \theta_j \cdot \textit{Change in FFR}_{t-j} \cdot \textit{WSF to RD}_{i,t-4} \\
&\quad + \psi \cdot \textit{WSF to RD}_{i,t-4} + \sum_{j=1}^{4} \beta_j \cdot \textit{Change in FFR}_{t-j} \\
&\quad + \gamma \cdot X_{t-4} + \delta \cdot X_{i,t-4} + \epsilon_{i,t}. \qquad (4)
\end{aligned}$$

Column (1) reports the regression result in our full sample. The dependent variable is the quarterly *Change in WSF to RD*. The main independent variables are the four-quarter-lagged level of *WSF to RD*, the four lags of *Changes in FFR*, and the interaction between them. The sum of the coefficients for the interaction terms ($\Sigma_{j=1}^{4} \theta_j$) is 0.02, with a t-statistic of 3.98. Column (2) reports similar results for small banks, and column (3) reports the results for large banks. As before, large banks are those within the top 5% of asset size. We find similar results for both the small and large groups, but the effect is three times larger for the large banks. Note that the difference in the effect (large minus small) of 0.0257 is significant, with a t-statistic of 2.27.

3.7. Extended Time Period

In this section, we extend our time series to include more recent years, ending in 2017Q4. Our main sample excluded the post-2007 period for the following reasons: (i) wholesale funding dried up and retail deposits increased during the crisis due to money market stress and flight to quality, but this coincided with the decrease in the policy rate and would bias our estimates; (ii) the policy rate barely changed once it hit the zero lower bound; and (iii) the FDIC increased its insurance limit to $250,000 from $100,000 during the crisis, which changed the realm of retail deposits, but banks filing the FR Y-9C started to report the amount of time deposits beyond this new threshold only after 2017. Here, we overestimate the amount

Figure 4. (Color online) The Concentration of Wholesale Funding and the Federal Funds Rate



Notes. We plot the time series of the wholesale funding distribution in the U.S. banking sector and the federal funds rate quarterly from 1990 to 2014. The solid line plots the difference between the 90th percentile and 10th percentile in the distribution of the wholesale funding to retail deposits ratio (WSF to RD). The dashed line plots the federal funds rate.

Table 10. The Change in Wholesale Funding Reliance and the Federal Funds Rate by Previous Wholesale Funding Reliance Level

	Change in WSF to RD		
	All banks	Small banks	Large banks
Variables	(1)	(2)	(3)
Change in FFR ($t-1$ to t)	−0.025	−0.008	−0.152
	(−0.17)	(−0.06)	(−0.29)
Change in FFR ($t-2$ to $t-1$)	0.066	0.027	0.573
	(0.38)	(0.17)	(0.99)
Change in FFR ($t-3$ to $t-2$)	0.135	0.176	−0.233
	(0.66)	(0.90)	(−0.45)
Change in FFR ($t-4$ to $t-3$)	0.023	0.089	−0.594
	(0.17)	(0.69)	(−1.41)
Sum of effects	0.20**	0.28***	−0.41
	(2.08)	(3.13)	(−0.86)
WSF to RD ($t-4$)	−0.033***	−0.033***	−0.034***
	(−10.16)	(−9.58)	(−4.13)
WSF to RD ($t-4$) × *Change in FFR* ($t-1$ to t)	0.019***	0.018***	0.021
	(3.18)	(3.20)	(1.61)
WSF to RD ($t-4$) × *Change in FFR* ($t-2$ to $t-1$)	0.004	0.006	−0.005
	(0.64)	(1.04)	(−0.31)
WSF to RD ($t-4$) × *Change in FFR* ($t-3$ to $t-2$)	−0.006	−0.008	0.005
	(−0.83)	(−1.19)	(0.38)
WSF to RD ($t-4$) × *Change in FFR* ($t-4$ to $t-3$)	0.002	−0.001	0.020*
	(0.41)	(−0.23)	(1.75)
Sum of effects	0.02***	0.01***	0.04***
	(3.98)	(2.98)	(3.50)
Observations	129,492	123,038	6,454
R^2	0.066	0.062	0.136
Bank FEs and quarter-of-year FEs	Yes	Yes	Yes
Bank-level controls	Yes	Yes	Yes
Macro controls	Yes	Yes	Yes

Notes. We report the panel regression estimates of the relationship between the change in banks' wholesale funding reliance and the change in the FFR, by the level of banks' wholesale funding reliance in four quarters prior. We use bank-quarter observations from 1992 to 2006. We define large banks as banks with an asset size above the 95th percentile in the banks' asset distribution, and the rest as small banks. Column (1) reports the results with all banks, column (2) reports the results with small banks, and column (3) reports the result with large banks. The dependent variable is the change in banks' wholesale funding to retail deposits ratio (*Change in WSF to RD*) from the previous quarter. The independent variables include four lags of the change in the FFR, the level of four-quarter lagged *WSF to RD*, and their interactions. Other independent variables include bank-level controls (*RE Loan to Total Loan Ratio*, *CI Loan to Total Loan Ratio*, log *Assets*, *Capital Ratio*, *Bank-Level Total Loan Growth*, *Liquid Asset Ratio*, *Securitization*) and macro controls (*CP Spread*, *Term Premium*, *Aggregate-Level Total Loan Growth*). We use four-quarter-lagged bank characteristics and macro variables in our analysis. For brevity, we do not report the controls in the table. We also include bank fixed effects (FEs) and quarter-of-year fixed effects (for seasonality). We report the sums of the estimates of the lagged FFR and the interaction terms with the t-statistic of the sums. The table reports point estimates with t-statistics in parentheses. All standard errors are clustered at the year-quarter level.

