# 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 retail deposit supply due to, for example, a decrease in bank reserves or in money demand, banks try to substitute the deposit outflows with more wholesale funding in order to mitigate the policy impact on their lending. Banks have varying degrees of accessibility to wholesale funding sources because of financial frictions, and those banks that are large or that have a greater reliance on wholesale funding increase their wholesale funding more. As a result, monetary tightening increases both the reliance on and the concentration of wholesale funding within the banking sector, indicating that monetary tightening could increase systemic risk. Our findings also suggest that introducing liquidity requirements can bolster monetary policy transmission through the bank lending channel by limiting the funding substitution of large banks.

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# 1. Introduction

The recent financial crisis clearly showed the risks of a short-term wholesale funding dependency in banks, critically increasing funding liquidity risks during the market disruption. In response, 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. While previous studies have analyzed the risks of the reliance on wholesale funding during the crisis,[1] it remains an open question as to what contributed to the rapid buildup of the banking sector's reliance on wholesale funding running up to the crisis, as well as how the new liquidity regulations would interact with existing policy measures, in particular, monetary policy.

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 buildup of banking sectors' reliance on wholesale funding, as well as systemic imbalances, that is, the distribution of the reliance on wholesale funding becomes more concentrated among heavy users or large banks. This implies that a financial system could become more vulnerable during monetary tightening in terms of funding liquidity risks and potential spillover effects (e.g., fire-sale externalities that are increasing in the bank asset size). 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

[1] See, e.g., 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 the wholesale funding reliance and bank lending during the 2007–09 crisis; Irani and Meisenzahl (2015) on the bank liquidity risks from the wholesale funding reliance and secondary market liquidation; and Perignon et al. (2016) on wholesale funding dry-ups and bank fundamentals.

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 are cheaper in terms of funding costs (Berlin and Mester (1999), DeYoung and Rice (2004)), have lower interest rate-elasticity (Amel and Hannan (1999)) owing to transactional or storage (i.e., "monetary") purposes of depositors, and are more "sticky" with regard to funding liquidity risks and sensitivity to financial markets 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 markets when they wish to expand their lending.

We first discuss the relationship between changes in monetary policy stances and the growth of wholesale funding reliance in the banking sector, where we measure the wholesale funding reliance of a bank as the ratio of total wholesale funding to retail deposits. Previous studies widely 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, and by raising the opportunity cost of holding such "bank money," which pays upward-sticky interest, if any at all (Hannan and Berger (1991), Hutchison and Pennacchi (1996), Drechsler et al. (2015)). Facing the deposit outflows, banks increase their reliance on alternative funding sources, such as wholesale funding, in order to smooth their lending. Using quarterly panel data from the Consolidated Financial Statements for Holding Companies ("FR-Y9C") 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. Monetary tightening does decrease banks' retail deposits and increase wholesale funding.

Next, we analyze the cross-sectional implications of this funding substitution during monetary tightening. Using a simple model, we argue that banks facing fewer financial frictions in the wholesale funding market, in equilibrium, choose to use more wholesale funding and become larger. In response to monetary tightening, which causes retail deposit outflows to squeeze lending, the banks increase their wholesale funding until the marginal cost of the funding is equal to the marginal product from lending. This implies that banks that are already large and sit on more wholesale funding add more wholesale funding, because they face a less elastic supply curve (i.e., the funding cost increases less rapidly as they increase their wholesale borrowing) due to the fewer financial frictions. As a result, the overall reliance on wholesale funding of the banking sector increases, and the increase is more pronounced in larger banks. The cross-sectional difference of the wholesale funding reliance would also increase rapidly during monetary tightening, because the heavier wholesale borrowers would add more wholesale borrowing. Our empirical analysis supports this prediction. When the policy rate increases, the funding substitution is more active for banks with greater assets, and banks with a greater reliance on wholesale funding experience larger changes in their reliance. Thus, wholesale funding in the financial system become more concentrated among such banks during monetary tightening.

In addition to the change in bank funding composition, our model indicates that banks with more active funding substitution would be less affected by the lending channel. Defining the sensitivity of funding substitution to monetary policy as the correlation between the change in the federal funds rate and the change in wholesale funding reliance, we find that lending for a bank with a higher funding substitution sensitivity fluctuates less as the monetary policy stance changes.

Our empirical specifications, regressing bank-level balance sheet adjustments on changes in the monetary policy stance, could have an identification problem if our regression confounds the changes in bank loan demand. In order to mitigate this problem, we incorporate various controls that reflect loan demand in our main specification, including both macro and bank-level variables. We also implement a robustness check that limits our sample to "local" banks that operate predominantly within a single MSA, with MSA-level controls reflecting local demand.

In addition, we take advantage of demographic variations (among "senior" and "non-senior" depositors) across regions. We argue that the deposit supply of seniors, who should use bank deposit accounts primarily for "storage" purposes, would be less sensitive to a change in the policy rate than that of non-seniors, who should have more saving or "investment" incentives.[2] Therefore, all else being equal, banks facing a younger deposit base should experience greater retail deposit outflows during monetary tightening and, thus, increase their wholesale funding more. We estimate the fraction of seniors a local bank would face in local markets using the FDIC Summary of Deposits and Census, and verify that our prediction holds using the bank-level depositor demographic variable.

We furthermore compare large and small local banks within the age demographic groups, based on the demographic variations across regions, to support the previous argument. Here, we can identify more clearly whether banks facing a young deposit base have more *willingness* to reach out to wholesale funding, because of greater funding outflows, rather than responding *passively* to the demand change. When examining the scale of the funding substitution across banks, we should observe greater cross-sectional differences by asset size, if these banks are more willing to borrow but are financially constrained. However, we should see smaller differences if the greater retail deposit decrease is caused by a greater decline in local demand—financial frictions would then matter less in this case. We find that large local banks with a younger deposit-base engage in more active funding substitution than their smaller counterparts. However, this is not the case for banks with an older deposit-base. Thus, this result supports the effect of monetary policy on retail deposit supply and the funding composition response, rather than the effect through the local demand change.

This relationship between the bank funding composition and monetary policy suggests several novel policy implications. First, systemic vulnerability could increase when central banks try to contain excessive credit growth by implementing monetary tightening. In their attempt to unwind the tightening effect by the lending channel, banks might increase their

[2] We use this demographic structure as a measure of the deposit supply sensitivity to monetary policy changes, instead of as a measure of the deposit supply level, as in Becker (2007), and Han et al. (2015). Vintage analysis is widely used in practice to model depositor behavior for interest rate risk (IRR) management, which indicates that decay rate goes down as the age (tenure) of the account increases.

reliance on highly runnable funding sources. This is more pronounced in "systemic" banks, which are larger and more exposed to liquidity risks, amplifying potential externalities on the entire system. In this case, the liquidity requirements could promote financial stability by imposing additional costs on the substitution of retail deposits with wholesale funding, which would prevent the surge in wholesale funding reliance and funding liquidity risks. Therefore, our study provides a novel perspective on the importance of the interaction between monetary policy and macroprudential regulations.

Furthermore, our results suggest that monetary policy could have a more pronounced effect on real output through a bolstered bank lending channel when combined with liquidity regulation. Since regulatory liquidity requirements are more binding for large banks, which usually rely more on wholesale funding, and thus, have a lower LCR, the implicit substitution cost of the two funding sources would be higher for large banks. This contrasts with the findings in the bank lending literature, in which large banks can easily smooth their lending through better accessibility to alternative funding sources (Kashyap and Stein (2000), Kishan and Opiela (2000)), mitigating any *aggregate* effect through the lending channel (Romer and Romer (1990)). Since large banks with binding liquidity requirements might need to reduce their lending in response to monetary tightening, this could decrease the aggregate bank credit. In order to validate this argument, we build a proxy for the LCR ("Liquidity Ratio") based on publicly available data (FR-Y9C). Our analysis indicates that, historically, (i) larger banks have lower liquidity ratios, and (ii) changes in the liquidity ratio are negatively associated with federal fund rate changes. In summary, liquidity requirements could be more binding during monetary tightening, particularly for large banks.

**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 focus on the asset side. Instead, we focus on the liability side with novel predictions. A recent paper by Drechsler et al. (2015) also examines the liability side, and proposes "deposit channel" of monetary policy focusing on banks' deposit pricing behaviors across different markets and their implication on monetary transmission, while our paper focuses on the effect of monetary policy on the bank funding composition across heterogeneous banks as well as the implication on the interaction between monetary policy and liquidity regulation.

Previous studies examine the risks for banks of wholesale funding, particularly the impact of wholesale funding reliance during financial crises (see, e.g., Shin (2009); Gorton and Metrick (2012); Copeland et al. (2014); Krishnamurthy et al. (2014); Cornett et al. (2011); Ivashina and Scharfstein (2010); De Haas and Van Lelyveld (2014); Dagher and Kazimov (2015); Irani and Meisenzahl (2015)). 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. (2015) examine the substitution between core and non-core funding during bank stress when wholesale funding flows out, and Hahm et al. (2013) study the relation between non-core funding reliance and financial stability.

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

The remainder of this paper is organized as follows. Section 2 discusses our theoretical argument and develops our empirical hypotheses. Section 3 explains our data and presents the empirical results. Section 4 discusses the implications of the interaction between monetary policy and liquidity regulation, based on our results. Finally, Section 5 concludes the paper.

# 2. Theory

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 of total checkable deposits[3] from the Federal Reserve Board's Money Stock Measures data and the federal funds rates. There exists a clear negative relationship between the two time series; checkable deposits in the banking sector tend to decrease during monetary tightening when the federal funds rate is increasing. In our model, we assume this negative relationship between the retail deposit supply and the policy rate as given exogenously, without attempting to explain the mechanism, which is widely documented in the literature (e.g., Bernanke and Blinder 1992; Kashyap and Stein 1995). Here, we briefly enumerate some of the channels

[3]This is a proxy for the retail deposits. Our definition of retail deposits is more comprehensive, including small time deposits. See Section 3 for our variable definitions.

through which monetary tightening drains retail deposits from the banking sector.

**1. Decrease in central bank reserves** Monetary tightening reduces the central bank reserves through open market operations. This limits the amount of reservable deposits (mostly retail deposits) that banks can issue, owing to the reserve requirement or liquidity concerns, and leads to less money creation by banks (see, e.g., Bernanke and Blinder (1992), Kashyap and Stein (1995), and Bianchi and Bigio (2014)).

**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,[4] which shifts the supply curve of retail deposits to the banking sector upward (Bernanke and Blinder (1988)).

**3. Substitution to alternative money-like assets (e.g., MMFs)** The previous channel focuses on switching from a money-like asset to more illiquid non-money assets (a decrease in money demand). In addition, financial innovation has introduced alternative money-like assets, which led to a substitution between different "private monies" (see, e.g., Nagel (2016)). 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

[4]Though some retail deposits bear small amount of interests, their rates do not respond quickly to monetary tightening. See, e.g., Hannan and Berger (1991), Hutchison and Pennacchi (1996), and Drechsler et al. (2015) on deposit rate upward stickiness. One rationale for this upward stickiness 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 would have to apply this higher rate to all interest bearing (maturing, or with no maturity) deposits, which significantly inflates the overall funding cost. Therefore, it could be cheaper for the banks to reach out to alternative funding sources than to raise the deposit rates, in the event of marginal changes in the deposit supply.

deposits.[5] Panel B of Figure 1 shows a negative relationship between MMF asset growth and checkable deposit growth, especially after the 1990s, when MMFs became popular. Because MMFs offer more market-competitive yields than do retail deposits, the yield spread between MMFs and bank deposits increases when the policy rate increases. This creates a substitution within money-like assets; funds are reallocated from retail deposits to MMFs during tightening, shifting the supply curve of retail deposits to the banking sector upward.[6]

## 2.2. Model: Bank funding and liquidity implications

We build a simple static model to solve for the optimal bank portfolio problem, given a policy rate. We then analyze the bank responses to deposit outflows caused by monetary tightening, and develop empirical hypotheses. Our interests lie in the funding composition of banks (i.e., retail versus wholesale funding), as well as in the liquidity ratios of banks that measure the liquidity mismatch of their balance sheets (e.g., LCR).

We consider two risk-neutral banks, Bank 1 and Bank 2, who face identical functional forms of retail deposit supply and loan demand, for simplicity. Given a loan demand schedule, a bank finances its assets from two sources of funding,[7] retail deposits and wholesale funding. We assume that retail deposits only reflect the money demand of depositors and are non-interest bearing,[8] and that their cost is negligible for the banks. Furthermore, the supply of retail deposits banks face is exogenous and decreasing in the policy rate $r$, as discussed in the previous section, and is denoted by $M(r)$ with $M'(r) < 0$, which is identical across the two banks. Let $M_i$ be the amount of retail deposits that Bank $i$ (where $i = 1, 2$) chooses to attract.

[5]Historically, MMFs were created as a substitute for bank deposits in the 1970s when deposit interest payments were restricted by Regulation Q, and started to grow rapidly in the 1990s. The aggregate asset size of the MMFs in the United States grew from around 0.4 trillion in 1990 to almost 2 trillion by the end of 2000.

[6]Note that some of these retail deposit outflows to MMFs re-enter the banking sector as wholesale funding, because MMFs are one of the main suppliers of bank wholesale funding.

[7]We do not consider equity issuances, for simplicity.

[8]Alternatively, we could assume that the supply is highly inelastic to the interest rate offered by banks.

The only difference between the two banks is the cost incurred when attracting wholesale funding (reflecting heterogeneous accessibility to money markets). Due to financial frictions, such as agency problems, the borrowing cost of wholesale funds increases in the size of the total borrowing. Let the marginal cost of wholesale funding for Bank $i(=1,2)$ be $MC_i(Q_i) = c_i + d_i Q_i$, where $Q_i$ is the amount of total wholesale funding for Bank $i$. We assume $c_2 > c_1 > 0$ and $d_2 > d_1 > 0$, such that wholesale funding is more costly for Bank 2, which faces a more inelastic supply curve, implying greater financial frictions.

Using their funding $M_i + Q_i$, the banks can either issue loans, denoted by $L_i$, or hold the funding as reserves $R_i$, such that $M_i + Q_i = L_i + R_i$ . We assume that all banks are monopolists in their own loan markets, and face a downward sloping loan demand curve $D(L_i)$, which is identical for both banks. We denote the marginal product of lending as $MP(L_i) = a - bL_i$.[9] In short, both banks face similar degrees of competition in the lending and retail deposit markets. The only notable difference is the financial frictions each bank faces in the wholesale funding markets. Reserves do not generate a return, but the banks are subject to reserve requirements, such that $R_i \geq \delta M_i$ with $0 < \delta < 1$.

We now solve for the optimal bank portfolio decision $(M_i^*, Q_i^*, L_i^*, R_i^*)$ to maximize their profits, given the initial policy rate $r = r_0$. Since the retail deposit supply is perfectly inelastic with no cost, banks exploit retail deposits for lending before reaching out for wholesale funding, such that $M_i^* = M(r_0)$. Banks also hold minimum reserves to meet the reserve requirements, such that $R_i^* = \delta M_i^*$.

After lending out all their retail deposits, banks use wholesale funding until the marginal product of lending is equal to the marginal cost of wholesale funding, such that $MC_i(Q_i^*) = MP(L_i^*)$, where total lending is equal to $L_i^* = Q_i^* + (1-\delta)M_i^*$. Solving this, we have

$$Q_i^* = \frac{a - c_i - b(1-\delta)M_i^*}{b + d_i}.$$

[9]Both $a$ and $b$ are positive, and we assume that $a$ is large enough that banks use both funding sources in equilibrium.

Thus, we obtain the following proposition comparing the two banks, suggesting that banks facing fewer financial frictions borrow more wholesale funding and become larger.

