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ABSTRACT

According to the conventional bank lending channel of monetary policy, wholesale funding in economies with well-developed financial markets moves negatively with retail deposits in response to changes in the monetary policy rate, thereby weakening the transmission of monetary policy. We present a theoretical model to demonstrate that in economies with financial repression, (i) retail deposits and wholesale funding comove positively in response to changes in the policy rate and (ii) wholesale funding strengthens, rather than weakens, the transmission of monetary policy to bank loans. We support these findings by bank-level evidence with deposit rate ceilings.

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I. Introduction

Understanding the effects of wholesale funding on the composition of banks' funding is critical for discussions of the transmission mechanism of monetary policy. According to the conventional view, wholesale funding weakens the transmission of monetary policy by providing an alternative source of funding in lieu of retail deposits. When the monetary authority reduces the interest rate, banks often substitute retail deposits for wholesale funding, and the opposite holds true when the interest rate is raised. Such a substitution effect leads to a negative correlation between retail deposits and wholesale funding in response to changes in the policy rate. This view is supported by both the classical bank lending channel (e.g., Stein (1998) and Bianchi and Bigio (2022)), where the Federal Reserve influences banks' ability to create deposits through the opportunity cost of holding reserves, and the more recent deposits channel (e.g., Drechsler et al. (2017) and Wang et al. (2022)), where changes in the federal fund rate affect banks' deposit market power.

While past studies have centered on economies with liberalized financial markets, many emerging-market economies have since World War II introduced measures of financial repression (Brunnermeier et al., 2022), such as interest rate ceilings.[1] These regulations can make it difficult for policy interest rates to effectively impact bank credit supply through retail deposits. Consequently, the relationship between changes in the policy rate and banks' funding composition, the role of wholesale funding in the transmission of monetary policy, and the implications of regulations on wholesale funding for the effectiveness of monetary policy may differ significantly from economies without financial repression. In this study, we explore how wholesale funding affects monetary policy transmission by incorporating deposit rate ceilings into a standard banking model. Our results show that in economies with financial repression, wholesale funding comoves positively with retail deposits in response to changes in the policy rate, thus enhancing the transmission of monetary policy to bank lending. This is in contrast to the scenario without financial repression. We support our theory with empirical evidence using bank-level data from China, a country that has long been subject to financial repression through interest rate ceilings.

In our model, deposit rate ceilings play a crucial role in the transmission of monetary policy through wholesale funding. In the absence of such ceilings, banks tend to substitute retail

[1] In the United States, interest rate ceilings were applied to various types of bank deposits from 1933 to 1986, under what was known as Regulation Q. This regulation, however, is not the focus of our study due to the lack of a wholesale funding market during that period.

deposits for wholesale funding when the policy rate falls, resulting in a negative comovement between the two sources of external funding. Even though the capital constraint becomes relaxed with an increase in the bank's equity, this negative comovement persists. When deposit rate ceilings are binding, however, an increase in retail deposits is constrained due to the lower bound on the deposit spread. Nevertheless, the decrease in the cost of retail deposits enhances the value of banks' equity and relaxes capital constraints, allowing them to expand their funding sources through wholesale funding. As a result, wholesale funding and retail deposits comove positively, which strengthens the transmission of monetary policy to bank loans. Similarly, when the policy rate rises, wholesale funding decreases due to a tightening of capital constraints.

Our paper contributes to the literature on the bank lending channel of monetary policy transmission. According to the traditional view, the transmission of monetary policy to bank loans begins with a quantitative change in bank reserves, which limits banks' deposit creation and credit supply (Bernanke and Blinder, 1992; Kashyap and Stein, 1995). Recent studies have examined the role of bank market power in deposit markets in the transmission of the monetary policy rate to retail deposits and wholesale funding (see, for example, Drechscher et al. (2017), Drechscher et al. (2021a), Xiao (2020), and Wang et al. (2022)). While the relative importance of the traditional bank lending channel and the deposit market power channel is still under debate, existing literature consistently finds that wholesale funding weakens monetary policy transmission by comoving negatively with retail deposits. This result suggests that liquidity regulations, such as the Basel III Liquidity Coverage Ratio (LCR) regulation, which restrict banks' exposure to wholesale funding, could enhance monetary policy transmission (Choi and Choi (2021)). However, our study departs from previous work by showing that in economies with financial repression, wholesale funding complements retail deposits in the transmission of monetary policy. As a result, liquidity regulation may hinder monetary policy transmission. Moreover, our model emphasizes that the capital constraint, which is largely ignored in the literature on the bank lending channel, is crucial for generating a positive comovement between wholesale funding and retail deposits. Our paper also contributes to the literature on the impact of deposit rate regulations (e.g., Regulation Q) on credit supply.[2] To the best of our knowledge, our study is the first to explore how deposit rate regulations affect the impact of the monetary policy rate on banks' funding composition. Moreover, our study examines the transmission of interest-rate-based