*10% statistical significance; **5% statistical significance; ***1% statistical significance.

of wholesale funding and underestimate that of retail deposits starting in 2008Q4 by using the previous threshold to define large time deposits.

With these caveats in mind, we reestimate our major regressions reported in Tables 3, 4, 7, and 8 using the extended time period.[33] Our results are qualitatively similar although less significant. The only exception is the result for Table 7, where we compare banks with more senior depositors to those with fewer senior depositors. With the extended time series including the Great Recession, we do not observe the smaller negative correlation between retail deposits and the change in FFR for banks with a more senior deposit base. We suppose that this may be due to the flight-to-quality effect—if seniors had shifted more funds into the banking sector during the crisis because of their higher risk aversion, banks with more senior depositors would have experienced a larger increase in retail deposits during the crisis. This variation may offset the effect on which we focus.

4. Monetary Policy and Liquidity Regulations

In this section, we discuss how the introduction of new liquidity requirements affects the implications of monetary policy, based on our previous results on bank funding substitution.

4.1. Financial Stability

The recent crisis reignited the longstanding debate between leaning versus cleaning (see, e.g., White 2009, Blanchard et al. 2010, Mishkin 2011), which asks whether monetary policy should have an ex ante role in the accumulation of financial imbalances and systemic risks and what the role of macroprudential regulation should be (see, e.g., Freixas et al. 2015). However, this debate focuses more on the accumulation of *asset-side* risks during monetary *loosening*, implicitly assuming that monetary tightening would mitigate these vulnerabilities. In contrast, our results suggest that monetary policy could contribute to an accumulation of *liability-side* systemic vulnerability if central banks attempt to slow a credit boom using monetary *tightening* and banks then attempt to unwind the tightening effect.

Our analysis suggests that monetary tightening could increase the funding liquidity risks of the banking sector as a by-product; banks replace their stable retail deposits with runnable wholesale funding. In addition, as shown in the previous section, this substitution is more noticeable in larger banks, which could impose larger externalities (e.g., fire-sale spillovers) during a liquidity stress event, as well as in banks that are already exposed to greater liquidity risks and have a higher wholesale funding ratio.[34]

Note that macroprudential regulations, in particular, liquidity regulations, could effectively mitigate these financial imbalances in the system by imposing "taxes" on wholesale funding reliance. These regulations treat sticky funding (e.g., retail deposits) and unstable funding (e.g., wholesale funding) differently. For instance, the Basel III LCR (Bank for International Settlements 2013) imposes a runoff rate of 3% to 10% for retail deposits while assuming much higher runoff rates up to 100% for other wholesale funding sources. Thus, banks already borrowing heavily from wholesale funding markets and becoming large would not be able to implement funding substitution as freely as banks with low liquidity risks could, which limits the surge in liquidity risk.

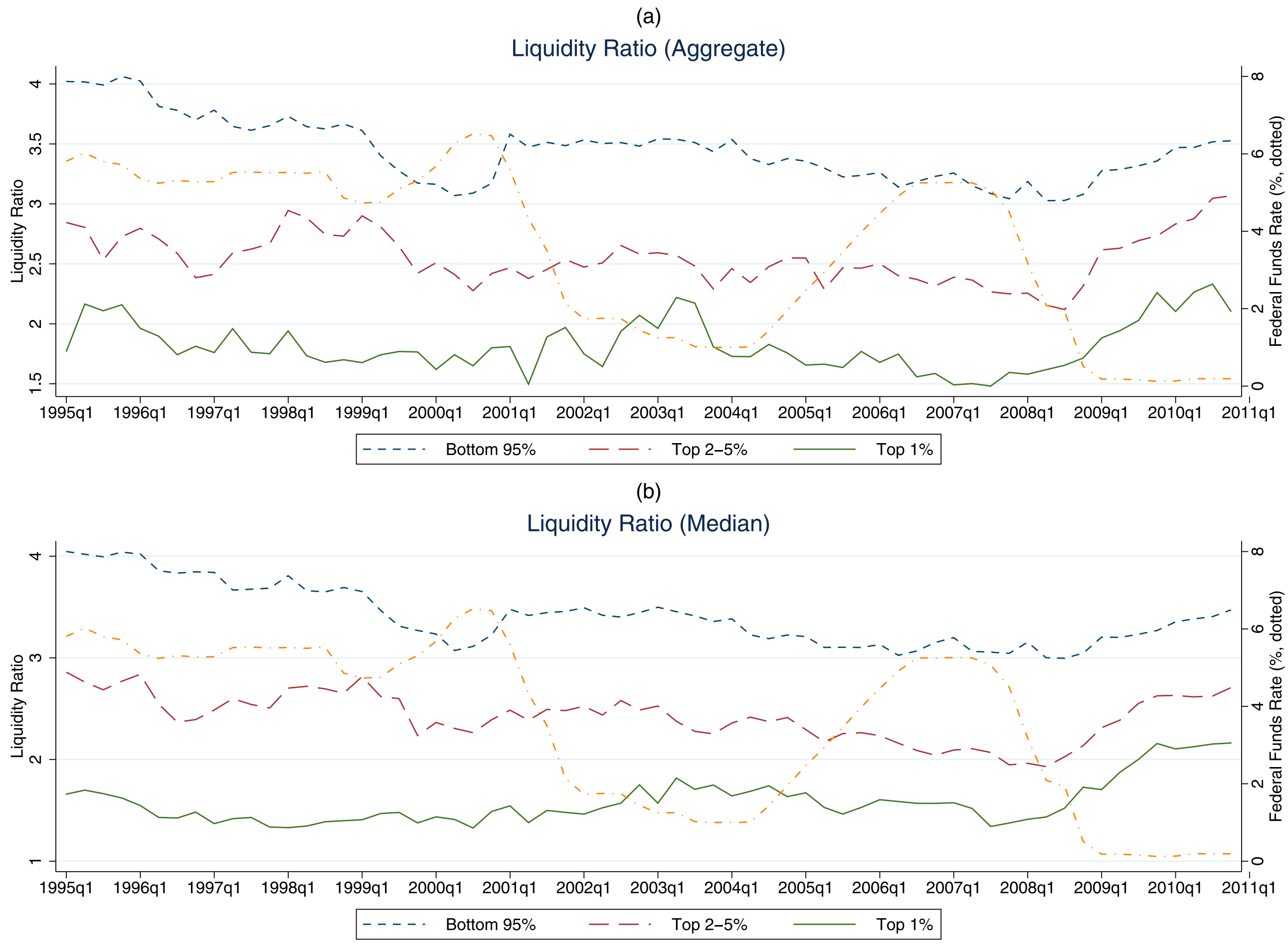
4.2. Liquidity Requirements and Monetary Policy Transmission