**Proposition 1.** $Q_1^* > Q_2^*$, and $L_1^* > L_2^*$.

We define Bank $i$'s wholesale funding reliance ("$WFR_i$") as the ratio between wholesale funding and retail deposits (i.e., $WFR_i = \frac{Q_i^*}{M_i^*}$). We also define a "liquidity ratio" for the banks, measuring the liquidity mismatch risks, in order to reflect statutory liquidity measures such as the LCR or NSFR. We calculate the liquidity ratio by dividing aggregate liquidity-adjusted assets by aggregate liquidity-adjusted liabilities. More specifically, the liquidity ratio ("$LR$") is defined as

$$LR_i = \frac{\alpha_R R_i + \alpha_L L_i}{\beta_M M_i + \beta_Q Q_i},$$

where $\alpha_R > \alpha_L$ and $\beta_M < \beta_Q$, implying that reserves are more liquid than loans and retail deposits are stickier than wholesale funding, as per Basel III assumptions. We also assume $\alpha_L < \beta_M$, reflecting the liquidity transformation of a bank. A higher value of $LR$ implies less liquidity risk exposure. Thus, we obtain the following corollary, comparing the wholesale funding reliance and the liquidity ratios of the two banks.

**Corollary 1.** $WFR_1 > WFR_2$ and $LR_1 < LR_2$.

From Corollary 1, we obtain the following empirical prediction.

**Prediction 1.** Larger banks rely more on wholesale funding, and their (statutory) liquidity ratios are lower.

Now, suppose the central bank tightens monetary policy, such that the new policy rate is $r_1(> r_0)$. For simplicity, we assume that this does not affect loan demand $D(L)$, so that we focus explicitly on the bank lending channel.[10] We also assume, for simplicity, that the cost of wholesale funding is not affected by the policy changes.[11]

Monetary tightening shifts the retail deposit supply curve to the left, and the banks can attract retail deposits only up to $M_i^{**} = M(r_1)$, which is less than $M_i^*$. Consequently, the banks would need to reduce their lending by $(1-\delta)(M_i^* - M_i^{**}) = (1-\delta)(M(r_0) - M(r_1))$. In order to maintain their lending, they borrow additional wholesale funding until the marginal cost of borrowing and the marginal product of lending are equalized. That is, bank $i$'s wholesale funding increases from $Q_i^*$ to $Q_i^{**} = \frac{a-c_i-b(1-\delta)M_i^{**}}{b+d_i}$, and we now have the following proposition comparing the two banks.

**Proposition 2.** $Q_2^{**} - Q_2^* < Q_1^{**} - Q_1^*$ and $L_2^{**} - L_2^* < L_1^{**} - L_1^* < 0$.

This proposition implies that banks with better access to wholesale funding can better mitigate the policy shock and smooth lending, which is in line with the argument in the bank lending channel literature (e.g., Kashyap and Stein, 2000; Kishan and Opiela, 2000). We now obtain the following prediction with regard to the 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 monetary policy impact on lending by implementing such funding substitution more actively.

Note that the banks that add more wholesale funding (larger $Q_i^{**} - Q_i^*$) are those with

[10] This assumption shuts down the "interest-rate channel" of monetary policy, through which interest rate changes directly affect demand. A weaker assumption we would need is that the response of loan demand to monetary policy is more sluggish than the response of the retail deposit supply.

[11] If monetary tightening significantly increased the wholesale funding cost, banks would decrease their wholesale funding, which is the opposite of our prediction. Note that we would have the same empirical predictions even when the costs of wholesale funding increase (e.g., both $c_1$ and $c_2$ increase by the same amount), as long as the increase is not so large that it leads to a decrease in wholesale borrowing.

relatively large wholesale funding usage prior to the policy change (larger $Q_i^*$) and with a larger asset size. In our model, the retail deposit outflows, which occur when the policy rate increases, are exogenous (e.g., due to depositors' preferences) and are not bank-type specific. However, banks face heterogeneous costs when substituting these funding outflows with wholesale funding. Thus, some banks experience a more rapid increase in their funding costs as they increase wholesale borrowing, and add less wholesale funding than do banks whose funding cost increases slowly. Note that these are the banks who choose to borrow less wholesale funds, even under the old policy rate $r_0$, owing to those financial frictions. We now have the following prediction on the concentration of wholesale funding in the banking sector.

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

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 the fire-sale episodes. Our prediction indicates that this distortion would become greater during monetary tightening as the larger banks add more wholesale funding, which increases their exposure to liquidity risks.

Next, we compare otherwise equal banks in two banking markets with different deposit supply elasticities. Suppose that the retail deposit supply $M(r)$ is more sensitive to changes in $r$ in banking market $A$ than in banking market $B$. This implies that when $r$ increases, changes in retail deposit supply $M_i^* - M_i^{**}$ is greater in market $A$ than in market $B$. As a result, banks in $A$-market increase their wholesale funding reliance more compared to banks in $B$-market.

**Prediction 4.** During monetary tightening, banks in a market with more elastic retail deposit supply experience greater decrease in retail deposit funding and increase in wholesale funding reliance.

We lastly discuss the impact of liquidity requirements on the bank lending channel. With the funding substitution, the liquidity ratios of the banks decrease (i.e. lower $LR_i$) during monetary tightening owing to an increase in the reliance on flighty wholesale funding and a decrease in liquid reserves. When the introduction of new liquidity requirements imposes a mandatory lower bound on the liquidity ratio, this constraint becomes more binding during the tightening period. In addition, the constraint would be more binding for the larger bank (Bank 1), because its liquidity ratio is lower as in Corollary 1. In this case, because the larger banks cannot easily substitute their deposit outflows with wholesale funding to smooth their lending, we have the following prediction.

**Prediction 5.** Liquidity requirements become more binding in the monetary tightening regime, particularly for larger banks. Compared with an economy without such requirements, larger banks would reduce their lending by relatively more in response to monetary tightening.

This implies that monetary tightening could have a greater effect on the lending of larger banks with the introduction of liquidity requirements, because these requirements increase the implicit cost of the funding substitution from retail to wholesale funding. In other words, we could have more pronounced monetary policy transmission on aggregate lending through a greater effect on the larger banks. This contrasts with the prediction of the conventional lending channel literature, in which only small banks with limited access to alternative funding sources are affected, leading to a non-significant aggregate effect (Romer and Romer (1990)).

# 3. Empirical Results

## 3.1. Data

We collect quarterly data from the Consolidated Financial Statements for Holding Companies ("FR-Y9C") and the Federal Reserve's Report of Condition and Income ("Call Reports") from 1990:I to 2014:IV in order to construct the bank-quarter variables. If a bank fulfills the FR-Y9C's reporting criteria, we use bank holding company (BHC)-level variables directly from the FR-Y9C. For banks that do not file an FR-Y9C, but that have the Call Report item RSSD9348 (RSSD ID of the top holder) populated, we aggregate the bank-level variables by RSSD9348 as 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 as stand-alone commercial banks. We refer to both BHCs and commercial banks as banks, for simplicity. For each quarter, our sample consists of 3728 banks, on average.[12]

We construct variables for bank funding composition in the following way. RD is the amount of bank retail deposits, calculated by subtracting wholesale deposits (brokered and foreign deposits, as well as large time deposits beyond $100,000) from total deposits. WSF is a bank's total wholesale funding, which is the sum of wholesale deposits, fed funds, repo borrowing,[13] and other borrowed money. We then construct the wholesale funding to retail deposit 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 changes in the monetary policy stance using the quarterly changes in the effective federal funds rate (FFR), retrieving data from the Board of Governors of the Federal Reserve System. We drop years after the recent financial crisis, owing to the lack of variation in the FFR, while the wholesale funding reliance goes down significantly during the QE periods

[12]We drop bank-quarter samples if the bank had more than a 10% change in total assets in a quarter, following Campello (2002). We also drop banks whose average assets size is smaller than 10 mils. We drop banks with total deposit to total assets or total loan to total assets lower than 25%. We only include banks with all control variables.

[13]In our robustness check, we instead use *net* fed funds and repo borrowing by subtracting fed funds lending and reverse repo. See the Appendix.

as can be seen in Figure 3. We also drop the crisis years, starting in 2007, when the wholesale funding supply dried up for exogenous reasons other than monetary policy. Thus, our sample period is from 1992 to 2006.[14]

## 3.2. Summary statistics

Table 1 reports the summary statistics of variables in our analysis. Bank retail deposits (RD) have a mean of 444 million dollars and a standard deviation of 5.23 billion dollars. The distribution of retail deposits is highly right-skewed (skewness of 42.33). Bank wholesale funding (WSF) has a mean of 298 million dollars and a standard deviation of 8.96 billion dollars. The distribution of wholesale funding is also highly right-skewed (skewness of 87.44). The ratio of wholesale funding to retail deposits (WSF to RD) has a mean of 21.47% and a standard deviation of 17.61%. The distribution of WSF to RD is less skewed (skewness of 2.21) than is WSF or RD, because we are controlling for common factors that affect the skewness of RD and WSF by taking the ratio.

We are interested in the change in bank funding composition. The % Change in RD is the quarterly percentage change in a bank's RD; this has a mean of 1.07% and a standard deviation of 3.83%. The % Change in WSF is the quarterly percentage change in a bank's WSF; this has a mean of 4.22% and a standard deviation of 19.71%. The Change in WSF to RD is the quarterly change in a bank's WSF to RD ratio; this has a mean of 0.31% and a standard deviation of 3.49%.

Although we include bank fixed effects in our analysis to control for time-invariant characteristics, we also control for additional lagged bank characteristics. log Assets is the log of a bank's total assets; Capital Ratio is the ratio of a bank's total equity to total assets to control bank soundness;[15] Liability Interest Rate is the ratio of total interest expenses to average

[14] In our analysis, we control for bank-level and aggregate-level year-to-year loan growth with a four-quarter lag. Thus, our sample starts from 1992. Robustness check with different sample periods can be found in the Appendix.

[15] We compute asset-weighted top holder-level capital ratios from bank-level capital ratios if the top holder does not file a Y-9C.

total liabilities to control funding costs; Liquid Asset Ratio is the ratio of liquid assets (sum of cash, fed funds lending and reverse repo, and securities holding) to bank assets to control asset liquidity; 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 year-to-year growth rate of total bank lending to control investment opportunity/demand; Aggregate-level Total Loan Growth is the year-to-year growth rate of aggregate lending by all banks to control aggregate demand; Credit Spread is the spread between Moody's Aaa and 10 year treasury; and Term Premium is the term premium for 10 years maturity from NY Fed.

## 3.3. Wholesale funding reliance and liquidity ratio by asset size

We empirically test the predictions from our model. First, from Prediction 1, we expect that wholesale funding reliance is greater and the liquidity ratio is lower for large banks than it is for small banks. Figure 2 shows the correlation between WSF to RD and log Assets, and between Liquid Asset Ratio and log Assets of the banks in our sample. We take the time-series average of WSF to RD, Liquid Asset Ratio, and log Assets by bank from 1992 to 2006. Here, we find a strong positive relationship, with a $t$-statistic of 35.79 between log Assets and WSF to RD. We also find a strong negative relationship, with a $t$-statistic of -18.64, between log Assets and the Liquid Asset Ratio. This confirms that, in general, larger banks rely more on wholesale funding and hold less liquid assets.

## 3.4. Change in bank funding composition

We next estimate the responses of bank funding composition to changes in the monetary policy stance. From Prediction 2, we expect that during monetary tightening (loosening), (i) banks' retail deposits would decrease (increase), (ii) banks' wholesale funding would increase (decrease), (iii) as a result, the banks would increase (decrease) their overall reliance on wholesale funding, and (iv) banks facing fewer financial frictions in the markets for borrowed money would experience greater change in their funding composition.

Figure 3 shows the time series of WSF to RD, our measure of wholesale funding reliance, along with the fed funds rate from 1990 to 2014. Panel A reports the aggregate WSF to RD ratio, which is a ratio of aggregate wholesale funding to aggregate retail deposits, using FR Y-9C. Note that there was a general upward trend in the reliance on wholesale funding running up to the recent financial crisis, but that in 2014, it fell to the 1996 level. The period 2001–2004 showed a slight drop in wholesale funding reliance, which coincides with the period of declining interest rates. Overall, we can observe a positive association between the policy rate and the wholesale funding reliance of the banking sector. Panel B reports the average WSF to RD ratio using bank-level WSF to RD. This is quite similar to the aggregate trend, but the general levels are lower, and we no longer see the dip in 2001–2004. The unweighted average of WSF to RD in this Panel puts less weight on the larger banks (who are also likely to have high WSF to RD) and more weight on the smaller banks (who are likely to have low WSF to RD) than in Panel A. Thus, a comparison of the two panels indicates that the general level and the variation of the wholesale funding reliance are greater for the large banks (with high WSF to RD).

### 3.4.1. Baseline result

Table 2 reports the panel regressions of the changes in bank funding composition on the changes in the federal funds rate (FFR). We use a distributed-lag model to incorporate the lagged FFR effect on a bank's funding composition (i.e., Kashyap and Stein (2000)). We control for bank fixed-effects and quarter fixed-effects. In addition, we control for following bank characteristics, as of a year ago, to mitigate simultaneity problems: in addition to the asset size, we control the ratio of real estate loan and C&I loan to total loan to capture the business models; and capital ratio, liability interest rate, and liquid asset ratio to reflect the soundness. In order to capture the changes in loan demand, we further include total loan growth both in bank and aggregate level. As a macroeconomic control, we control for credit spread using the spread between Moody's Aaa and 10 year treasury, and term premium of 10 year maturity.

Column (1) reports the regression result of the changes in bank retail deposits on the changes in FFR. The four lags of quarterly changes in FFR are our main independent variables. The sum of the effects from the four lags of FFR changes is -0.7264, with a *t*-statistic of -26.61, where standard errors are clustered by bank. That is, an increase in FFR decreases a bank's retail deposits, and this relationship is statistically significant. Column (2) reports the regression result of the changes in bank wholesale funding usage on the changes in FFR, using the same controls as in column (1). We find that there is a statistically significant, positive change in the wholesale funding amount when the FFR increases.

Column (3) reports the regression result of the changes in bank wholesale funding reliance—measured by WSF to RD—on the changes in FFR, which is our main focus. We find a statistically significant increase in the wholesale funding reliance with increasing FFR, as expected. This result comes directly from columns (1) and (2): RD decreases and WSF increases with FFR. The opposite happens when the FFR decreases. To have a better sense in comparing the effects, we normalize retail deposit and wholesale funding by total liabilities. Column (4) use the change in banks' retail deposit to total liabilities ratio and Column (5) use the change in banks' wholesale funding to total liabilities ratio.[16] Our result is unchanged.

Table 3 reports the same regressions as in Table 2, but by different bank asset size groups. As in the lending channel literature, we implicitly assume that the larger banks face fewer financial frictions in their funding markets. From Prediction 2, we thus expect to find greater substitution in funding in larger banks than in smaller banks. Following Kashyap and Stein (2000), we define a bank as small if the asset size of the bank is below the 95th percentile in the asset distribution of banks in the quarter; as medium if the asset size is within the 95th percentile and 99th percentile; and as large if the asset size is above the 99th percentile. In our sample, there are on average 3542 small banks, 149 medium banks, and 37 large banks.

Columns (1)-(3) report the estimation results of the changes in banks' reliance on wholesale

[16]We also adopt the change in retail deposits (or wholesale funding) divided by total liabilities for robustness, and the results are unchanged.

funding on the change in the FFR. Column (1) comprises small banks, column (2) comprises medium banks, and column (3) comprises large banks. All three groups show statistically significant increase in their wholesale funding reliance when the FFR increases. Note that the scale of the estimated effects is greater for the larger banks, suggesting that larger banks increased their wholesale funding reliance more as predicted in Prediction 2.

We estimate the effect of the changes in retail deposits and wholesale funding on the change in the FFR separately. For the comparison of effects across different groups of bank, we use the ratio of retail deposits to total liability and wholesale funding to total liability. Columns (4)-(6) report the results of changes in the ratio of retail deposits to total liabilities, by bank size, on the change in the FFR. We find a statistically significant decrease in the retail deposit reliance in all groups. Columns (7)-(9) report the regression results of the changes in the ratio of wholesale funding to total liabilities, our alternative measure of wholesale funding reliance, on the change in the FFR. The results are similar to those in column (1) - (3).