[2]See Koch (2015) and Drechscher et al. (2021b), among others.

monetary policy in the Chinese context, thereby contributing to the emerging literature on the effects of monetary policy on China's banking system.[3]

II. A banking model with financial repression

In this section, we develop a simple model that illustrates how financial repression affects the transmission of monetary policy to banks' funding composition. Our model assumes that banks are subject to reserve requirements, which are the standard component of the bank lending channel for transmitting monetary policy. In addition, banks are subject to a capital constraint, and monetary policy influences the tightness of this constraint. In our model, financial repression is characterized by a ceiling on deposit rates, which effectively places a lower bound on the spread between the policy rate and the deposit rate. We show that in this economic setting, wholesale funding can enhance the transmission of monetary policy.

II.1. **Environment.** The economy has two types of agents: competitive banks and the representative household. Banks have the option to borrow through deposits (d) or wholesale funding (w). Deposits are subject to reserve requirements, whereas wholesale funding is not. Banks can use these funds for two purposes: bank loans (l) and liquid assets in the form of cash (a). The representative household demands deposits and does not lend directly. Our analysis focuses on banks that are subject to a binding ceiling constraint on deposit rates.

II.1.1. *The household.* The household is endowed with an initial wealth of W_0 and can invest in retail deposits as well as less liquid assets, which we refer to as bonds. At the beginning of the period, the household chooses B, bonds, and D, deposits. Deposits provide liquidity services that are reflected in utility, while bonds do not. We assume that the utility of liquidity services takes the log form that results in a downward-sloping curve of demand for deposits.[4] Without loss of generality, the gross return on bonds is equal to the gross policy rate R_b set by the central bank. By choosing $\{C, D, B\}$, the household maximizes the sum of consumption and liquidity value

$$C + \beta_m \log D$$

[3]See Chen et al. (2018), Cong et al. (2019), and Chen et al. (2023), among others.

[4]In Internet Appendix A.1, we generalize the utility of liquidity services to have a form of constant relative risk aversion (CRRA) and examine the parameter configuration that allows the deposit rate ceiling to be unbinding for some banks but binding for others.

subject to

$$C \leq W_0 R_b - DS = BR_b + DR_d,$$

where C represents consumption, β_m is the share parameter between consumption and liquidity services, and R_d denotes the gross return of deposits. Note that $W_0 = B + D$. The household's cost of holding deposits instead of bonds is captured by the deposit spread $S = R_b - R_d$. A first-order condition for this optimization problem leads to the following key equation that relates the household's demand for bank deposits to the deposit spread:

$$D = \frac{\beta_m}{S}. \tag{1}$$

Under financial repression, there exists a ceiling for deposit rates such that

$$R_d \leq (1 - \lambda) R_b, \tag{2}$$

which implies a lower bound for the deposit spread: $S \geq \lambda R_b$, where $0 < \lambda < 1$. Without deposit rate ceilings, the household's demand for deposits increases in response to a reduction in the deposit spread. When the deposit rate ceiling is binding, however, the amount of deposits that banks can supply becomes constrained. By combining Equation (1) and (2), we derive the following constraint for the demand of deposit, which individual banks take as given:

$$D \leq \frac{\beta_m}{\lambda R_b} = \bar{D}. \tag{3}$$

II.1.2. *Reserve requirement.* We follow Bianchi and Bigio (2022) and assume that after making their portfolio decisions, banks are exposed to an idiosyncratic deposit withdrawal, ωd, where $\omega \sim \mathscr{F}(\cdot)$. The cumulative distribution of ω, denoted as $\mathscr{F}(\omega)$, follows a uniform distribution on the interval $[-1, 1]$. Since $\int_{-1}^{1} \omega d\mathscr{F}(\omega) = 0$, all deposit withdrawals occur within the banking system. The shock ω reflects the constant circulation of deposits within the banking system during payment transactions.