We next discuss how liquidity regulations would affect monetary policy transmission through the bank lending channel. In an economy with no liquidity regulation, banks could smooth their lending by reaching out to alternative funding sources when facing deposit outflows from monetary tightening (Romer and Romer 1990). The conventional bank lending channel literature finds that large banks, which tend to have better access to alternative funding, can mitigate the monetary policy shock more effectively than small banks (e.g., Kashyap and Stein 2000, Kishan and Opiela 2000, Williams 2016). As financial innovation has further reduced market frictions, more banks can mitigate the impact of monetary policy on their lending (Altunbas et al. 2009, Loutskina and Strahan 2009, Loutskina 2011). This raises the question of monetary transmission through the lending channel. However, this funding substitution might no longer be operative under liquidity requirements, particularly if the statutory liquidity ratio of a bank (e.g., LCR, NSFR) is close to the regulatory minimum.

As banks increase their wholesale funding to cope with monetary tightening, their LCRs decrease. The LCR could also decline during the tightening because central bank reserves, the most liquid assets, shrink through open-market operations (Keister and Bech 2012), and banks substitute for their liquid asset cushion with more illiquid loans (Kashyap and Stein 2000). This implies that monetary policy could affect bank lending more when regulatory liquidity requirements act as a binding constraint. Here, the bank would reduce its lending instead of engaging in funding substitution between retail deposits and wholesale funding or converting its liquid assets to illiquid loans. Furthermore, this mechanism would apply more to large banks if their statutory liquidity ratios were lower (Predictions 1 and 4 in Section 2).

To analyze the relationship between the statutory liquidity ratios, such as the LCR, and monetary policy, we construct a proxy for the LCR, denoted *Liquidity Ratio*, using the variables reported in the FR Y-9C.[35] This index is an approximation, at best, because it uses only publicly available data and excludes any contribution from derivative activities. Thus, its absolute value has less meaningful implications. Therefore, the exercise is intended to capture the approximate time-series variation and the cross-sectional differences. We then examine whether monetary tightening reduces the *Liquidity Ratio* and whether larger banks are more affected by liquidity regulations.

Figure 5. (Color online) Historical Trends of the Liquidity Ratio



Notes. We plot the time series of the *Liquidity Ratio* (our proxy for LCR) for three groups of bank size. We use the sample of BHCs in the FR Y9C quarterly from 1995 to 2010. Panel (a) reports the aggregate *Liquidity Ratio* by bank asset size. Following Kashyap and Stein (2000), the solid line plots the aggregate *Liquidity Ratio* of the banks in the top 1% of asset size, the longer-dashed line plots the aggregate *Liquidity Ratio* of the banks in the top 2%–5% of asset size, and the shorter-dashed line plots the aggregate *Liquidity Ratio* of the bottom 95% of banks in terms of asset size. The dotted dashed line plots the federal funds rate quarterly. Panel (b) reports the median *Liquidity Ratio* by bank asset size.

We first show that a negative relationship exists between bank size and the level of the *Liquidity Ratio*, confirming Prediction 1. Figure 5 compares the *Liquidity Ratio* for three asset size groups, as in the previous figures, the top 1%, top 2%–5%, and bottom 95%. Panel (a) reports the aggregate *Liquidity Ratio*, and panel (b) reports the median *Liquidity Ratio*. The graphs clearly show that larger banks have a lower *Liquidity Ratio*.

Table 11 presents panel regression results to examine the relationship among *Liquidity Ratio*, bank asset size, and monetary policy. We first estimate the regression using all banks completing the FR Y-9C in columns (1) to (4), and then limit the analysis to "noncommunity" banks with assets greater than $1 billion in columns (5) to (8). We previously found that banks with access to wholesale funding markets substitute their funding sources when the policy rate changes. Hence, the negative relationship between the policy rate change and LCR may be less pronounced for very small banks with little access to those markets, so we exclude them from our second regression.