### 3.4.2. Potential endogeneity due to the loan demand effect

One of our main identification problems is that changes in bank loan demand could have a confounding effect. For instance, a positive relationship between the wholesale funding reliance of a bank and a change in the FFR could emerge, not through the policy impact, but through the change in local loan demand. With increasing borrowing demand, banks are willing to use more wholesale funding to meet the demand while the central bank decides to tighten monetary policy, simply responding to this credit boom.[17] Cross-sectional results could also be driven by different loan demand faced by banks.

To mitigate the impact of potential changes in loan demand, we control for bank-level total loan growth and aggregate-level loan growth in our baseline regression. We further implement

[17] In the context of our model in Section 2, this would correspond to the upward shift in loan demand (i.e., $MP(L_i)$), which increases the wholesale funding reliance in equilibrium. However, monetary tightening usually shifts the loan demand downward (so called "interest-rate channel" of monetary policy), which would go against our empirical predictions. Thus, it is when the timing of monetary tightening coincides with very strong growth in loan demand that could bias our estimation results.

the following robustness analyses of our results. We control for MSA characteristics such as population, income per capita, and unemployment rate in order to capture the local business cycle. We limit our sample to "local" banks that operate mainly in a single MSA, so that our MSA-level controls better capture the economic environment a bank is facing. Based on Summary of Deposit data, we define a bank as local if it collects more than 70% of its deposits from one MSA, on average across the time series, and assign the MSA with the most deposits as the primary market of that bank. Table 4 reports the regression results using local banks only and controlling for MSA characteristics. We find that these MSA variables indeed reflect the local business cycle: higher income is positively associated with changes in retail deposits, wholesale funding, and the wholesale funding to retail deposit ratio, whereas a higher unemployment rate presents the opposite association. However, our main results are unaffected.

#### 3.4.3. Differentiating monetary policy impact using local age demographics

Using our samples of the local banks, we further implement the following analysis, exploiting the demographic variation across regions. Becker (2007) suggests that areas populated with more seniors tend to have more deposits in banks, and uses this demographic characteristic as an instrument for deposit supply *level* to the banking sector. We instead use this regional demographic variation as a measure of deposit supply *sensitivity* to monetary policy, driven by the different motivations among the old and young generations for parking money in bank deposit accounts.

Seniors, who mainly consume their accumulated savings as retirees, use bank deposit accounts primarily for "storage" purposes. Non-seniors are more sensitive to saving or "investment" incentives. Therefore, non-seniors are more yield-sensitive, and given the upward stickiness of the deposit interest rate, the deposit supply by non-seniors to the banks would decrease more in response to an increase in the policy rate (i.e., $M(r)$ in our model of Section 2 is steeper for non-seniors). Hence, banks whose deposit-base in the local market consists mostly of non-seniors would experience more deposit outflows during monetary tightening, and so more actively increase their reliance on wholesale funding (Prediction 4 in Section 2).[18]

Based on the Census annual population estimate, we first compute the fraction of the population older than 65 for all US counties. Using the Summary of Deposit data on banks' branch-level deposit distributions, we then compute the deposit-weighted fraction of the old population for each bank. This is a proxy for the fraction of seniors that a bank would face in its local market. To better capture the demographic characteristics of deposit-base across banks, we focus only on local banks as defined previously, which collect most of their deposits from a single MSA.[19] We define a Young Deposit-Base dummy, indicating that the bank is below the median for a quarter.

We first test whether the banks facing a younger deposit-base experience a larger retail deposit outflow when monetary policy tightens. Table 5 reports the estimation results. We interact the Young Deposit-Base dummy with the changes in the FFR to test the difference in the policy effect between banks with a younger deposit-base and those with an older deposit-base. As in our baseline results, we find that an increase in the FFR decreases a bank's retail deposits, increases a bank's wholesale funding usage, and increases a bank's reliance on wholesale funding. When we interact the change in the FFR with the Young Deposit-Base dummy, for banks facing younger deposit-base in their local deposit markets, we find a larger decrease in a bank's retail deposit, a larger increase in a bank's wholesale funding usage, and a larger increase in the bank's wholesale funding reliance. This indicates that a monetary policy shock on banks' retail deposit outflows differs by area and demographics of banks'

[18]As an alternative channel, regions with more seniors can be interpreted as "loan poor, deposit rich" markets while those with more non-seniors can be interpreted as "loan rich, deposit poor" markets (Han et al. (2015), Pennacchi (2016)). Hence, banks with young depositors face greater retail lending demand relative to retail deposits supply, and with relatively few retail deposits, banks use wholesale funding at the margin. On the other hand, banks with old depositors face greater retail deposits supply relative to retail lending demand, and with more retail deposits, banks invest in securities at the margin. Hence, facing the increase in the federal funds rate and thus decline in the retail deposits, banks with young depositors, whose marginal funding is wholesale funding and with less securities holding, increase their wholesale funding more than those with old depositors, which is consistent with our empirical results. We thank George Pennacchi for this suggestion.

[19]Note that two local banks operating in the same MSA may face different levels of an elderly population, because we construct our measure from a more granular county-level composition, and weight-average it with county-level deposit amounts.

deposit-base. Greater retail deposit outflows are associated with a larger increase in wholesale funding usage, resulting in a greater reliance on wholesale funding, as predicted.

However, this difference in the retail deposit decrease could still be a product of difference in omitted characteristics (e.g., business cycle sensitivity) between the two age-regional groups, and does not necessarily imply that banks with a younger deposit-base engage in more *active* funding substitution to reverse the greater funding outflow shock. For instance, greater retail deposit outflows of banks with younger deposit-base could reflect a decline in local demand rather than a policy shock on the deposit supply. In order to confirm that the decrease of the retail deposit supply during monetary tightening leads to funding substitution, we examine whether financial frictions matter more for banks facing a young deposit-base (i.e., they have more *willingness* to reach out to wholesale funding, rather than *passively* allow outflows of (unnecessary) deposits). If the decrease in local demand contributed to the retail deposit decrease, then the financial frictions would have mattered less, because the banks now face less loan demand and the funding substitution is less necessary.

Specifically, we compare large and small local banks' funding substitution activity within banks with younger or older deposit-base, and examine how this differs across the groups. In our baseline result in Section 3.1.1, we found that larger banks are more likely to substitute retail deposit outflows with wholesale funding, reflecting fewer financial frictions. Note that in the absence of financial frictions, we would not observe this difference between the groups. 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 for funding substitutions would be greater. Thus, we test whether the difference in funding substitution activity (to monetary stance change) across the bank size groups is larger when facing younger deposit-base with greater deposit outflows. Table 6 shows the results by group: banks with a young deposit-base and banks with an elderly deposit-base. We find similar results in both groups: an increase in the FFR decreases a bank's retail deposits, increases a bank's wholesale funding usage, and increases a bank's reliance on wholesale funding. Note that the effects are larger in banks with a younger deposit-base.

We define a Large-Medium (LM) Bank dummy, indicating a bank asset size in the top 5% of banks. As we interact the change in the FFR with the LM Bank dummy, we find an increase in the sensitivity of wholesale funding reliance for large banks compared to small ones, but only significant for banks with young deposit-base. That is, the monetary shock on bank funding is amplified by local age demographics, and greater retail deposit outflows for banks with younger depositors increase their willingness to attract wholesale funding, rather than reflecting the decline in local loan demand. We infer that monetary tightening induces banks to implement funding substitution.

## 3.5. The effect of bank funding sensitivity on bank lending

We now analyze how the change in wholesale funding reliance associates with banks' lending behaviors during a change in the monetary policy stance. Prediction 2 suggests that banks could mitigate the policy effect through the lending channel by replacing deposit outflows with wholesale funds. We here estimate how this funding substitution activity associates with the impact of monetary policy on the bank lending growth.

We conduct a two-stage estimation, as in Kashyap and Stein (2000). For each quarter, we measure the bank-level funding composition sensitivity to monetary policy by calculating the correlation between the changes in the federal funds rate (dFFR) and the changes in the bank wholesale funds reliance (dWSFtoRD). We interpret a higher correlation as a sign of more active funding substitution in response to changes in the monetary policy stance. We use four measures of bank funding sensitivity in each quarter and for each bank: (1) a five-year correlation of dFFR and dWSFtoRD; (2) the decile of (1), by year-quarter; (3) a three-year correlation of dFFR and dWSFtoRD; and (4) the decile of (3).

Using this measure of bank funding sensitivity, denoted by $B_{i,t}$, 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 $\beta_t$ captures the effect of the bank funding composition sensitivity on the bank lending growth for the quarter. In the second-stage, we regress the four lags of quarterly changes in the federal funds rate on $\beta_t$ from the first-stage regression. We are interested in whether the sum of the coefficients in the four lags of changes in the FFR is positive and significant. This would imply a mitigated association between lending for banks with greater funding composition sensitivity and changes in monetary policy stance.

Figure 4 shows the time series plot of $\beta_t$ from the first-stage regression, using a three-year correlation. We eliminate the seasonality (by quarter fixed effect) and the linear time trend. These residuals of $\beta_t$ are centered around zero, and co-move positively with the quarterly changes in the FFR, suggesting that a bank with higher funding composition sensitivity tends to lend more during monetary tightening than does a bank with lower funding sensitivity.

Table 7 reports the second-stage regression results, where columns (1)–(4) use the four different measures of bank funding sensitivity. In all specifications, we find significantly positive effects, confirming our prediction that the banks implementing more active funding substitution lend more than their counterparts when the FFR increases, which suggests a mitigated tightening effect via the lending channel.

## 3.6. Concentration in wholesale funding reliance

Prediction 3 suggests that banks with a greater reliance on wholesale funding would increase their wholesale funding more during monetary tightening. We next examine this prediction, testing whether monetary policy affects the funding composition of banks differently, by comparing banks with varying levels of wholesale funding reliance.

Figure 5 shows the time trend of the wholesale distribution in the banking sector. We plot the difference between the 90th percentile and 10th percentile in the distribution of WSF to RD, by quarter. Comparing this series with the historical FFR, the two series tend to move in the same direction;[20] Monetary tightening is associated with an increase in this heterogeneous difference, which suggests a greater concentration of wholesale funding among banks that are more reliant on wholesale funding.

Table 8 reports the panel regression results of the changes in WSF to RD on the lagged levels of WSF to RD and the changes in FFR, as well as the interaction of the two. These results test whether banks with higher WSF to RD ratios experience greater increases in this ratio during monetary tightening. Column (1) reports the results based on all banks. The dependent variable is the quarterly change in WSF to RD, and the main independent variables are the interactions among the four lags of changes in the FFR and the four-quarter-lagged WSF to RD. We include the same controls and fixed effects as in Table 2. The sum of the coefficients for the interaction terms is 0.020, with a $t$-statistic of 8.87. That is, a higher WSF to RD (four quarters lagged) amplifies the changes in the WSF to RD owing to the changes in monetary policy. Column (2) reports the results for small banks; column (3) reports the results for medium banks; and column (4) reports the results for large banks. Similarly, we find a positive effect of high wholesale funding reliance (four quarters previously) on the change in wholesale funding reliance in all groups. The result is the largest for the large banks.

## 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.

[20] An exception is the financial crisis period of 2007–09.

## 4.1. Financial stability

The recent crisis reignited the longstanding debate between "leaning versus cleaning" (see, e.g., White (2009), Mishkin (2011), and Blanchard et al. (2010)), asking whether monetary policy have an ex-ante role in the buildup of financial imbalances and systemic risks, and what is the role of macroprudential regulation (See, e.g., Freixas et al. (2015)). However, the focus of this debate is more on the buildup of financial risks during monetary *loosening*, implicitly assuming that monetary tightening would mitigate these vulnerabilities. In contrast, our results suggest that monetary tightening could *exacerbate* financial imbalances if central banks try to slow down a credit boom using monetary tightening. Here, systemic risks could increase through banks' attempts to unwind the tightening effect.

Our analysis suggests that monetary tightening increases the funding liquidity risks of the banking sector as a byproduct; 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.

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, Basel III LCR (BIS (2013)) imposes the run-off rate of 3 to 10% for retail deposits, while assuming much higher run-off rates up to 100% for other wholesale funding sources. Thus, banks already borrowing heavily from the wholesale funding markets and becoming large would not be able to implement funding substitution as freely as banks with low liquidity risks could. This could contain the potential surge in liquidity risk exposure during the monetary tightening regime.

## 4.2. Liquidity requirements and monetary policy transmission

In this section, we discuss how liquidity regulations (e.g., Basel III LCR) affect monetary policy transmission through the bank lending channel, based on our findings on bank funding responses.

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 can (e.g., Kashyap and Stein (2000), Kishan and Opiela (2000)). As financial innovation has further reduced market frictions, more banks can mitigate the impact of monetary policy on their lending (Loutskina and Strahan (2009), Altunbas et al. (2009)). This raised the question on monetary transmission through the lending channel. However, this funding substitution might no longer be operative with 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 go down during the tightening because the central bank reserves, counted as the most liquid of assets, shrink through open-market operations (Bech and Keister (2013)), and banks substitute their liquid assets cushion with more illiquid loans (Kashyap and Stein (2000)). This implies that monetary policy could affect bank lending more when the 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 are lower (Prediction 1).

In order to analyze the relationship between the statutory liquidity ratios, such as the LCR and monetary policy, we construct a proxy of the LCR, denoted as "Liquidity Ratio," based on the variables reported in the FR Y-9C (see Appendix for the construction). This index is an approximation, at best, because it only uses 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 the liquidity regulation.

We first show that there exists a negative relationship between bank size and the level of Liquidity Ratio, confirming Prediction 1. Figure 6 compares Liquidity Ratio for three asset size groups; large, medium, and small. We include Y-9C filing entities in any quarter with asset size larger than 1 billion dollars. Banks smaller than the 95 percentile of asset size belong to "small" group, banks within the 95 percentile and the 99 percentile belong to "medium" group, and banks with the 99 percentile above belong to "large" group. Panel A reports the aggregate liquidity ratio and Panel B reports the median liquidity ratio. Graphs clearly shows that larger banks have lower Liquidity Ratio.

In column (1) of Table 9, we regress the level of Liquidity Ratio on bank assets, and find a significant negative relation. That is, larger banks tend to have a lower LCR, because they rely more on wholesale funding, while holding less liquid assets (see Figure 2). In columns (2) to (6), we regress the changes in Liquidity Ratio on the lagged changes in the FFR. Here, we find that the coefficient is significantly negative in all specifications. This implies that the liquidity requirement would be more binding during monetary tightening.

From these results and our previous empirical findings, we induce an important implication of liquidity requirements on monetary policy transmission. As discussed in Section 3, larger banks engage more in funding substitution during tightening, but in future, 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 bank's lending, with a non-significant aggregate effect. Macroprudential regulation could bolster the monetary policy transmission in this respect, affecting the 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, deriving novel policy implications. Monetary tightening leads to a decline in retail deposits in the banking sector and, in order to mitigate the impact on their lending, banks try to attract more wholesale funding. Since banks face varying degrees of financial frictions and, thus, different accessibility to the 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. This implies that monetary tightening could lead to systemic vulnerability if banks actively try 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. This contrasts with conventional wisdom that monetary tightening could mitigate systemic imbalances by slowing down a credit boom; here, systemic risks could instead build up through banks' attempts to unwind the tightening effect.

Our analysis implies that new liquidity requirements could help mitigate the increase in the 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. Since larger banks are more affected by the liquidity requirements, monetary tightening could affect the aggregate lending of the banking sector, because large banks might be forced to reduce their lending when faced with retail deposit outflows.