Each bank is subject to a reserve requirement at the end of the period,

$$a - \omega d \geq \rho (1 - \omega) d$$

where a represents the bank's cash position and ρ is the required reserve ratio set by the central bank. Since banks make their portfolio decisions before the realization of the withdrawal shock ω, they may not have sufficient reserves as required after the shock occurs. The resulting reserve shortfall can be expressed as

$$\rho(1 - \omega)d - (a - \omega d) = [\rho + \omega(1 - \rho)]d - a.$$

If a bank's reserves fall below the required level, it may borrow directly from the central bank's discount window at a (net) rate of $r_b \equiv R_b - 1$ to cover the shortfall. On the other hand, if a bank has a surplus of reserves, it can deposit its excess reserves with the central bank and earn interest income on those reserves over the period. To insure itself against the risk of reserve shortfall at the beginning of the period, a bank incurs a fixed cost of τr_b paid to the central bank, in addition to its expected interest cost for recouping the reserve shortfall.[5] The total cost of recouping reserves can be expressed as

$$\begin{aligned}\chi &= r_b \int_{-1}^{1} [\tau + (\rho + \omega(1-\rho))d - a] f(\omega) d\omega \\ &= r_b(\tau + \rho d - a),\end{aligned} \tag{4}$$

which is always positive. It follows from equation (4) that a loosening of monetary policy (i.e., a decrease in r_b) leads to a reduction in the total cost of recouping reserves.

Reserve requirements are important for many emerging-market economies, as they represent one of the bank lending channels through which monetary policy influences deposits. In general, however, the effects of monetary policy on banks' funding composition as well as bank loans do not hinge on this particular channel (see, for example, Wang et al. (2022)).

II.1.3. *Banks.* Banks consume all of their net worth at the end of the period. The net worth of a competitive bank at the end of the period is denoted as n, and it represents the sum of the gross return on cash and bank loans, net of the cost of retail deposits and wholesale funding. That is,

$$n = R_a a + R_l l - R_w w - R_d d, \tag{5}$$

where a represents the amount of cash held by the bank and l denotes loans issued by the bank. The gross interest rates on cash, bank loans, and wholesale funding are denoted respectively by R_a, R_l, and R_w.

An individual bank uses deposits or wholesale fund to finance its loans, cash holdings, and insurance premium for reserve shortfall. The flow-of-funds constraint is

$$l = w + d - a - \chi. \tag{6}$$

The bank's ability to raise funds is subject to the capital requirement:

$$\theta \left(w + d + \varphi w^2 \right) \leq E, \tag{7}$$

[5]This assumption makes banks homogeneous ex post, which simplifies our analysis and makes it tractable.

where $0 < \varphi, \theta \leq 1$ and E denotes the equity value of the bank, which is equal to its end-of-period net worth (n). Thus, the bank's equity must exceed a certain fraction of its total funding and associated costs, including a quadratic financing cost of wholesale funding (φw^2).[6]

We proceed to the individual bank's optimization problem.[7] The bank's objective is to maximize its net worth at the end of the period,

$$E = \max_{a,l,w,d} \{n\}, \tag{8}$$

subject to the requirement that the bank holds a minimum amount of cash ($a \geq \kappa$), the balance sheet equation (5), the flow-of-funds constraint (6), the capital constraint (7), and the deposit constraint expressed as:

$$0 \leq d \leq \overline{d} \equiv \frac{\beta_m}{\lambda R_b} = h(R_b), \tag{9}$$

where $h'(R_b) < 0$.[8]

By substituting equations (4), (5), and (6) into equation (8), we rewrite the bank's optimization problem as

$$E = \max_{d,w} (\mu_d d + \mu_w w + \mu_a \kappa + \upsilon_l) \tag{10}$$

subject to (9) and

$$\theta[d + w + \varphi w^2] \leq \mu_d d + \mu_w w + \mu_a \kappa + \upsilon_l, \tag{11}$$

where

$$\mu_a = R_a - R_l(1 - r_b),\ \mu_d = R_l(1 - \rho r_b) - R_d,\ \mu_w = R_l - R_w,\ \upsilon_l = -R_l \tau r_b.$$

The variables μ_d, μ_w, and μ_a correspond to, respectively, the effective net returns on deposits, wholesale funding, and cash holdings. Since deposits are subject to the reserve requirement, changes in the policy rate affect the overall funding cost of deposits. As a result, $\partial \mu_d / \partial r_b < 0$, indicating that the effective net return on deposits decreases as the policy rate increases. On the other hand, because wholesale funding is not subject to reserve requirements and therefore not directly affected by changes in the policy rate, $\partial \mu_w / \partial r_b = 0$.