In columns (1) and (5) of Table 11, we regress the level of the *Liquidity Ratio* on bank assets and year-quarter fixed effects. Confirming the patterns in the previous figures, we find a significant negative relationship that larger banks tend to have a lower *Liquidity Ratio*. This also coincides with our previous result of larger banks relying more on wholesale funding while holding fewer liquid assets. We then regress *Liquidity Ratio* on the four lags of *Changes in FFR*, as we did in the previous sections. We first add no bank or macroeconomic controls (columns (2) and (6)), then add bank controls (columns (3) and (7)), and finally include additional macro controls (columns (4) and (8)). We do not include *Liquid Asset Ratio*, *RE Loan to Total Loan Ratio*, or *CI Loan to Total Loan Ratio*

Table 11. Liquidity Ratio, Asset Size, and Monetary Policy

	Liquidity ratio							
	All banks				Banks above $1 billion in assets			
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Change in FFR ($t-1$ to t)		−0.096	−0.073	−0.128**		−0.047	−0.024	−0.079**
		(−0.88)	(−1.05)	(−2.39)		(−0.66)	(−0.47)	(−2.05)
Change in FFR ($t-2$ to $t-1$)		−0.078	−0.061	−0.075		−0.060	−0.048	−0.053
		(−0.65)	(−0.80)	(−1.22)		(−0.74)	(−0.83)	(−1.32)
Change in FFR ($t-3$ to $t-2$)		−0.025	−0.010	−0.019		−0.026	−0.008	−0.016
		(−0.23)	(−0.13)	(−0.39)		(−0.38)	(−0.14)	(−0.48)
Change in FFR ($t-4$ to $t-3$)		0.103	0.026	0.035		0.002	−0.014	0.010
		(1.00)	(0.38)	(0.77)		(0.04)	(−0.29)	(0.29)
Sum of effects		−0.10	−0.12*	−0.19***		−0.13*	−0.09**	−0.14***
		(−0.87)	(−1.74)	(−3.76)		(−1.87)	(−2.07)	(−4.44)
log *Assets* ($t-4$)	−0.288***		−0.448***	−0.431***	−0.344***		−0.350***	−0.346***
	(−44.16)		(−10.38)	(−8.36)	(−27.20)		(−9.70)	(−10.84)
Capital Ratio ($t-4$)			0.011**	0.011**			0.006	−0.001
			(2.28)	(2.26)			(1.21)	(−0.30)
Securitization ($t-4$)			−2.491***	−2.470***			−0.791*	−0.751**
			(−6.46)	(−8.79)			(−1.68)	(−2.21)
CP Spread ($t-4$)				−0.097				−0.118
				(−0.64)				(−1.42)
Term Premium ($t-4$)				0.145***				0.107***
				(4.68)				(5.38)
Observations	99,798	99,798	99,621	99,621	8,327	8,327	8,304	8,304
R^2	0.162	0.768	0.791	0.797	0.251	0.795	0.813	0.819
Fixed effects	Year-quarter	Bank	Bank	Bank	Year-quarter	Bank	Bank	Bank

Notes. We report the empirical analysis based on the sample of BHCs in the FR Y9C quarterly from 1995 to 2006. Columns (1)–(4) report the results using all banks. Column (1) reports the panel regression results of *Liquidity Ratio* on the lagged bank asset size. *Liquidity Ratio* is a proxy for the LCR, constructed using the variables reported in the FR Y-9C. See Online Appendix C for the construction. We include year-quarter fixed effects. Columns (2)–(4) report the panel regression results of *Liquidity Ratio* on the lagged changes in the federal funds rate. Column (2) includes bank fixed effects. Column (3) includes log *Assets*, *Capital Ratio*, *Securitization*, and bank fixed effects. Column (4) includes log *Assets*, *Capital Ratio*, *Securitization*, *CP Spread*, *Term Premium*, and bank fixed effects. Columns (5)–(8) report the results using the banks with asset size larger than $1 billion. We report the sum of the estimates of the lagged FFR and the *t*-statistics of the sum. The table reports point estimates with *t*-statistic in parentheses. All standard errors are clustered at the year-quarter level.

*10% statistical significance; **5% statistical significance; ***1% statistical significance.

because these are directly related to the construction of the dependent variable. Our estimates suggest that a 100-basis-point increase in the FFR leads to a decrease in the *Liquidity Ratio* of 9 to 19 percentage points after four quarters, with smaller *p*-values when we exclude the very small banks. This implies that the liquidity requirement may bind more during monetary tightening.

From these results and our previous empirical findings, we deduce an important implication of liquidity requirements for monetary policy transmission. As discussed in Section 3, larger banks engage in more funding substitution during tightening, but under the Basel III rules, they might not be able to do so because of the existence of the liquidity requirement. In this case, it would be the *large* banks whose lending is more affected by monetary tightening, which could generate a larger aggregate effect. This implication contrasts with the findings of the bank lending channel literature, in which monetary tightening mostly affects small banks' lending, with a nonsignificant aggregate effect. Macroprudential regulation could bolster monetary policy transmission in this respect, affecting aggregate credit through the supply side, on top of the demand effect from the interest rate channel.

5. Conclusion

This study analyzes the relationship between monetary policy and bank funding composition. Monetary tightening leads to a decline in retail deposits, and banks attempt to attract more wholesale funding to mitigate the impact on their lending. Because banks face varying degrees of financial frictions and, thus, different levels of access to wholesale funding markets, banks that rely more on wholesale funding, usually larger banks, increase their wholesale funding borrowing by more than those banks that use less wholesale funding. As a result, monetary tightening leads to an increased reliance and a greater concentration of wholesale funding in the banking sector. Hence, monetary tightening could contribute to systemic vulnerability on banks' liability side if banks actively attempt to reverse the deposit outflows by engaging in funding substitution. This would increase funding liquidity risks, especially for those systemic banks that are already large and exposed to more liquidity risks. Our analysis suggests that liquidity requirements could help mitigate the increase in this systemic risk by making funding substitution more costly. It also suggests that monetary policy transmission could become more pronounced by bolstering the bank lending channel under liquidity regulation. Monetary tightening could then affect the aggregate lending of the banking sector if large banks facing a binding liquidity requirement are forced to reduce their lending.