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## Table 1: Summary Statistics

We report summary statistics of variables we construct from the Consolidated Financial Statements for Holding Companies ("FR-Y9C") and the Federal Reserve's Report of Condition and Income ("Call Reports"). If a bank qualifies for criteria reporting FR-Y9C, we use BHC-level variables directly from FR-Y9C. For those banks without FR-Y9C but with the Call Reports item RSSD9348 (RSSD ID of holding company), we aggregate up bank-level variables by RSSD9348 for BHC-level variables. For those banks without FR-Y9C and without RSSD9348, we use the bank-level variables interpreting them as stand-alone commercial banks. RD is the amount of retail deposit funding, calculated by subtracting wholesale deposit (brokered and foreign deposits as well as large time deposit beyond $100,000) from total deposit. WSF is the amount of wholesale funding, which is the sum of wholesale deposits, fed funds and repo borrowing, and other borrowed money. We construct wholesale funding to retail deposit ratio (WSF to RD = WSF / RD), which is our main measure for a bank's wholesale funding reliance. % Change in RD is the percent change of a bank's RD from previous quarter. % Change in WSF is the percent change of a bank's WSF from previous quarter. Change in WSF to RD is the change in WSF to RD ratio from the previous quarter. Change in RD to TL is the change in RD to total liability ratio from the previous quarter. Change in WSF to TL is the change in WSF to total liability ratio from the previous quarter. Change in (WSF+RD) to TL is the change in the ratio of WSF and RD to total liability from the previous quarter. log Assets is the log of a bank's asset. Capital Ratio is the ratio of a bank's total equity to total asset. Liability Interest Rate is the ratio of total interest expenses to average total liabilities. Liquid Asset Ratio is the ratio of liquid assets (summation of cash, fed funds lending and reverse repo, and securities holdings) to total asset. RE Loan to Total Loan Ratio is the ratio of real estate loan to total loan. CI Loan to Total Loan Ratio is the ratio of CI loan to total loan. Bank-level Total Loan Growth is the growth rate of total loan of a bank from a year ago. Aggregate-level Total Loan Growth is the growth rate of total loan aggregated for all banks from a year ago. Credit Spread is the spread between Moody's Aaa and 10 year treasury. Term Premium is the term premium for 10 years maturity from NY Fed. Sample period is from 1992 to 2006. We winsorize all variables at 1% and 99% level by quarter, except RD and WSF which we don't use in our regressions and macro variables.

| Variables | Obs | Mean | Std. Dev. | 10th Percentile | 90th Percentile |
|---|---|---|---|---|---|
| RD | 223679 | 444 mils | 5.23 bils | 19.3 mils | 326 mils |
| WSF | 223679 | 298 mils | 8.96 bils | 1.68 mils | 89.3 mils |
| WSFtoRD | 223679 | 21.47 | 17.61 | 5.44 | 42.47 |
| % Change in RD | 223679 | 1.07 | 3.83 | -3.51 | 5.97 |
| % Change in WSF | 223679 | 4.22 | 19.71 | -13.90 | 23.66 |
| Change in WSF to RD | 223679 | 0.31 | 3.49 | -3.15 | 4.11 |
| Change in RD to TL | 223679 | -0.18 | 2.03 | -2.59 | 2.05 |
| Change in WSF to TL | 223679 | 0.18 | 2.01 | -2.02 | 2.57 |
| Change in (WSF+RD) to TL | 223679 | 0.00 | 0.29 | -0.24 | 0.26 |
| Log Assets | 223679 | 18.41 | 1.26 | 16.98 | 19.87 |
| Capital Ratio | 223679 | 9.88 | 2.72 | 7.06 | 13.48 |
| Liability Interest Rate | 223679 | 1.01 | 1.61 | 0.01 | 3.80 |
| Liquid Asset Ratio | 223679 | 37.75 | 13.72 | 20.85 | 56.88 |
| RE Loan to Total Loan Ratio | 223679 | 56.97 | 18.24 | 31.72 | 79.91 |
| CI Loan to Total Loan Ratio | 223679 | 6.56 | 10.28 | 0.00 | 21.70 |
| Bank-level Total Loan Growth | 223679 | 7.44 | 9.75 | -4.22 | 19.65 |
| Aggregate-level Total Loan Growth | 223679 | 9.54 | 14.00 | -4.59 | 28.60 |
| Credit Spread | 223679 | 1.27 | 0.40 | 0.82 | 1.95 |
| Term Premium | 223679 | 1.70 | 0.89 | 0.55 | 3.10 |

## Table 2: Bank Funding Decomposition and the Federal Funds Rate

We report the panel regression estimates of the relationship between the change in bank fund composition and the change in federal funds rate (FFR). We use bank-quarter observations from 1992 to 2006. The dependent variables are the percentage change in retail deposit (RD) of a bank in column (1), the percentage change in wholesale funding (WSF) in column (2), the change in wholesale funding to retail deposit ratio (WSF to RD) in column (3), the change in RD to total liability ratio (RD to TL) in column (4), and the change in WSF to total liability ratio (WSF to TL) in column (5). The independent variables include 4 lags of the change in FFR, Credit Spread (the spread between Moody's Aaa and 10 year treasury), Term Premium (the term premium for 10 years maturity from NY Fed), RE Loan to Total Loan Ratio, the fraction of the real estate loan in bank's total loan, CI Loan to Total Loan Ratio, the fraction of the CI loan in bank's total loan, log Assets, the log of bank's asset size, Capital Ratio, the ratio of equity to assets, Bank-level Total Loan Growth, Aggregate-level Total Loan Growth, the growth rate of total lending of bank from previous quarter, Liability Interest Rate, the ratio of total interest expense to average total liabilities, and Liquid Asset Ratio, the ratio of liquid asset in bank's total asset. We use 4 quarter lags of bank characteristics in the analysis and 1 quarter lags of Credit Spread and Term Premium. We also include bank fixed-effect and quarter fixed effect. We report the sum of the estimates of lagged FFR. The table reports point estimates with t-statistics in parentheses. All the standard errors are clustered at the bank level. ***, **, * denotes 1%, 5%, and 10% statistical significance.

| Variables | (1)<br>% Change in<br>RD | (2)<br>% Change in<br>WSF | (3)<br>Change in<br>WSF to RD | (4)<br>Change in<br>RD to TL | (5)<br>Change in<br>WSF to TL |
|---|---|---|---|---|---|
| Change in FFR (t-1 to t) | -0.745*** | 1.274*** | 0.383*** | -0.238*** | 0.233*** |
| | (-25.26) | (7.664) | (13.31) | (-14.06) | (13.83) |
| Change in FFR (t-2 to t-1) | 0.175*** | 1.916*** | 0.0582* | -0.0914*** | 0.0661*** |
| | (4.906) | (10.10) | (1.739) | (-4.598) | (3.358) |
| Change in FFR (t-3 to t-2) | 0.241*** | -0.525*** | 0.0299 | 0.0413** | -0.0150 |
| | (7.208) | (-2.785) | (0.951) | (2.172) | (-0.798) |
| Change in FFR (t-4 to t-3) | -0.397*** | 0.607*** | -0.0548** | -0.0474*** | -0.0210 |
| | (-13.45) | (3.710) | (-1.985) | (-2.887) | (-1.284) |
| *Sum of Effects* | -0.7264*** | 3.2712*** | 0.4167*** | -0.3353*** | 0.2627*** |
| | (-26.61) | (21.91) | (16.73) | (-23.45) | (18.37) |
| Credit Spread (t-1) | 0.267*** | -0.0459 | -0.111*** | 0.0505*** | -0.0373*** |
| | (10.69) | (-0.376) | (-4.865) | (4.019) | (-2.982) |
| Term Premium (t-1) | -0.154*** | -0.701*** | -0.184*** | 0.101*** | -0.125*** |
| | (-12.13) | (-10.31) | (-15.88) | (15.56) | (-19.25) |
| Capital Ratio (t-4) | 0.00535 | 0.530*** | 0.0773*** | -0.0541*** | 0.0471*** |
| | (0.763) | (15.24) | (12.29) | (-16.09) | (14.19) |
| Log Assets (t-4) | -0.580*** | -3.386*** | -0.128*** | 0.127*** | -0.160*** |
| | (-15.23) | (-19.37) | (-3.588) | (7.394) | (-9.295) |
| Liability Interest Rate (t-4) | -0.0489*** | -0.175*** | -0.0372*** | 0.0208*** | -0.0192*** |
| | (-5.117) | (-3.854) | (-3.952) | (4.211) | (-3.920) |
| Liquid Asset Ratio (t-4) | -0.00837*** | 0.0168** | -0.00536*** | 0.00313*** | -0.00255*** |
| | (-6.216) | (2.565) | (-4.608) | (4.834) | (-3.998) |
| RE Loan to Total Loan Ratio (t-4) | 0.00301** | -0.0134** | -0.000979 | 0.00111* | -0.000804 |
| | (2.301) | (-2.069) | (-0.849) | (1.750) | (-1.280) |
| CI Loan to Total Loan Ratio (t-4) | 0.00369* | 0.0153* | -8.68e-06 | -0.000341 | 0.000637 |
| | (1.827) | (1.712) | (-0.00468) | (-0.345) | (0.651) |
| Bank-level Total Loan Growth (t-4) | 0.0165*** | 0.0355*** | 0.000358 | -0.000523 | 0.000528 |
| | (17.35) | (7.436) | (0.410) | (-1.100) | (1.116) |
| Aggregate-level Total Loan Growth (t-4) | -0.0123*** | 0.0272*** | 0.00722*** | -0.00385*** | 0.00425*** |
| | (-22.52) | (9.926) | (13.83) | (-12.74) | (14.09) |
| Observations | 223,679 | 223,679 | 223,679 | 223,679 | 223,679 |
| R-squared | 0.124 | 0.044 | 0.060 | 0.056 | 0.052 |
| Bank FE and Quarter FE | Yes | Yes | Yes | Yes | Yes |

## Table 3: Bank Funding Decomposition and the Federal Funds Rate: By Asset Size

We report the panel regression estimates of the relationship between the change in bank funding composition and the change in the federal funds rate by bank asset size. We follow Kashyap and Stein (2000) to define size groups, and define a bank as small if the asset size of the bank is below 95 percentile in the asset distribution of banks in the quarter. We define a bank as medium if the asset size is within 95 percentile to 99 percentile, and as large if the asset size is above 99 percentile. Regression specification is the same as in Table 2 except we use Change in WSF to RD as dependent variable in columns (1)-(3), Change in RD to TL in columns (4)-(6), and Change in WSF to TL in columns (7)-(9). We report the sum of the estimates of lagged FFR. The table reports point estimates with t-statistics in parentheses. All the standard errors are clustered at the bank level. ***, **, * denotes 1%, 5%, and 10% statistical significance.

| | Small | Medium | Large | Small | Medium | Large | Small | Medium | Large |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Variables | Change in WSF to RD | | | Change in RD to TL | | | Change in WSF to TL | | |
| Change in FFR (t-1 to t) | 0.366*** | 0.659*** | 0.528 | -0.232*** | -0.300*** | -0.266 | 0.227*** | 0.308*** | 0.194 |
| | (12.69) | (3.385) | (1.036) | (-13.39) | (-3.292) | (-1.346) | (13.21) | (3.452) | (0.936) |
| Change in FFR (t-2 to t-1) | 0.0394 | 0.189 | 1.032* | -0.0819*** | -0.158 | -0.597** | 0.0580*** | 0.137 | 0.468* |
| | (1.176) | (0.814) | (1.732) | (-4.035) | (-1.416) | (-2.592) | (2.889) | (1.234) | (1.971) |
| Change in FFR (t-3 to t-2) | 0.0439 | -0.106 | -0.537 | 0.0262 | 0.289*** | 0.467** | -0.00589 | -0.201** | -0.151 |
| | (1.393) | (-0.500) | (-1.126) | (1.341) | (2.991) | (2.583) | (-0.305) | (-2.084) | (-0.772) |
| Change in FFR (t-4 to t-3) | -0.0586** | -0.0328 | 0.401 | -0.0409** | -0.139 | -0.298** | -0.0226 | 0.0303 | -0.0935 |
| | (-2.104) | (-0.158) | (1.133) | (-2.427) | (-1.540) | (-2.302) | (-1.349) | (0.327) | (-0.733) |
| *Sum of Effects* | 0.3908*** | 0.71** | 1.4233*** | -0.3287*** | -0.3077*** | -0.6947*** | 0.2568*** | 0.2743** | 0.4176** |
| | (16.02) | (2.24) | (2.78) | (-22.67) | (-2.71) | (-3.87) | (17.71) | (2.46) | (2.23) |
| Credit Spread (t-1) | -0.123*** | 0.148 | -0.325 | 0.0537*** | -0.0151 | 0.106 | -0.0421*** | 0.0890 | -0.102 |
| | (-5.415) | (0.931) | (-0.771) | (4.166) | (-0.221) | (0.719) | (-3.283) | (1.340) | (-0.635) |
| Term Premium (t-1) | -0.173*** | -0.451*** | -0.149 | 0.0989*** | 0.186*** | 0.0165 | -0.121*** | -0.236*** | -0.0899 |
| | (-14.97) | (-5.132) | (-0.700) | (14.76) | (5.014) | (0.208) | (-18.24) | (-6.220) | (-1.062) |
| Capital Ratio (t-4) | 0.0750*** | 0.147*** | 0.372*** | -0.0536*** | -0.0760*** | -0.129*** | 0.0468*** | 0.0586*** | 0.117** |
| | (12.04) | (2.904) | (2.701) | (-15.61) | (-3.668) | (-2.960) | (13.86) | (2.637) | (2.482) |
| Log Assets (t-4) | -0.0793** | -0.787*** | -0.845** | 0.111*** | 0.438*** | 0.309** | -0.142*** | -0.509*** | -0.373*** |
| | (-2.270) | (-2.894) | (-2.454) | (6.037) | (3.994) | (2.563) | (-7.770) | (-4.443) | (-2.736) |
| Liability Interest Rate (t-4) | -0.0358*** | -0.0777 | 0.0717 | 0.0205*** | 0.0844** | -0.0631 | -0.0192*** | -0.0631 | -0.0281 |
| | (-3.910) | (-0.759) | (0.415) | (4.081) | (2.116) | (-0.984) | (-3.843) | (-1.636) | (-0.440) |
| Liquid Asset Ratio (t-4) | -0.00564*** | 0.00272 | 0.0175 | 0.00320*** | -0.00225 | -0.00188 | -0.00266*** | 0.00187 | 0.00352 |
| | (-4.842) | (0.269) | (0.698) | (4.826) | (-0.493) | (-0.228) | (-4.082) | (0.407) | (0.395) |
| RE Loan to Total Loan Ratio (t-4) | -0.00162 | 0.00632 | -0.0229 | 0.00137** | -0.00508 | 0.0102 | -0.00107* | 0.00536 | -0.0143 |
| | (-1.453) | (0.450) | (-0.765) | (2.136) | (-0.913) | (1.209) | (-1.684) | (0.894) | (-1.409) |
| CI Loan to Total Loan Ratio (t-4) | -2.21e-06 | 0.00657 | -0.0515 | -0.000355 | -0.00447 | 0.0262* | 0.000713 | 0.00372 | -0.0272* |
| | (-0.00121) | (0.333) | (-0.986) | (-0.353) | (-0.540) | (1.838) | (0.717) | (0.444) | (-1.661) |
| Bank-level Total Loan Growth (t-4) | 0.000600 | -0.0109 | -0.00890 | -0.000667 | 0.00417 | 0.00151 | 0.000687 | -0.00494* | -0.000247 |
| | (0.692) | (-1.566) | (-0.564) | (-1.377) | (1.425) | (0.261) | (1.428) | (-1.670) | (-0.0402) |
| Aggregate-level Total Loan Growth (t-4) | 0.00680*** | 0.0147*** | 0.0183** | -0.00378*** | -0.00559*** | -0.00447 | 0.00408*** | 0.00787*** | 0.00662* |
| | (12.97) | (4.227) | (2.320) | (-12.19) | (-3.477) | (-1.357) | (13.23) | (4.759) | (1.854) |
| Observations | 212,510 | 8,940 | 2,229 | 212,510 | 8,940 | 2,229 | 212,510 | 8,940 | 2,229 |
| R-squared | 0.058 | 0.106 | 0.148 | 0.055 | 0.089 | 0.136 | 0.051 | 0.088 | 0.117 |
| Bank FE and Quarter FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