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Endnotes

[1] See, for example, Gorton and Metrick (2012), Copeland et al. (2014), and Krishnamurthy et al. (2014) on the risks of repo funding; Cornett et al. (2011), Ivashina and Scharfstein (2010), De Haas and Van Lelyveld (2014), and Dagher and Kazimov (2015) on wholesale funding reliance and bank lending during the 2007–2009 crisis; Irani and Meisenzahl (2017) on bank liquidity risks from wholesale funding reliance and secondary market liquidation; and Perignon et al. (2018) on wholesale funding dry-ups and bank fundamentals.

[2] We use this demographic structure as a measure of deposit supply elasticity, rather than as a measure of the level of deposit supply, as in Becker (2007) and Han et al. (2015). However, our model in Online Appendix A suggests that we would reach similar empirical predictions when assuming differential levels.

[3] See Section 3 for our variable definitions.

[4] This channel has been less pronounced in recent years. When the majority of deposits are not subject to reserve requirements, banks hold a substantial amount of excess reserves, and the Federal Reserve raises the policy rate by paying higher interest on excess reserves.

[5] Although some retail deposits bear a small amount of interest, their rates do not respond quickly to policy rate increases. See, for example, Hannan and Berger (1991), Hutchison and Pennacchi (1996), and Drechsler et al. (2017) on deposit rate upward stickiness as banks' optimal decision. In our model in Online Appendix A, we further provide two channels that result in a decrease in retail deposits through banks' optimal pricing: the noninterest costs of deposit issuance and rate-dependent deposit elasticities. Another rationale could come from the very short maturity of retail deposits: if a bank decides to raise its deposit rate to retain more deposits on the margin, it might also have to apply this higher rate to other existing depositors if it cannot price discriminate between the marginal depositors and other incumbent depositors, which significantly inflates the overall funding cost. Therefore, it could be cheaper for banks to seek alternative funding sources than to raise deposit rates in the event of marginal changes in the deposit supply.

[6] Historically, MMFs were created as a substitute for bank deposits in the 1970s, when deposit interest payments were restricted by Regulation Q. MMFs began to grow rapidly in the 1990s. The aggregate asset size of the MMFs in the United States grew from approximately $0.4 trillion in 1990 to almost $2 trillion by the end of 2000. Note that the recent regulatory reforms for MMFs may have reduced this substitutability by requiring institutional prime and municipal MMFs to adopt the floating net asset value (NAV), and all prime and municipal MMFs to introduce a system of gates and fees on redemptions.

[7] Some of these retail deposit outflows to MMFs reenter the banking sector as wholesale funding, because MMFs are one of the main suppliers of bank wholesale funding. The recent MMF reforms may constrain this channel because investors responded by shifting their assets from prime funds with floating NAV to government funds that still adopt fixed NAV. Government MMFs, however, are not allowed to fund private banks directly.

[8] Because our focus is banks' short-term funding adjustments, we do not consider equity issuance, which comes with high fixed costs (for a theoretical model, see, e.g., Myers and Majluf 1984; for empirical evidence, see Baron 2018). See also Park and Pennacchi (2008) for a model of banks' longer-term decision between deposits and equity.

[9] We use the branch-level deposits from the Summary of Deposits to identify "single-branch" banks. Our main results are robust to other sample criteria, that is, banks with an average asset size of more than $500 million, or banks including single-branch banks. See Online Appendix B, Section B.4.

[10] Here, we assume that all nonforeign checkable deposits are retail deposits, although some of them might actually come from wholesale depositors. In Online Appendix B, Section B.2, we show that our results are robust when we adopt the narrower definition of retail deposits as the sum of interest-bearing demand deposits, MMDA and savings deposits, and small time deposits (less than $100,000).

[11] We aggregate asset-weighted top-holder-level capital ratios from the bank-level capital ratios if the top holder does not file an FR Y-9C but has call report item RSSD9348 (RSSD ID of the top holder) populated.

[12] In our analysis, we drop years after the recent financial crisis because of the lack of variation in the FFR. Note, however, that the

reliance on wholesale funding still decreases significantly during the quantitative easing periods. See Section 3.7 for an analysis with an extended sample period ending in 2017Q4.

[13] See Figure B.1, in Online Appendix B, which separates the long-term trend using the Hodrick–Prescott filter from the variation around the trend.

[14] In Online Appendix B, Section B.3, we report results that decompose *Change in FFR* into *Surprise Change* and *Expected Change* following Kuttner (2001). Because depositors have few incentives to respond preemptively in anticipation of future rate changes, we predict that *expected* changes in the policy rate should still result in the bank funding responses that we predict. Nonetheless, this additional analysis should enable us to better control for macroeconomic news that coincides with a rate change by isolating the unexpected changes.

[15] Our empirical results are robust when we scale them to total assets instead.

[16] Throughout this paper, we report *t*-statistics with standard errors clustered by year-quarter. We report these conservative results based on year-quarter clustering, but the results based on bank-level clustering are stronger (and available from the authors upon request).

[17] In our alternative specification, we also include *CP Spread* × *Large Bank* to control for the differential flight-to-quality effect by bank size, and our results remain the same. Our results also remain unchanged when we include year-quarter fixed effects.

[18] Our model in Online Appendix A also suggests that banks with a very high cost of wholesale funding attempt to retain more retail deposits during monetary tightening than banks with easier access to wholesale funding markets; moreover, they pay higher interest to their retail depositors to attract more deposits. In Online Appendix B, Section B.1, we additionally test whether banks with a higher retail (or wholesale) deposit rate have retail deposits whose quantities are less sensitive to changes in the policy rate. We confirm such a relationship.

[19] We presents summary statistics comparing local banks and nonlocal banks in Online Appendix B, Table B.7.

[20] See Online Appendix B, Table B.8, for the results.

[21] Note that our identification strategy still assumes identical loan demand responses to monetary policy across regions. We later discuss this assumption in greater detail.

[22] Note that we have the same prediction across regions, that is, a greater increase in wholesale funding reliance for banks facing nonsenior depositors in response to monetary tightening, when we instead assume different levels of deposit supply without relying on the differential deposit supply elasticities. In this case, the regions with more seniors can be interpreted as loan-poor, deposit-rich markets, whereas those with more nonseniors can be interpreted as loan-rich, deposit-poor markets (Becker 2007, Han et al. 2015, Pennacchi 2019). Banks in the regions with more nonseniors face greater loan demand relative to their retail deposit supply, and having relatively fewer retail deposits, they exploit most of the available local retail deposits to tap wholesale funding at the margin. On the other hand, banks in regions with more seniors face greater retail deposit supply relative to loan demand, and having more retail deposits, these banks do not need to attract "flighty" depositors and invest in liquid securities at the margin. Facing an increase in the policy rate and, thus, a decline in retail deposits, banks with nonsenior depositors, whose marginal funding is wholesale funding and have less securities holdings, would lose more retail deposits (as some of depositors are very flighty) and increase their wholesale funding more compared with those with senior depositors. Please see the discussion in Online Appendix A on the two types of corner solutions in our model. We thank George Pennacchi for this suggestion.

[23] Kiser (2002a) finds that 41% of households with an age greater than 65 as of 1999 remained with their first ever bank, whereas only 24% and 27% did so for the age groups 35–49 and 49–65, respectively. She claims that this suggests a cohort effect rather than an age effect in bank switching behavior.

[24] See page 49 of https://www.ici.org/pdf/2006_factbook.pdf.

[25] Although savers' willingness to take investment risk tends to decline as they age, we do not make a judgment on whether the low risk appetites and higher switching costs among the seniors in our sample period reflect an age effect or a cohort effect (see Kiser 2002a), which is not necessary for our purpose. Nonetheless, a more recent survey seems to support the latter. The Investment Company Institute (2018), based on a 2017 survey, finds that a mere 19% of mutual fund owners in the baby boomer generation are willing to take only below-average risks or no risks at all, which is comparable to those in Generation X (19%) or the millennial generation (18%, born between 1981 and 2004). This ratio is 32% for those in the silent and G.I. generations. Hence, baby boomers tend to have higher risk tolerance than their seniors, even after retirement.

[26] Note that this comparison also addresses the concern regarding a confounding effect driven by investors' flight to quality. Because our senior group is more risk averse, as discussed above, banks with a deposit base of more seniors would experience a greater inflow of retail deposits during the flight-to-quality event. If this effect drove the negative correlation between retail deposit growth and the policy rate change, that correlation should be more pronounced for banks with more senior depositors. However, we predict the opposite.

[27] Note that two local banks operating in the same MSA may face different levels of senior population. We construct our measure from a more granular county-level population composition and average them using the bank's county-level deposit weights.

[28] Our results are robust when we exclude deposits in banks' headquarters. See Online Appendix B, Section B.4, for the results and discussions.

[29] When banks originate new loans, they simultaneously increase deposits on the liability side. Therefore, the greater retail deposit decrease experienced by banks with a younger deposit base may mechanically reflect a greater decrease in local loan demand in response to monetary tightening.

[30] For a robustness check, we reestimate Tables 7 and 8 (which use only the local banks) by including all banks. Table B.9 in Online Appendix B reports the regression results, and we find qualitatively similar, albeit less statistically significant, results.

[31] We present the summary statistics comparing "young" MSAs and "old" MSAs in Online Appendix B, Table B.7.

[32] The results are available from the authors upon request.

[33] We presents the estimates for the coefficients of interest in Online Appendix B, Table B.6.

[34] Although bank funding from wholesale investors resulted in a severe funding shock during the 2008 crisis, it can also help banks manage their liquidity risks. As discussed above, funds from wholesale investors flow into deposit-insured banks during flight-to-quality episodes (Gatev and Strahan 2006, Pennacchi 2006), and larger banks receive greater inflows of such funds. Banks can use them to meet the drawdown requests of their commitments, instead of hoarding additional liquid assets as a buffer (Kashyap et al. 2002).

[35] See Online Appendix C for the construction. This variable starts in 1995, because the FR Y-9C form does not provide detailed information on the types of securities before 1994, which is necessary to calculate the measure consistently.

References

Acharya V, Mora N (2015) A crisis of banks as liquidity providers. *J. Finance* 70(1):1–43.

Adrian T, Shin HS (2008) Financial intermediaries, financial stability, and monetary policy. Staff Report 346, Federal Reserve Bank of New York, New York.

Adrian T, Shin HS (2009) Money, liquidity, and monetary policy. *Amer. Econom. Rev.* 99(2):600–605.

Adrian T, Shin HS (2010) Financial intermediaries and monetary economics. Friedman BM, Woodford M, eds. *Handbook of Monetary Economics* (Elsevier, Amsterdam), 601–650.

Allen F, Gale D (2004) Asset price bubbles and monetary policy. Desai M, Said Y, eds. *Global Governance and Financial Crises* (Routledge, Abingdon, UK), 19–42.

Altunbas Y, Gambacorta L, Marques-Ibanez D (2009) Securitisation and the bank lending channel. *Eur. Econom. Rev.* 53(8):996–1009.

Amel DF, Hannan TH (1999) Establishing banking market definitions through estimation of residual deposit supply equations. *J. Banking Finance* 23(11):1667–1690.