## Table 4: Bank Fund Decomposition and the Federal Funds Rate: Local Bank Subsample with MSA Controls

We report the panel regression estimates of the relationship between the change in bank funding composition and the change in the federal funds rate for the subsample of local banks with MSA control variables. We only include local banks, that is, the banks with more than 70% of deposit on average coming from one MSA. Regression specification is the same as in Table 2 except we have additional MSA controls including MSA log Population, MSA Income Per Capita, and MSA Unemployment Rate. We report the sum of the estimates of lagged FFR. The table reports point estimates with t-statistics in parentheses. All the standard errors are clustered at the bank level. ***, **, * denotes 1%, 5%, and 10% statistical significance.

| Variables | (1)<br>% Change in<br>RD | (2)<br>% Change in<br>WSF | (3)<br>Change in<br>WSF to RD | (4)<br>Change in<br>WSF to TL |
|---|---|---|---|---|
| Change in FFR (t-1 to t) | -0.778*** | 1.438*** | 0.403*** | 0.252*** |
| | (-18.39) | (6.385) | (9.596) | (10.46) |
| Change in FFR (t-2 to t-1) | 0.179*** | 2.028*** | 0.0965** | 0.0859*** |
| | (3.577) | (7.981) | (1.973) | (3.040) |
| Change in FFR (t-3 to t-2) | 0.378*** | -0.511** | -0.00767 | -0.0370 |
| | (8.060) | (-2.036) | (-0.170) | (-1.397) |
| Change in FFR (t-4 to t-3) | -0.522*** | 0.624*** | -0.00546 | 0.00847 |
| | (-12.51) | (2.814) | (-0.136) | (0.362) |
| *Sum of Effects* | -0.7422*** | 3.5784*** | 0.4858*** | 0.3094*** |
| | (-18.79) | (17.71) | (13.17) | (15.02) |
| MSA log Population | 1.567*** | 8.172*** | 0.247 | 0.347** |
| | (4.041) | (4.926) | (0.768) | (1.982) |
| MSA Income Per Capita | 7.82e-06 | -0.000105*** | 1.60e-05*** | 2.75e-06 |
| | (1.289) | (-4.004) | (2.957) | (0.975) |
| MSA Unemployment Rate | -0.0378** | -0.776*** | -0.0785*** | -0.0528*** |
| | (-2.572) | (-9.901) | (-5.053) | (-6.315) |
| Credit Spread (t-1) | 0.244*** | 0.152 | -0.176*** | -0.0542*** |
| | (6.685) | (0.896) | (-5.071) | (-2.878) |
| Term Premium (t-1) | -0.117*** | -0.302** | -0.109*** | -0.0856*** |
| | (-4.959) | (-2.425) | (-4.540) | (-6.474) |
| Capital Ratio (t-4) | 0.0199** | 0.514*** | 0.0745*** | 0.0449*** |
| | (1.967) | (11.37) | (7.886) | (9.169) |
| Log Assets (t-4) | -0.744*** | -2.881*** | -0.190*** | -0.168*** |
| | (-9.998) | (-9.513) | (-3.140) | (-5.264) |
| Liability Interest Rate (t-4) | -0.0441*** | -0.203*** | -0.0200* | -0.0125** |
| | (-3.725) | (-3.645) | (-1.795) | (-2.029) |
| Liquid Asset Ratio (t-4) | -0.00928*** | 0.00659 | -0.00383** | -0.00172* |
| | (-4.852) | (0.745) | (-2.224) | (-1.858) |
| RE Loan to Total Loan Ratio (t-4) | 0.00232 | 0.0141 | -0.000758 | 3.37e-05 |
| | (1.230) | (1.595) | (-0.462) | (0.0374) |
| CI Loan to Total Loan Ratio (t-4) | 0.00470* | 0.0169 | -0.00204 | -0.000140 |
| | (1.828) | (1.448) | (-0.868) | (-0.111) |
| Bank-level Total Loan Growth (t-4) | 0.0175*** | 0.0229*** | 6.34e-05 | 6.94e-05 |
| | (12.89) | (3.592) | (0.0495) | (0.102) |
| Aggregate-level Total Loan Growth (t-4) | -0.0122*** | 0.0214*** | 0.00682*** | 0.00389*** |
| | (-15.86) | (5.779) | (9.036) | (9.067) |
| Observations | 112,277 | 112,277 | 112,277 | 112,277 |
| R-squared | 0.111 | 0.047 | 0.059 | 0.051 |
| Bank FE and Quarter FE | Yes | Yes | Yes | Yes |

## Table 5: Difference in Funding Composition Sensitivity by Deposit-base Faced by Local Banks

We report the panel regression estimates of the relationship between the change in bank funding composition and the change in the federal funds rate by deposit-base faced by local banks. We only include local banks, that is, the banks with more than 70% of deposit on average coming from one MSA. For each local bank, we compute the deposit-weighted fraction of senior population from the county-level fraction of senior population (whose age is above 65). We define a bank as facing young deposit-base if its average deposit-weighted fraction of old population is below the median. Young Deposit-base is a dummy variable for banks facing young deposit-base. We interact the changes in thefederal funds rate with Young Deposit-Base dummy. Other regression specification is the same as in Table 2 except additional MSA-level variables. We report the sum of the estimates of lagged FFR. The table reports point estimates with t-statistics in parentheses. All the standard errors are clustered at the bank level. ***, **, * denotes 1%, 5%, and 10% statistical significance.

| Variables | (1)<br>% Change in<br>RD | (2)<br>% Change in<br>WSF | (3)<br>Change in<br>WSF to RD | (4)<br>Change in<br>WSF to TL |
|---|---|---|---|---|
| Change in FFR (t-1 to t) | -0.680*** | 0.532 | 0.300*** | 0.183*** |
| | (-10.01) | (1.554) | (4.213) | (4.576) |
| Change in FFR (t-2 to t-1) | 0.473*** | 1.230*** | -0.0246 | -0.00840 |
| | (5.531) | (3.303) | (-0.311) | (-0.184) |
| Change in FFR (t-3 to t-2) | -0.00988 | -0.494 | 0.00603 | -0.0111 |
| | (-0.126) | (-1.248) | (0.0775) | (-0.241) |
| Change in FFR (t-4 to t-3) | -0.242*** | 0.305 | -0.0711 | -0.0321 |
| | (-3.711) | (0.939) | (-1.132) | (-0.867) |
| *Sum of Effects* | -0.4594*** | 1.5724*** | 0.21*** | 0.1312*** |
| | (-7.34) | (5.78) | (3.40) | (3.93) |
| Young Deposit-Base | 0.0149 | 0.240 | 0.0509 | 0.0196 |
| | (0.220) | (0.842) | (0.705) | (0.545) |
| Young Deposit-Base x Change in FFR (t-1 to t) | -0.0546 | -0.320 | -0.00482 | -0.0173 |
| | (-0.602) | (-0.733) | (-0.0524) | (-0.335) |
| Young Deposit-Base x Change in FFR (t-2 to t-1) | -0.0101 | 0.0312 | 0.117 | 0.0552 |
| | (-0.0845) | (0.0626) | (1.083) | (0.896) |
| Young Deposit-Base x Change in FFR (t-3 to t-2) | 0.0382 | 0.673 | 0.0843 | 0.0566 |
| | (0.346) | (1.284) | (0.793) | (0.917) |
| Young Deposit-Base x Change in FFR (t-4 to t-3) | -0.177** | 0.139 | 0.0468 | 0.0211 |
| | (-2.035) | (0.346) | (0.562) | (0.442) |
| *Sum of Effects* | -0.2032*** | 0.5241* | 0.2432*** | 0.1155*** |
| | (-2.80) | (1.71) | (3.40) | (3.05) |
| MSA log Population | 2.215*** | 8.322*** | 0.0318 | 0.242 |
| | (4.339) | (3.556) | (0.0650) | (0.929) |
| MSA Income Per Capita | 6.52e-06 | -4.04e-05 | 2.17e-05*** | 7.83e-06** |
| | (0.887) | (-1.228) | (2.984) | (2.029) |
| MSA Unemployment Rate | -0.0531*** | -0.559*** | -0.0882*** | -0.0503*** |
| | (-3.041) | (-6.236) | (-4.027) | (-4.503) |
| Credit Spread (t-1) | 0.391*** | -1.521*** | -0.326*** | -0.175*** |
| | (8.624) | (-7.463) | (-6.864) | (-6.843) |
| Term Premium (t-1) | -0.135*** | 0.373*** | -0.0527* | -0.0391** |
| | (-4.702) | (2.594) | (-1.664) | (-2.335) |
| Capital Ratio (t-4) | 0.0396*** | 0.426*** | 0.0940*** | 0.0511*** |
| | (3.184) | (7.784) | (7.410) | (7.947) |
| Log Assets (t-4) | -0.955*** | -3.802*** | -0.243*** | -0.221*** |
| | (-10.69) | (-10.01) | (-2.874) | (-4.990) |
| Liability Interest Rate (t-4) | -0.0499*** | -0.157** | -0.0266* | -0.0145* |
| | (-3.322) | (-2.356) | (-1.763) | (-1.808) |
| Liquid Asset Ratio (t-4) | -0.00736*** | -0.0116 | -0.00951*** | -0.00453*** |
| | (-2.953) | (-1.018) | (-3.955) | (-3.561) |
| RE Loan to Total Loan Ratio (t-4) | 0.00175 | 0.00955 | -0.00132 | -0.000331 |
| | (0.760) | (0.879) | (-0.593) | (-0.270) |
| CI Loan to Total Loan Ratio (t-4) | 0.00549* | 0.0226* | -0.000420 | 0.000830 |
| | (1.835) | (1.745) | (-0.143) | (0.539) |
| Bank-level Total Loan Growth (t-4) | 0.0163*** | 0.00548 | -0.00140 | -0.00107 |
| | (9.799) | (0.749) | (-0.840) | (-1.253) |
| Aggregate-level Total Loan Growth (t-4) | -0.0134*** | 0.0321*** | 0.00817*** | 0.00485*** |
| | (-15.78) | (8.009) | (9.760) | (10.19) |
| Observations | 85,330 | 85,330 | 85,330 | 85,330 |
| R-squared | 0.115 | 0.056 | 0.063 | 0.054 |
| Bank FE and Quarter FE | Yes | Yes | Yes | Yes |

# Table 6: Difference in Funding Composition Sensitivity by Deposit-base Faced by Local Banks and by the Size of Bank

We report the panel regression estimates of the relationship between the change in bank fund composition and the change in the federal funds rate by the size of banks and by deposit-base faced by local banks. We only include local banks, that is, the banks with more than 70% of deposit on average coming from one MSA. For each local bank, we compute the deposit-weighted fraction of senior population from the county-level fraction of senior population (whose age is above 65). We define a bank as facing young(old) deposit-base if its average deposit-weighted fraction of old population is below(above) the median. We define a bank as LM bank dummy if its asset size is above 95 percentile among all banks. We interact the changes in the federal funds rate with LM Bank dummy. Columns (1), (3), (5) report the results of banks facing old deposit-base and columns (2), (4), (6) report the results of banks facing young deposit-base. Other regression specification is same as in Table 2 except additional MSA-level variables. We report the sum of the estimates of lagged FFR. The table reports point estimates with t-statistics in parentheses. All the standard errors are clustered at the bank level. ***, **, * denotes 1%, 5%, and 10% statistical significance.

| | Old | Young | Old | Young | Old | Young |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Variables | % Change in RD | | % Change in WSF | | Change in WSF to RD | |
| Change in FFR (t-1 to t) | -0.559*** | -0.863*** | 0.534 | 0.221 | 0.265*** | 0.299*** |
| | (-7.858) | (-12.01) | (1.400) | (0.615) | (3.460) | (3.961) |
| Change in FFR (t-2 to t-1) | 0.445*** | 0.492*** | 1.174*** | 1.336*** | -0.0472 | 0.117 |
| | (5.260) | (5.845) | (3.026) | (3.540) | (-0.588) | (1.446) |
| Change in FFR (t-3 to t-2) | -0.101 | 0.125 | -0.374 | 0.0254 | 0.0518 | 0.0224 |
| | (-1.279) | (1.535) | (-0.905) | (0.0652) | (0.649) | (0.287) |
| Change in FFR (t-4 to t-3) | -0.201*** | -0.436*** | 0.298 | 0.529 | -0.0905 | 0.00111 |
| | (-2.879) | (-6.264) | (0.821) | (1.554) | (-1.354) | (0.0163) |
| *Sum of Effects* | -0.4158*** | -0.6823*** | 1.6306*** | 2.1105*** | 0.1788** | 0.4394*** |
| | (-5.77) | (-10.17) | (4.96) | (6.79) | (2.54) | (6.44) |
| LM Bank | -0.427 | 0.157 | -0.932 | 0.691 | 0.0389 | -0.0247 |
| | (-0.909) | (0.735) | (-0.353) | (0.834) | (0.0545) | (-0.123) |
| LM Bank x Change in FFR (t-1 to t) | 0.777** | 0.134 | -1.977 | 0.0443 | -0.796* | 0.502 |
| | (2.290) | (0.572) | (-1.275) | (0.0461) | (-1.723) | (1.501) |
| LM Bank x Change in FFR (t-2 to t-1) | -1.160** | 0.0468 | 0.488 | -0.704 | 0.976 | -0.364 |
| | (-2.356) | (0.156) | (0.217) | (-0.565) | (1.386) | (-0.870) |
| LM Bank x Change in FFR (t-3 to t-2) | 0.0783 | -0.496 | 1.841 | 0.366 | 0.238 | 0.506 |
| | (0.152) | (-1.642) | (0.890) | (0.322) | (0.360) | (1.278) |
| LM Bank x Change in FFR (t-4 to t-3) | -0.375 | -0.141 | -1.486 | -0.635 | 0.0628 | 0.0260 |
| | (-0.948) | (-0.564) | (-1.016) | (-0.757) | (0.169) | (0.0748) |
| *Sum of Effects* | -0.6796* | -0.4558** | -1.1338 | -0.9286 | 0.4807 | 0.6701** |
| | (-1.66) | (-2.12) | (-1.05) | (-1.35) | (0.99) | (2.35) |
| MSA log Population | 2.310*** | 1.703** | 9.696*** | 7.829** | 0.266 | 0.424 |
| | (3.319) | (2.107) | (2.669) | (2.383) | (0.417) | (0.554) |
| MSA Income Per Capita | 2.15e-06 | 1.41e-05 | -0.000120** | 3.89e-06 | 8.21e-06 | 2.67e-05** |
| | (0.192) | (1.414) | (-2.242) | (0.0926) | (0.787) | (2.528) |
| MSA Unemployment Rate | -0.00845 | -0.0735*** | -0.449*** | -0.682*** | -0.0974*** | -0.0922*** |
| | (-0.325) | (-3.027) | (-3.344) | (-5.158) | (-3.640) | (-2.852) |
| Credit Spread (t-1) | 0.397*** | 0.384*** | -1.374*** | -1.579*** | -0.298*** | -0.339*** |
| | (5.947) | (6.112) | (-4.532) | (-5.594) | (-4.321) | (-5.040) |
| Term Premium (t-1) | -0.228*** | -0.0742* | 0.256 | 0.509** | -0.0366 | -0.0439 |
| | (-5.373) | (-1.848) | (1.204) | (2.490) | (-0.864) | (-0.944) |
| Capital Ratio (t-4) | 0.0356** | 0.0368** | 0.350*** | 0.479*** | 0.0700*** | 0.112*** |
| | (2.059) | (2.015) | (4.255) | (6.280) | (3.795) | (6.134) |
| Log Assets (t-4) | -0.854*** | -1.037*** | -3.665*** | -3.931*** | -0.247* | -0.237** |
| | (-6.270) | (-8.195) | (-5.813) | (-7.931) | (-1.892) | (-2.031) |
| Liability Interest Rate (t-4) | -0.00352 | -0.0968*** | -0.147 | -0.178* | -0.0585*** | 0.00146 |
| | (-0.164) | (-4.486) | (-1.542) | (-1.799) | (-2.614) | (0.0664) |
| Liquid Asset Ratio (t-4) | -0.00607 | -0.00688* | -0.0340* | -0.00209 | -0.0147*** | -0.00670** |
| | (-1.610) | (-1.952) | (-1.804) | (-0.139) | (-3.775) | (-2.089) |
| RE Loan to Total Loan Ratio (t-4) | -0.00453 | 0.00477 | 0.00280 | 0.0217 | 0.00131 | -0.00224 |
| | (-1.200) | (1.551) | (0.163) | (1.459) | (0.387) | (-0.702) |
| CI Loan to Total Loan Ratio (t-4) | -0.000464 | 0.00901** | 0.0116 | 0.0259 | -0.00101 | -0.00112 |
| | (-0.0969) | (2.218) | (0.493) | (1.603) | (-0.199) | (-0.290) |
| Bank-level Total Loan Growth (t-4) | 0.0167*** | 0.0159*** | 0.00437 | -7.32e-05 | -0.00359 | -0.00120 |
| | (6.978) | (7.027) | (0.368) | (-0.00755) | (-1.392) | (-0.548) |
| Aggregate-level Total Loan Growth (t-4) | -0.0147*** | -0.0125*** | 0.0343*** | 0.0301*** | 0.00935*** | 0.00723*** |
| | (-12.01) | (-10.58) | (5.674) | (5.578) | (7.960) | (6.205) |
| Observations | 36,625 | 48,705 | 36,625 | 48,705 | 36,625 | 48,705 |
| R-squared | 0.117 | 0.123 | 0.058 | 0.064 | 0.062 | 0.076 |
| Bank FE and Quarter FE | Yes | Yes | Yes | Yes | Yes | Yes |

## Table 7: The Impact of Monetary Policy on the Effect of Bank Funding Composition Sensitivity on Bank Total Lending

We report the time series regression estimates of the relationship between the effect of bank funding composition sensitivity on bank total lending and the change in the federal funds rate (FFR). We follow the two-stage regression of Kashyap and Stein (2000). The dependent variables are the regression coefficients from the first stage regression ($\beta_t$), where we estimate quarter by quarter effect of funding composition sensitivity on bank total lending. We measure a bank's funding composition sensitivity to monetary policy in four different ways: (1) the correlation between the quarterly change in WSF to RD and the quarterly change in FFR using past 5 years of sample; (2) the decile groups by the correlation in (1); (3) the correlation as in (1) with 3 years of sample; and (4) the decile groups by the correlation in (3). For each quarter, we first run the following regression:

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

where $B_{i,t}$ is the measure of bank funding composition sensitivity. Column (1)-(4) report the second-stage results where the dependent variables are $\{\beta_t\}$ from the first-stage using the respective measures of bank's funding composition sensitivity ((1)-(4) above). The independent variables are 4 lags of the change in FFR, quarter fixed effects, linear time trend and we report the sum of the estimates of lagged FFR. Columns (1)-(2) are from 1996 to 2006 and columns (3)-(4) are from 1994 to 2006. We report the sum of the estimates of lagged FFR. The table reports point estimates with t-statistics in parentheses. We report the Newey-West standard error with lag 4. ***, **, * denotes 1%, 5%, and 10% statistical significance.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Variables | The Effect on Bank Total Lending from the Bank Funding Sensitivity ($\beta_t$) | | | |
| Change in FFR (t-1 to t) | 0.00581** | 0.00707*** | 0.00397* | 0.00371 |
| | (2.188) | (2.849) | (1.988) | (1.600) |
| Change in FFR (t-2 to t-1) | 0.00224 | 0.000729 | 0.00282 | 0.00273 |
| | (1.035) | (0.311) | (1.610) | (1.307) |
| Change in FFR (t-3 to t-2) | -0.000218 | -0.000385 | -0.000924 | -7.92e-05 |
| | (-0.205) | (-0.236) | (-1.091) | (-0.0667) |
| Change in FFR (t-4 to t-3) | 0.000642 | 0.000204 | -1.35e-05 | -0.00176 |
| | (0.758) | (0.240) | (-0.0123) | (-0.931) |
| *Sum of Effects* | 0.0085*** | 0.0076*** | 0.0059*** | 0.0046*** |
| | (6.54) | (6.33) | (4.54) | (3.29) |
| Linear Time Trend | -0.000315*** | -0.000344*** | -0.000197*** | -0.000215*** |
| | (-8.208) | (-8.450) | (-4.000) | (-4.115) |
| Observations | 44 | 44 | 52 | 52 |

## Table 8: Change in Wholesale Fund Reliance by Reliance Level and the Federal Funds Rate

We report the panel regression estimates of the relationship between the change in bank's wholesale fund reliance by the level of bank's wholesale fund reliance and the change in federal funds rate (FFR). We use bank-quarter observations from 1992 to 2006. Column (1) reports the results with all banks, column (2) reports the results with small banks (banks below 95% in asset distribution), column (3) reports the results with medium banks (banks within 95% to 99%), and column (4) reports the results with large banks (banks above 99%). The dependent variable is the change in bank's wholesale fund to retail deposit ratio (WSF to RD) from previous quarter. The independent variables include 4 lags of the change in FFR, the level of 4 quarter lagged WSF to RD, and the interactions of them. We report the sum of the estimates of interaction terms. Other bank-level characteristics are same as in Table 2. The table reports point estimates with t-statistics in parentheses. All the standard errors are clustered at the bank level. ***, **, * denotes 1%, 5%, and 10% statistical significance.

| | All | Small | Medium | Large |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Variables | Change in WSF to RD | | | |
| Change in FFR (t-1 to t) | -0.0211 | -0.0404 | 0.0473 | -0.0618 |
| | (-0.415) | (-0.755) | (0.171) | (-0.0670) |
| Change in FFR (t-2 to t-1) | 0.0492 | 0.0514 | 0.287 | 1.418 |
| | (0.816) | (0.813) | (0.805) | (1.223) |
| Change in FFR (t-3 to t-2) | 0.105* | 0.126** | -0.318 | 0.0478 |
| | (1.791) | (2.155) | (-0.823) | (0.0502) |
| Change in FFR (t-4 to t-3) | -0.149*** | -0.130*** | -0.0659 | -1.308 |
| | (-3.163) | (-2.740) | (-0.215) | (-1.548) |
| WSF to RD (t-4) | -0.0282*** | -0.0280*** | -0.0454*** | -0.0301*** |
| | (-14.76) | (-14.12) | (-5.399) | (-2.655) |
| WSF to RD (t-4) x Change in FFR (t-1 to t) | 0.0196*** | 0.0207*** | 0.0160* | 0.0120 |
| | (7.393) | (7.085) | (1.819) | (0.718) |
| WSF to RD (t-4) x Change in FFR (t-2 to t-1) | 0.000784 | -0.000354 | -0.00198 | -0.00696 |
| | (0.244) | (-0.101) | (-0.186) | (-0.282) |
| WSF to RD (t-4) x Change in FFR (t-3 to t-2) | -0.00530* | -0.00579* | 0.00466 | -0.0133 |
| | (-1.687) | (-1.774) | (0.361) | (-0.672) |
| WSF to RD (t-4) x Change in FFR (t-4 to t-3) | 0.00526** | 0.00428* | 0.00193 | 0.0325* |
| | (2.180) | (1.677) | (0.203) | (1.927) |
| *Sum of Effects* | 0.0204*** | 0.0188*** | 0.0207** | 0.0243* |
| | (8.87) | (8.55) | (2.03) | (1.91) |
| Credit Spread (t-1) | -0.00425 | -0.0294 | 0.423** | -0.0574 |
| | (-0.185) | (-1.300) | (2.582) | (-0.135) |
| Term Premium (t-1) | -0.204*** | -0.191*** | -0.473*** | -0.223 |
| | (-17.59) | (-16.65) | (-5.239) | (-1.040) |
| Capital Ratio (t-4) | 0.0621*** | 0.0595*** | 0.115** | 0.325** |
| | (9.471) | (9.268) | (2.059) | (2.501) |
| Log Assets (t-4) | 0.263*** | 0.304*** | 0.198 | -0.237 |
| | (6.336) | (7.750) | (0.646) | (-0.628) |
| Liability Interest Rate (t-4) | -0.00552 | -0.0116 | 0.0374 | 0.148 |
| | (-0.584) | (-1.262) | (0.440) | (0.822) |
| Liquid Asset Ratio (t-4) | -0.00702*** | -0.00778*** | 0.0120 | 0.0318 |
| | (-5.918) | (-6.527) | (1.193) | (1.388) |
| RE Loan to Total Loan Ratio (t-4) | -0.000523 | -0.00111 | 0.00363 | -0.00556 |
| | (-0.450) | (-1.000) | (0.276) | (-0.166) |
| CI Loan to Total Loan Ratio (t-4) | -0.00270 | -0.00203 | -0.00272 | -0.0445 |
| | (-1.478) | (-1.130) | (-0.145) | (-0.807) |
| Bank-level Total Loan Growth (t-4) | 0.00149* | 0.00151* | -0.00291 | -0.000838 |
| | (1.754) | (1.786) | (-0.448) | (-0.0555) |
| Aggregate-level Total Loan Growth (t-4) | 0.00725*** | 0.00684*** | 0.0144*** | 0.0176** |
| | (14.05) | (13.20) | (4.104) | (2.218) |
| Observations | 223,679 | 212,510 | 8,940 | 2,229 |
| R-squared | 0.065 | 0.062 | 0.115 | 0.154 |
| Bank FE and Quarter FE | Yes | Yes | Yes | Yes |

## Table 9: Liquidity Ratio, Asset Size, and Monetary Policy

This table shows the empirical analysis based on the sample of BHCs included in FR-Y9C, from 1995Q1 to 2015Q1. We exclude any bank-quarter sample with asset size lower than 1 billion dollars. Column (1) reports the panel regression result of Liquidity Ratio on lagged log bank asset size. We include time fixed effects and standard errors are clustered by bank. Columns (2) to (6) report the panel regression result of changes in Liquidity Ratio on lagged changes in the federal funds rate. The table reports point estimates with t-statistics in parentheses. ***, **, * denotes 1%, 5%, and 10% statistical significance.

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Variables | Liquidity Ratio | Change in Liquidity Ratio | | | |
| Change in FFR (t-2 to t-1) | | -0.0343*** | -0.0392*** | -0.0316*** | -0.0318*** |
| | | (-2.86) | (-7.61) | (-9.38) | (-11.00) |
| log Assets (t-1) | -0.134** | | 0.0066 | | 0.0091 |
| | (-1.97) | | (0.74) | | (1.39) |
| Loan Ratio (t-1) | | | -0.0027 | | -0.0032 |
| | | | (-0.68) | | (-1.43) |
| Capital Ratio (t-1) | | | 0.0187 | | 0.0148 |
| | | | (1.11) | | (1.15) |
| Liquid Asset Ratio (t-1) | | | -0.0060 | | -0.0097*** |
| | | | (-1.24) | | (-2.8) |
| Observations | 31652 | 29285 | 27842 | 29285 | 27842 |
| R-squared | 0.0173 | 0.0004 | 0.0157 | 0.0922 | 0.0942 |
| FE | Year x Quarter | – | – | Bank | Bank |

## Figure 1: Retail Deposit, Federal Funds Rate, and MMF

The figure shows the time series of the change in federal funds rate, the change in aggregate amount of checkable deposit, and the change in aggregate amount in money market funds. Panel A plots the change in aggregate amount of checkable deposit with the change in federal funds rate. Panel B plots the change in aggregate amount in money market funds with the change in aggregate amount of checkable deposit.

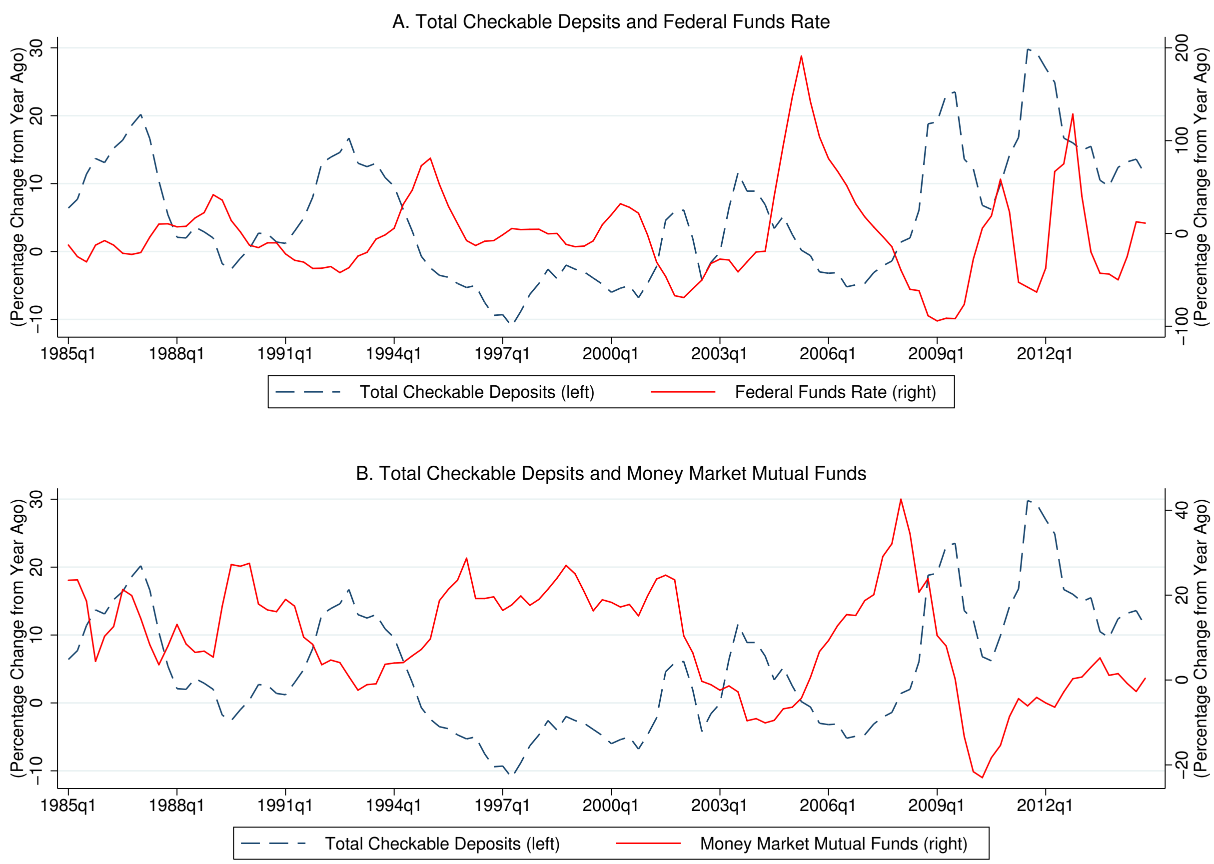
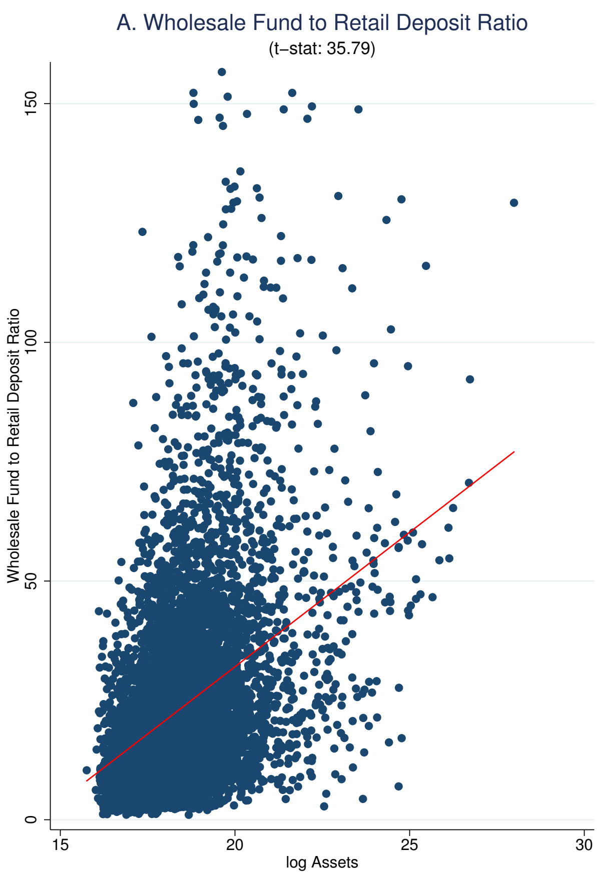


**Figure 2: Wholesale Fund to Retail Deposit Ratio and Liquidity Ratio by Asset Size**

The figure reports the correlation of bank size with wholesale fund to retail deposit ratio (WSF to RD) and liquid asset ratio. We take time series average of WSF to RD, Liquid Asset Ratio, and log Assets by bank from 1992 to 2006. Panel A shows the scatter plot of WSF to RD with log Assets. We include a linear fitted line on scatter plot. We report t-statistics of linear fitted line in parenthesis. Panel B shows the scatter plot of Liquid Asset Ratio with log Assets.