Bank for International Settlements (2013) Basel III: The liquidity coverage ratio and liquidity risk monitoring tools. Report, Bank for International Settlements, Basel, Switzerland.

Baron M (2018) Countercyclical bank equity issuance. Working paper, Cornell University, Ithaca, NY.

Baumol WJ (1952) The transactions demand for cash: An inventory theoretic approach. *Quart. J. Econom.* 66(4):545–556.

Becker B (2007) Geographical segmentation of US capital markets. *J. Financial Econom.* 85(1):151–178.

Berlin M, Mester LJ (1999) Deposits and relationship lending. *Rev. Financial Stud.* 12(3):579–607.

Bernanke BS, Blinder AS (1988) Credit, money, and aggregate demand. *Amer. Econom. Rev.* 78(2):435–439.

Bernanke BS, Blinder AS (1992) The federal funds rate and the channels of monetary transmission. *Amer. Econom. Rev.* 82(4): 901–921.

Bianchi J, Bigio S (2014) Banks, liquidity management and monetary policy. Working paper, Federal Reserve Bank of Minneapolis, Minneapolis.

Blanchard O, Dell'Ariccia G, Mauro P (2010) Rethinking macroeconomic policy. *J. Money Credit Banking* 42(1):199–215.

Borio C, Zhu H (2012) Capital regulation, risk-taking and monetary policy: A missing link in the transmission mechanism? *J. Financial Stability* 8(4):236–251.

Campello M (2002) Internal capital markets in financial conglomerates: Evidence from small bank responses to monetary policy. *J. Finance* 57(6):2773–2805.

Choi DB, Velasquez U (2016) Hidden cost of better bank services: carefree depositors in riskier banks? Working paper, Dong Beom Choi, Seoul National University, Seoul, Korea.

Copeland A, Martin A, Walker M (2014) Repo runs: Evidence from the tri-party repo market. *J. Finance* 69(6):2343–2380.

Cornett MM, McNutt JJ, Strahan PE, Tehranian H (2011) Liquidity risk management and credit supply in the financial crisis. *J. Financial Econom.* 101(2):297–312.

Dagher J, Kazimov K (2015) Banks' liability structure and mortgage lending during the financial crisis. *J. Financial Econom.* 116(3): 565–582.

De Haas R, Van Lelyveld I (2014) Multinational banks and the global financial crisis: Weathering the perfect storm? *J. Money Credit Banking* 46(S1):333–364.

Dell'Ariccia G, Laeven L, Marquez R (2014) Real interest rates, leverage and bank risk-taking. *J. Econom. Theory* 149(January):65–99.

Dell'Ariccia G, Laeven L, Suarez G (2017) Bank leverage and monetary policy's risk-taking channel: Evidence from the United States. *J. Finance* 72(2):613–654.

De Nicolò G, Dell'Ariccia G, Laeven L, Valencia F (2010) Monetary policy and bank risk-taking. Working paper, Johns Hopkins University, Baltimore.

DeYoung R, Rice T (2004) Noninterest income and financial performance at US commercial banks. *Financial Rev.* 39(1):101–127.

Di Maggio M, Kermani A, Keys BJ, Piskorski T, Ramcharan R, Seru A, Yao V (2017) Interest rate pass-through: Mortgage rates, household consumption, and voluntary deleveraging. *Amer. Econom. Rev.* 107(11):3550–3588.

Diamond DW (1984) Financial intermediation and delegated monitoring. *Rev. Econom. Stud.* 51(3):393–414.

Drechsler I, Savov A, Schnabl P (2017) The deposits channel of monetary policy. *Quart. J. Econom.* 132(4):1819–1876.

Egan M, Hortaçsu A, Matvos G (2017) Deposit competition and financial fragility: Evidence from the US banking sector. *Amer. Econom. Rev.* 107(1):169–216.

Federal Financial Institutions Examination Council (2019) Commercial banks in the U.S. [USNUM]. Accessed September 11, 2019, https://fred.stlouisfed.org/series/USNUM.

Flannery MJ, James CM (1984) The effect of interest rate changes on the common stock returns of financial institutions. *J. Finance* 39(4):1141–1153.

Freixas X, Laeven L, Peydró JL (2015) *Systemic Risk, Crises and Macroprudential Policy* (MIT Press, Cambridge, MA).

Gatev E, Strahan PE (2006) Banks' advantage in hedging liquidity risk: Theory and evidence from the commercial paper market. *J. Finance* 61(2):867–892.

Gorton G, Metrick A (2012) Securitised banking and the run on repo. *J. Financial Econom.* 104(3):425–451.

Hahm JH, Shin HS, Shin K (2013) Noncore bank liabilities and financial vulnerability. *J. Money Credit Banking* 45(S1):3–36.

Han J, Park K, Pennacchi G (2015) Corporate taxes and securitization. *J. Finance* 70(3):1287–1321.

Hannan TH, Berger AN (1991) The rigidity of prices: evidence from the banking industry. *Amer. Econom. Rev.* 81(4):938–945.

Hutchison DE, Pennacchi GG (1996) Measuring rents and interest rate risk in imperfect financial markets: The case of retail bank deposits. *J. Financial Quant. Anal.* 31(3):399–417.

Investment Company Institute (2006) Investment company fact book. Accessed September 11, 2019, https://www.ici.org/pdf/2006_factbook.pdf.

Investment Company Institute (2010) Investment company fact book. Accessed September 11, 2019, https://www.ici.org/pdf/2010_factbook.pdf.

Investment Company Institute (2018) Investment company fact book. Accessed September 11, 2019, http://www.icifactbook.org/ch7/18_fb_ch7.