## Figure 3: Wholesale Fund to Retail Deposit Ratio

The figure shows the time series of wholesale fund to retail deposit ratio (WSF to RD). Panel A shows the aggregate WSF to RD, which we aggregate retail deposit and wholesale fund by quarter for all banks in FR-Y9C and construct the ratio. Panel A plots the federal funds rate with the aggregate WSF to RD from 1990 to 2014. Panel B shows the average WSF to RD of banks in our sample by quarter from 1990 to 2014.

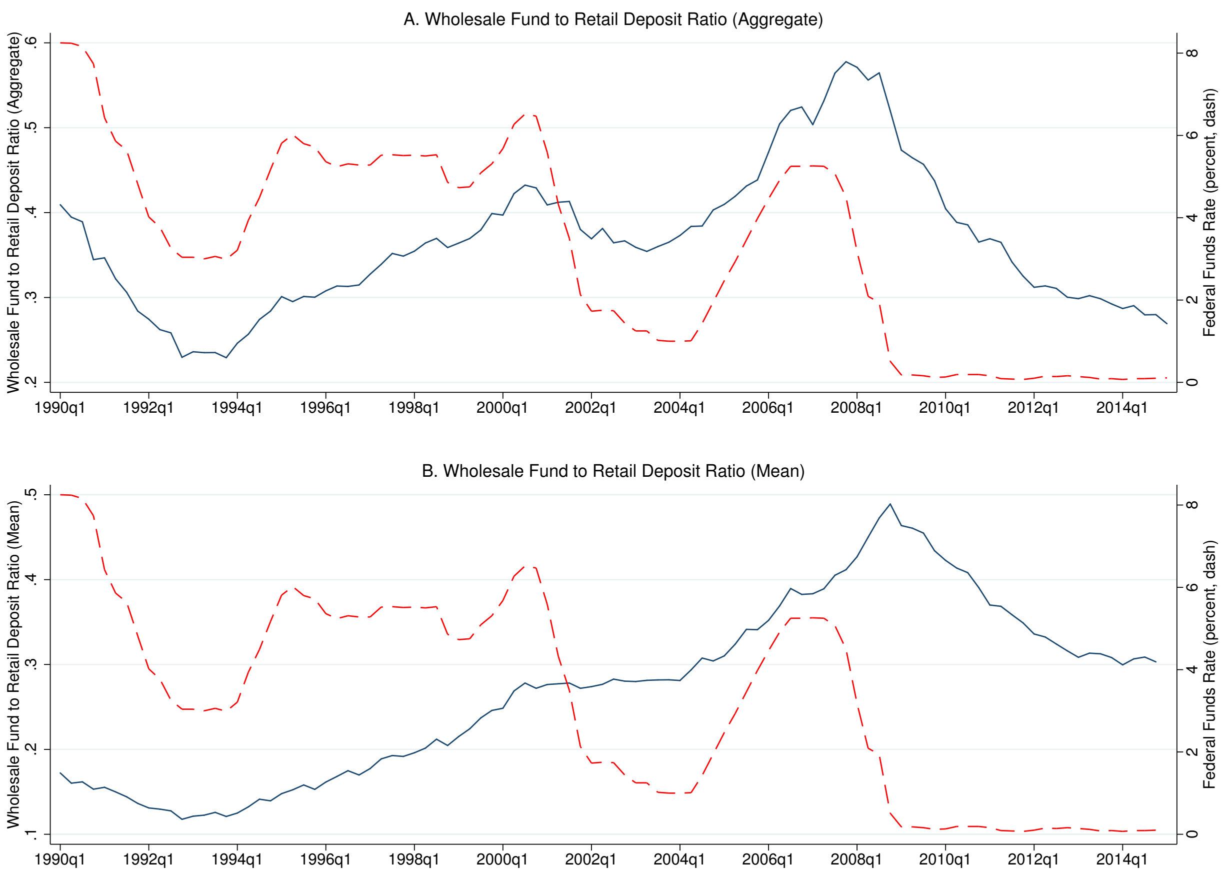


**Figure 4: The Effect of Bank Funding Composition Sensitivity on Bank Total Lending**

This figure shows the historical trends in the effect of the bank funding composition sensitivity on the bank lending. We plot the residuals from the regression of the impact of the bank funding composition sensitivity on the bank lending growth, i.e., $\{\beta_t\}$ from the first stage regression of Table 7, on quarter fixed effects and linear time trend. We use three year correlation between the change in the federal funds rate and the change in bank wholesale fund reliance (WSF to RD) as the measure of funding composition sensitivity to monetary policy. We also include the time series of the federal funds rate.

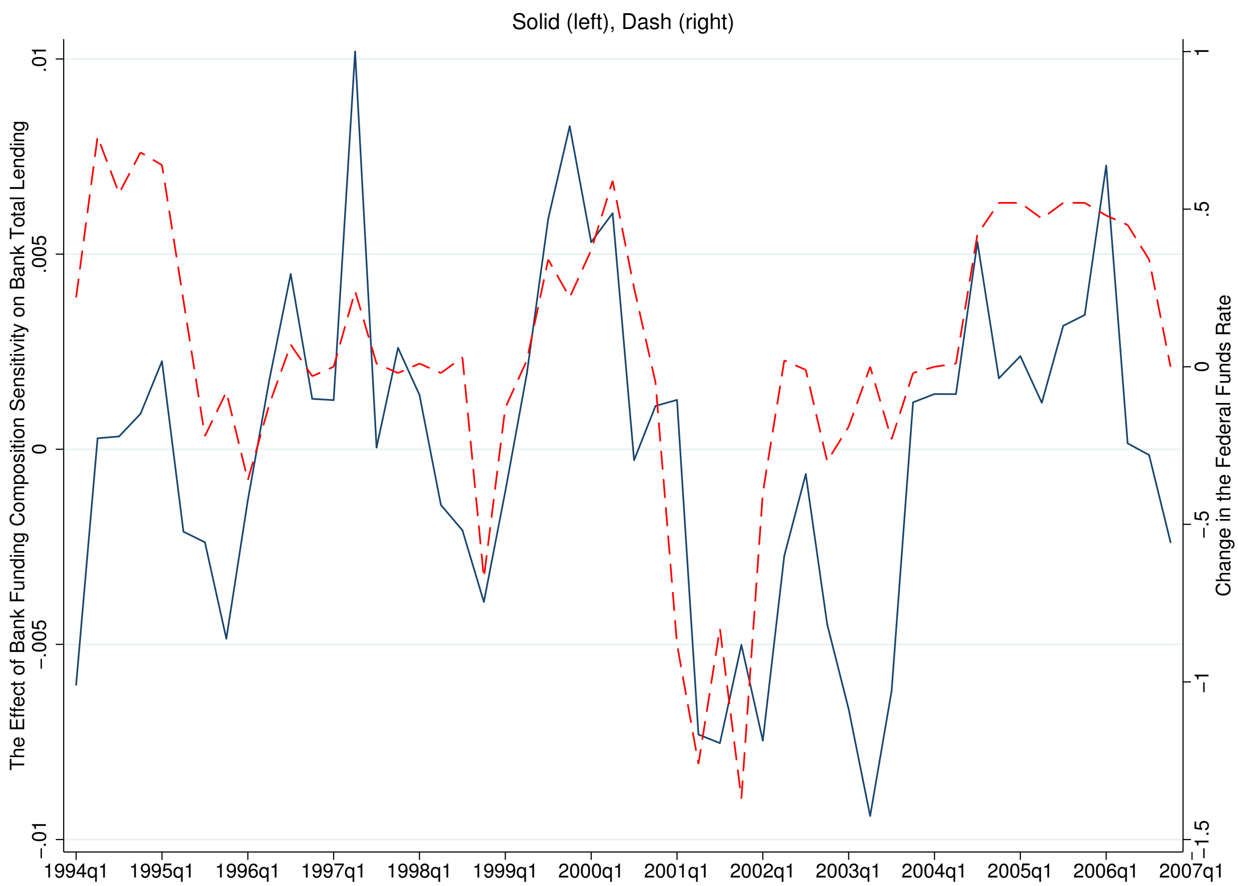
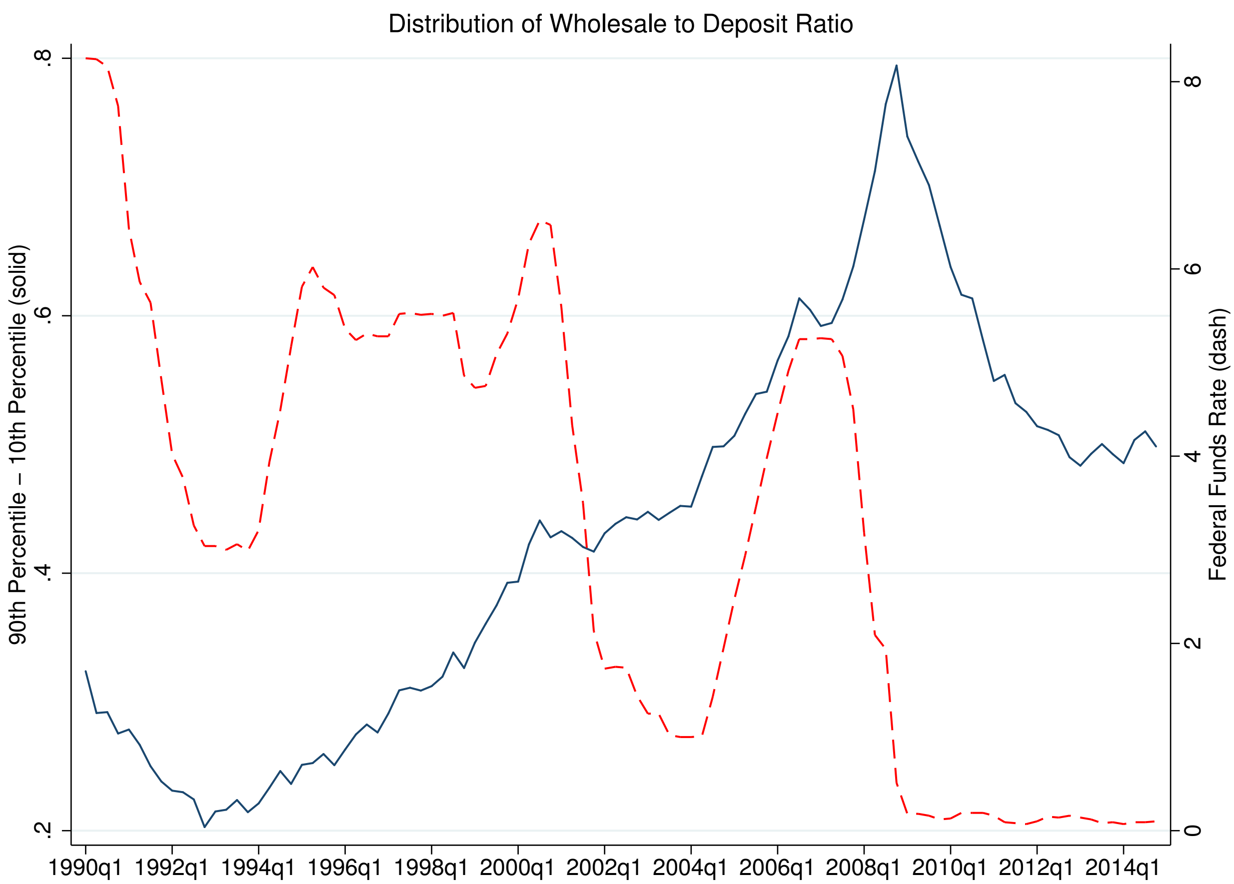


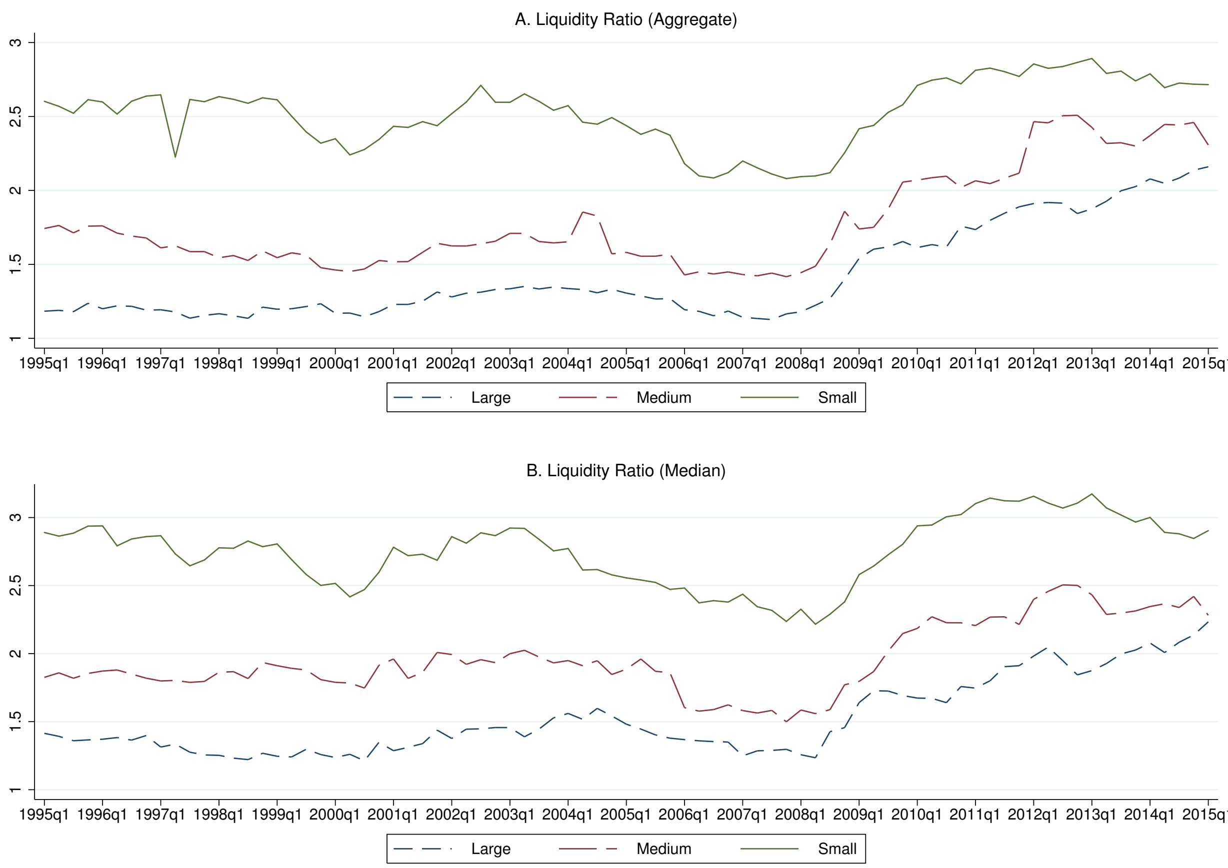
**Figure 5: Concentration of Wholesale Fund**

We plot the time trend of the wholesale distribution in banking sector. We plots the difference between 90 percentile and 10 percentile in the distribution of wholesale fund to retail deposit ratio (WSF to RD) for each quarter from 1990 to 2014. We include the time series of the federal funds rate.



## Figure 6: Historical Trends of Liquidity Ratio (LR)

This figure shows the time series of Liquidity Ratio (our proxy for LCR) for the three asset size groups. This figure is based on the sample of BHCs included in FR-Y9C, from 1995Q1 to 2015Q1. We exclude any bank-quarter sample with asset size lower than 1 billion dollars. In each quarter, any bank with asset size lower than the 95 percentile belongs to"small" group; "large" if greater than the 99 percentile; "medium" for the 95 to 99 percentile. Panel A reports the aggregate liquidity ratio and Panel B reports the median liquidity ratio.



# 6. Appendix

## 6.1. Construction of the Liquidity Ratio

In this section, we describe our construction of the Liquidity Ratio ("LR") of a bank based on the publicly available data sources (FR Y-9C form). *LR* is conceptually similar to and tries to approximate the LCR by calculating the potential liquidity stress of a bank during a liquidity stress scenario. We limit our analysis to the entities reporting FR Y-9C, with total asset larger than \$1 billion, and samples after 1995Q1 for consistency in the variable definitions.

The LR consists of two parts: The denominator is the sum of liabilities and off balance sheet exposures, weighted by liquidity adjustments reflecting the run-risk of each liability type or off balance sheet exposure; the numerator is the sum of assets, weighted by liquidity adjustments reflecting the market liquidity of each asset type. Adjusted liabilities grow when the expected funding outflow is higher during times of stress, while adjusted assets shrink when the expected price decline is greater in a market illiquidity event. Thus, a bank is more exposed to liquidity risks if its liquidity ratio is lower.[21]

$$\begin{aligned}\text{Liquidity Ratio} &= \frac{\text{potential liquidity inflow}}{\text{potential liquidity outflow}} \\ &= \frac{\text{liquidity adjusted assets}}{\text{liquidity adjusted liabilities and off balance sheet exposures}}\end{aligned}$$

Table A1 summarizes liquidity adjustments used in the calculation of the LR, which adopts some of the LCR assumptions when possible. Figure 6 describes the time series of LR, for the three groups based on the asset size.

[21] This is thus similar to LCR which is the ratio of the stock of high quality liquid assets (HQLA) to potential net cash-flow over the next 30 calendar day liquidity stress scenario. However, there are differences in the liquidity adjustments for certain assets and liability classes from those used in the LCR because we use publicly-available data. We also exclude any derivative exposures due to data limitation.

## Table A1: Liquidity Adjustments for Liquidity Ratio Calculation

This table presents the liquidity adjustments for balance sheet items based on FR Y-9C. Liquidity Ratio is defined as the ratio between liquidity-adjusted assets and liquidity-adjusted liabilities. Liquidity-adjusted assets are the summation of balance sheet assets weighted by respective liquidity adjustments, and liquidity-adjusted liabilities and off-balance-sheet exposures are calculated in a similar way. Stable deposits include money market deposit accounts and other savings accounts as well as time deposits of less than $ 100,000. All other deposits are considered as non stable deposits.

| Balance Sheet Items | Liquidity Adjustment |
|---|---|
| **Assets** | |
| Cash and balances due from depository institutions | 1 |
| Federal funds sold and securities purchased under agreements to resell | 1 |
| Treasury | 1 |
| Agency MBS | 0.9 |
| Non-agency MBS | 0.75 |
| Agency securities | 0.85 |
| Municipal securities | 0.85 |
| Other securities | 0.5 |
| Real Estate Loans | 0.3 |
| Commercial and Industrial Loans | 0.1 |
| Other Loans | 0.2 |
| **Liability** | |
| Federal funds purchased and securities sold under agreements to resell | 1 |
| Trading Liabilities | 0.5 |
| Commercial Paper | 0.5 |
| Other borrowed money, maturity less than 1 year | 0.4 |
| Deposit, non stable | 0.15 |
| Deposit, stable | 0.1 |
| **Off Balance Sheet Items** | |
| Unused Commitments | 0.1 |
| Standby letters of credit | 0.1 |
| Securities underwriting | 0.3 |
| Securities lent | 0.1 |

## Table A2: Bank Fund Decomposition and the Federal Funds Rate: Subsample of 1992 to 2000

We report panel regression estimate of the relationship between the change in bank fund composition and the change in federal funds rate (FFR). Regression specification is same as Table 2 except the sample period is from 1992 to 2000. We report the sum of the estimates of lagged FFR. The table reports point estimates with t-statistics in parentheses. All the standard errors are clustered at the bank level. ***, **, * denotes 1%, 5%, and 10% statistical significance.

| Variables | (1)<br>% Change in<br>RD | (2)<br>% Change in<br>WSF | (3)<br>Change in<br>WSF to RD | (4)<br>Change in<br>RD to TL | (5)<br>Change in<br>WSF to TL |
|---|---|---|---|---|---|
| Change in FFR (t-1 to t) | -1.291*** | 3.121*** | 0.716*** | -0.429*** | 0.441*** |
| | (-30.21) | (10.43) | (19.17) | (-17.53) | (18.20) |
| Change in FFR (t-2 to t-1) | 0.228*** | 2.652*** | 0.0636 | -0.104*** | 0.0844*** |
| | (4.700) | (8.368) | (1.516) | (-3.771) | (3.111) |
| Change in FFR (t-3 to t-2) | 0.435*** | -0.757*** | -0.213*** | 0.131*** | -0.139*** |
| | (10.01) | (-2.662) | (-5.658) | (5.250) | (-5.675) |
| Change in FFR (t-4 to t-3) | -0.411*** | -0.0182 | -0.114*** | -0.000775 | -0.0605*** |
| | (-10.21) | (-0.0674) | (-3.274) | (-0.0342) | (-2.682) |
| *Sum of Effects* | -1.0393*** | 4.9978*** | 0.4531*** | -0.4029*** | 0.3259*** |
| | (-31.02) | (21.95) | (15.95) | (-22.51) | (18.21) |
| Credit Spread (t-1) | 0.0662* | -1.604*** | -0.156*** | 0.145*** | -0.115*** |
| | (1.816) | (-6.932) | (-4.908) | (7.223) | (-5.767) |
| Term Premium (t-1) | -0.199*** | -1.246*** | -0.277*** | 0.171*** | -0.178*** |
| | (-9.821) | (-9.958) | (-16.12) | (16.71) | (-17.41) |
| Capital Ratio (t-4) | 0.0251** | 0.626*** | 0.0575*** | -0.0407*** | 0.0411*** |
| | (2.348) | (9.820) | (6.690) | (-7.744) | (7.877) |
| Log Assets (t-4) | -0.775*** | -4.194*** | -0.141** | 0.146*** | -0.157*** |
| | (-10.54) | (-9.584) | (-2.249) | (4.063) | (-4.350) |
| Liability Interest Rate (t-4) | -0.0360*** | -0.139** | -0.0176* | 0.0126** | -0.0135** |
| | (-2.874) | (-1.995) | (-1.704) | (2.002) | (-2.136) |
| Liquid Asset Ratio (t-4) | -0.00252 | 0.0364*** | -0.00327** | 0.00239** | -0.00166* |
| | (-1.250) | (3.284) | (-2.021) | (2.383) | (-1.676) |
| RE Loan to Total Loan Ratio (t-4) | 0.00905*** | -0.00614 | -0.00411** | 0.00202** | -0.00189** |
| | (4.726) | (-0.554) | (-2.559) | (2.101) | (-1.980) |
| CI Loan to Total Loan Ratio (t-4) | 0.00400 | -0.00169 | -0.00248 | 0.00141 | -0.00131 |
| | (1.543) | (-0.125) | (-1.110) | (1.061) | (-0.987) |
| Bank-level Total Loan Growth (t-4) | 0.0112*** | 0.0113 | -0.00188* | 0.00130** | -0.00104* |
| | (9.531) | (1.629) | (-1.955) | (2.171) | (-1.746) |
| Aggregate-level Total Loan Growth (t-4) | -0.0103*** | 0.0264*** | 0.00637*** | -0.00426*** | 0.00391*** |
| | (-15.39) | (6.693) | (10.64) | (-11.39) | (10.45) |
| Observations | 137,935 | 137,935 | 137,935 | 137,935 | 137,935 |
| R-squared | 0.154 | 0.052 | 0.069 | 0.065 | 0.060 |
| Bank FE and Quarter FE | Yes | Yes | Yes | Yes | Yes |

## Table A3: Bank Fund Decomposition and the Federal Funds Rate: Subsample of 2000 to 2006

We report panel regression estimate of the relationship between the change in bank fund composition and the change in federal funds rate (FFR). Regression specification is same as Table 2 except the sample period is from 2000 to 2006. We report the sum of the estimates of lagged FFR. The table reports point estimates with t-statistics in parentheses. All the standard errors are clustered at the bank level. ***, **, * denotes 1%, 5%, and 10% statistical significance.

| Variables | (1)<br>% Change in<br>RD | (2)<br>% Change in<br>WSF | (3)<br>Change in<br>WSF to RD | (4)<br>Change in<br>RD to TL | (5)<br>Change in<br>WSF to TL |
|---|---|---|---|---|---|
| Change in FFR (t-1 to 1) | -0.255*** | -0.0452 | 0.0119 | 0.00268 | 0.0168 |
| | (-5.540) | (-0.236) | (0.242) | (0.100) | (0.630) |
| Change in FFR (t-2 to t-1) | 0.230*** | -0.411* | -0.0414 | 0.0115 | -0.0550* |
| | (4.242) | (-1.923) | (-0.738) | (0.376) | (-1.811) |
| Change in FFR (t-3 to t-2) | -0.325*** | 0.572*** | 0.229*** | -0.100*** | 0.139*** |
| | (-6.290) | (2.662) | (4.250) | (-3.401) | (4.711) |
| Change in FFR (t-4 to t-3) | 0.0285 | 0.926*** | 0.0845 | -0.130*** | 0.0523* |
| | (0.536) | (4.329) | (1.478) | (-4.263) | (1.726) |
| *Sum of Effects* | -0.321*** | 1.041*** | 0.284*** | -0.216*** | 0.153*** |
| | (-7.24) | (6.17) | (6.17) | (-8.89) | (6.29) |
| Credit Spread (t-1) | 0.654*** | -2.537*** | -0.600*** | 0.433*** | -0.358*** |
| | (12.37) | (-11.61) | (-10.39) | (14.07) | (-11.67) |
| Tarm Premium (t-1) | -0.162*** | 0.191 | 0.0703** | -0.0945*** | 0.0394** |
| | (-5.110) | (1.534) | (2.006) | (-5.171) | (2.182) |
| Capital Ratio (t-1) | 0.0497*** | 0.557*** | 0.126*** | -0.0752*** | 0.0659*** |
| | (3.466) | (10.37) | (7.801) | (-9.471) | (8.428) |
| Log Assets (t-4) | -0.994*** | -6.412*** | -0.615*** | 0.539*** | -0.493*** |
| | (-9.400) | (-16.98) | (-5.106) | (9.202) | (-8.558) |
| Liability Interest Rate (t-4) | -0.0812*** | -0.291*** | -0.112*** | 0.0441*** | -0.0410*** |
| | (-4.039) | (-4.327) | (-4.919) | (4.004) | (-3.759) |
| Liquid Asset Ratio (t-4) | -0.00358 | -0.0493*** | -0.0190*** | 0.0102*** | -0.0100*** |
| | (-1.222) | (-4.365) | (-6.169) | (6.310) | (-6.221) |
| RE Loan to Total Loan Ratio (t-4) | 0.00735** | -0.0439*** | -0.00862*** | 0.00650*** | -0.00516*** |
| | (2.546) | (-4.055) | (-2.849) | (4.217) | (-3.389) |
| CI Loan to Total Loan Ratio (t-4) | 0.00771** | 0.0181 | -0.00169 | 0.000702 | 0.000605 |
| | (2.038) | (1.433) | (-0.396) | (0.339) | (0.296) |
| Bank-level Total Loan Growth (t-4) | 0.0114*** | -0.0156** | -0.00699*** | 0.00367*** | -0.00391*** |
| | (6.448) | (-2.323) | (-3.580) | (3.799) | (-4.066) |
| Aggregate-level Total Loan Growth (t-4) | -0.00374*** | 0.0517*** | 0.0114*** | -0.00584*** | 0.00687*** |
| | (-3.232) | (10.73) | (8.612) | (-8.581) | (10.09) |
| Observations | 99,586 | 99,586 | 99,586 | 99,586 | 99,586 |
| R-squared | 0.127 | 0.070 | 0.085 | 0.078 | 0.074 |
| Bank FE and Quarter FE | Yes | Yes | Yes | Yes | Yes |

## Table A4: Bank Wholesale Fund Decomposition

We report panel regression estimate of the relationship between the change in bank fund composition and the change in federal funds rate (FFR). Regression specification is same as Table 2 except we use subcomponents of wholesale funding as dependent variables: wholesale deposit, Repo, and Other borrowed liability. We report the sum of the estimates of lagged FFR. The table reports point estimates with t-statistics in parentheses. All the standard errors are clustered at the bank level. ***, **, * denotes 1%, 5%, and 10% statistical significance.

| Variables | (1) Change in Wholesale Deposit to TL | (2) Change in Repo Borrowing to TL | (3) Change in Other Borrowed Liability to TL |
|---|---|---|---|
| Change in FFR (t-1 to t) | 0.104*** | 0.0742*** | 0.0650*** |
| | (8.171) | (6.660) | (6.710) |
| Change in FFR (t-2 to t-1) | 0.121*** | -0.0497*** | -0.0155 |
| | (8.279) | (-3.664) | (-1.404) |
| Change in FFR (t-3 to t-2) | 0.0148 | -0.0638*** | -0.0145 |
| | (1.060) | (-4.892) | (-1.409) |
| Change in FFR (t-4 to t-3) | 0.137*** | -0.0435*** | -0.102*** |
| | (11.21) | (-4.099) | (-11.28) |
| *Sum of Effects* | 0.3762*** | -0.0827*** | -0.0669*** |
| | (33.59) | (-11.03) | (-8.16) |
| Credit Spread (t-1) | -0.0683*** | -0.0193*** | 0.0448*** |
| | (-6.956) | (-3.065) | (5.901) |
| Term Premium (t-1) | -0.0728*** | -0.0112*** | -0.0448*** |
| | (-14.76) | (-3.607) | (-12.10) |
| Capital Ratio (t-4) | 0.0167*** | 0.00826*** | 0.0214*** |
| | (6.559) | (5.497) | (11.38) |
| Log Assets (t-4) | 0.00711 | -0.0395*** | -0.129*** |
| | (0.570) | (-5.020) | (-12.22) |
| Liability Interest Rate (t-4) | -0.00161 | -0.00724*** | -0.0124*** |
| | (-0.450) | (-3.160) | (-4.017) |
| Liquid Asset Ratio (t-4) | 9.79e-05 | -0.00118*** | -0.00132*** |
| | (0.206) | (-3.891) | (-3.509) |
| RE Loan to Total Loan Ratio (t-4) | 0.000931* | -7.34e-05 | -0.00134*** |
| | (1.892) | (-0.265) | (-3.784) |
| CI Loan to Total Loan Ratio (t-4) | 0.000511 | 0.000670 | -0.000269 |
| | (0.672) | (1.350) | (-0.500) |
| Bank-level Total Loan Growth (t-4) | 0.00179*** | -0.00148*** | -0.000252 |
| | (4.952) | (-6.301) | (-0.939) |
| Aggregate-level Total Loan Growth (t-4) | 0.00133*** | 0.00233*** | 0.00104*** |
| | (5.720) | (12.54) | (5.643) |
| Observations | 223,679 | 223,679 | 223,549 |
| R-squared | 0.054 | 0.025 | 0.038 |
| Bank FE and Quarter FE | Yes | Yes | Yes |