Ioannidou V, Ongena S, PeydróJL (2009) Monetary policy, risk-taking and pricing: Evidence from a quasi-natural experiment. *Rev. Finance* 19(1):95–144.

Irani RM, Meisenzahl RR (2017) Loan sales and bank liquidity risk management: evidence from a U.S. credit register. *Rev. Financial Stud.* 30(10):3455–3501.

Ivashina V, Scharfstein D (2010) Bank lending during the financial crisis of 2008. *J. Financial Econom.* 97(3):319–338.

Jiménez G, Ongena S, Peydró JL, Saurina J (2014) Hazardous times for monetary policy: What do twenty-three million bank loans say about the effects of monetary policy on credit risk-taking? *Econometrica* 82(2):463–505.

Kashyap AK, Stein JC (1995) The impact of monetary policy on bank balance sheets. *Carnegie-Rochester Conf. Ser. Public Policy* 42(June): 151–195.

Kashyap AK, Stein JC (2000) What do a million observations on banks say about the transmission of monetary policy? *Amer. Econom. Rev.* 90(3):407–428.

Kashyap AK, Rajan R, Stein JC (2002) Banks as liquidity providers: An explanation for the coexistence of lending and deposit-taking. *J. Finance* 57(1):33–73.

Kashyap AK, Tsomocos DP, Vardoulakis AP (2014) How does macroprudential regulation change bank credit supply? NBER

Working Paper No. 20165, National Bureau of Economic Research, Cambridge, MA.

Keister T, Bech ML (2012) On the liquidity coverage ratio and monetary policy implementation. *BIS Quart. Rev.* 2012(December): 49–61.

Kiser EK (2002a) Household switching behavior at depository institutions: Evidence from survey data. *Antitrust Bull.* 47(4): 619–640.

Kiser EK (2002b) Predicting household switching behavior and switching costs at depository institutions. *Rev. Indust. Organ.* 20(4):349–365.

Kishan RP, Opiela TP (2000) Bank size, bank capital, and the bank lending channel. *J. Money Credit Banking* 32(1):121–141.

Krishnamurthy A, Nagel S, Orlov D (2014) Sizing up repo. *J. Finance* 69(6):2381–2417.

Kuttner KN (2001) Monetary policy surprises and interest rates: Evidence from the Fed funds future market. *J. Monetary Econom.* 47(3):523–544.

Landier A, Sraer D, Thesmar D (2015) The risk-shifting hypothesis: Evidence from subprime originations. Working paper, HEC Paris, Paris.

Lorenzoni G (2008) Inefficient credit booms. *Rev. Econom. Stud.* 75(3): 809–833.

Loutskina E (2011) The role of securitization in bank liquidity and funding management. *J. Financial Econom.* 100(3):663–684.

Loutskina E, Strahan PE (2009) Securitization and the declining impact of bank finance on loan supply: Evidence from mortgage originations. *J. Finance* 64(2):861–889.

Maddaloni A, Peydró JL (2011) Bank risk-taking, securitization, supervision, and low interest rates: Evidence from the Euro area and U.S. lending standards. *Rev. Financial Stud.* 24(6):2121–2165.

Maddaloni A, Peydro JL (2013) Monetary policy, macroprudential policy and banking stability: evidence from the euro area. *Internat J. Central Banking* 9(1):121–169.

Mishkin FS (2011) Monetary policy strategy: Lessons from the crisis. Working paper, Columbia University, New York.

Myers SC, Majluf NS (1984) Corporate financing and investment decisions when firms have information that investors do not have. *J. Financial Econom.* 13(2):187–221.

Nagel S (2016) The liquidity premium of near-money assets. *Quart. J. Econom.* 131(4):1927–1971.

Park K, Pennacchi G (2008) Harming depositors and helping borrowers: The disparate impact of bank consolidation. *Rev. Financial Stud.* 22(1):1–40.

Peek J, Rosengren ES (1995) Bank lending and the transmission of monetary policy. *Proc. Federal Reserve Bank Boston Conf. Ser.*, vol. 39 (Federal Reserve Bank of Boston, Boston), 47–68.

Pennacchi G (2006) Deposit insurance, bank regulation, and financial system risks. *J. Monetary Econom.* 53(1):1–30.

Pennacchi GG (2019) Banks, taxes, and nonbank competition. *J. Financial Services Res.* 55(1):1–30.

Perignon C, Thesmar D, Vuillemey G (2018) Wholesale funding dry-ups. *J. Finance* 73(2):575–617.

Romer CD, Romer DH (1990) New evidence on the monetary transmission mechanism. *Brookings Papers Econom. Activity* 1990(1): 149–198.

Shin HS (2009) Reflections on Northern Rock: The bank run that heralded the global financial crisis. *J. Econom. Perspect.* 23(1): 101–120.

Stein J (2012) Monetary policy as financial-stability regulation. *Quart. J. Econom.* 127(1):57–95.

Stein JC (1998) An adverse-selection model of bank asset and liability management with implications for the transmission of monetary policy. *RAND J. Econom.* 29(3):466–486.

Strauss W, Howe N (1992) *Generations: The History of America's Future, 1584 to 2069* (HarperCollins, New York).

Tobin J (1956) The interest-elasticity of transactions demand for cash. *Rev. Econom. Statist.* 38(3):241–247.

White WR (2009) Should monetary policy "lean or clean"? Working Paper 34, Federal Reserve Bank of Dallas, Dallas.

Williams E (2016) Monetary policy and funding structure of banks. Working paper, Harvard Business School, Boston.

Xiao K (2017) Shadow banks, deposit competition, and monetary policy. Working paper, Columbia University, New York.