[6] The capital constraint, which is represented by equation (7), reflects the regulatory requirements on banks' equity or capital. Both the capital constraint and the quadratic financing cost, as discussed in Wang et al. (2022), are commonly used features in the literature.

[7] For the detailed description of the optimal characteristics of the problem, see Internet Appendix A.2.

[8] The assumption $\kappa < \tau$ ensures a positive total cost of reserve recoup, denoted as χ.

II.2. **Effects of monetary policy on banks' funding composition.** In this section, we analyze the effects of monetary policy on banks' funding composition. Specifically, we compare the responses of deposits and wholesale funding under two scenarios: with and without deposit rate ceilings. We begin with the following proposition.

Proposition 1. In response to changes in the monetary policy rate,

(1) when there are no deposit rate ceilings, banks' supply of wholesale funding comoves negatively with their supply of retail deposits, i.e.,

$$\frac{\partial w}{\partial r_b} > 0, \frac{\partial d}{\partial r_b} < 0;$$

(2) when deposit rate ceilings are binding, there is a positive comovement between banks' supply of wholesale funding and their supply of retail deposits, i.e.,

$$\frac{\partial w}{\partial r_b} < 0, \frac{\partial d}{\partial r_b} < 0;$$

if and only if

$$(1-\lambda)\bar{d} + R_l\left(\rho\bar{d} + \tau - \kappa\right) > (\theta - \mu_d)\,\frac{\bar{d}}{R_b}. \tag{12}$$

Proof of Proposition 1.

(1) When there are no deposit rate ceilings, the capital constraint can be rewritten as

$$d = \frac{1}{\theta - \mu_d}(-\theta\varphi w^2 - (\theta - \mu_w)w + \upsilon_l + \mu_a\kappa). \tag{13}$$

Substituting equation (13) into the objective function (10), we solve for the optimal w as

$$w = \frac{\frac{\mu_w}{\mu_d} - 1}{2\varphi}. \tag{14}$$

Accordingly,

$$\frac{\partial w}{\partial r_b} = -\frac{\mu_w \partial\mu_d/\partial r_b}{2\varphi\left(\mu_d\right)^2} > 0$$

and

$$\frac{\partial d}{\partial r_b} = \frac{d}{\theta - \mu_d}\frac{\partial \mu_d}{\partial r_b} - \frac{\partial w/\partial r_b}{\theta - \mu_d}\left(2\theta\varphi w + \theta - \mu_w\right) - \frac{R_l\left(\tau - \kappa\right)}{\theta - \mu_d}. \tag{15}$$

Since $\partial\mu_d/\partial r_b < 0$, $\partial w/\partial r_b > 0$, $\mu_w < \theta + \theta\varphi w < \theta + 2\theta\varphi w$ and $\tau - \kappa > 0$, all three arguments on the right-hand side (RHS) of equation (15) are negative. Hence, $\frac{\partial d}{\partial r_b} < 0$.

(2) When deposit rate ceilings are binding, $S \geq \overline{S} = \lambda R_b$ and $d \leq \bar{d} = h(r_b) = \frac{\beta_m}{\lambda r_b}$, hence $\mu_d = R_l(1 - \rho R_b) - R_b(1 - \lambda)$ and $\frac{\partial \bar{d}}{\partial r_b} = h'(r_b) < 0$. We pin down w by solving the following equation:

$$\theta \varphi w^2 + (\theta - \mu_w)w + (\theta - \mu_d)\bar{d} - \mu_a \kappa - \upsilon_l = 0. \tag{16}$$

Equation (16) implies

$$\frac{\partial w}{\partial r_b} = -\left[(1-\lambda)\bar{d} + R_l\left(\tau - \kappa + \bar{d}\rho\right) + (\theta - \mu_d)\frac{\partial \bar{d}}{\partial r_b}\right]\frac{1}{2\theta\varphi w + \theta - \mu_w} \tag{17}$$

Hence, $\partial w / \partial r_b < 0$ if and only if (12) holds.

□

The intuition for Proposition 1 is illustrated by Figure 1, which plots a bank's capital constraint and its indifference curve between retail deposits and wholesale funding. The straight line is the bank's indifference curve, with the slope $-\mu_d/\mu_w$. The concave contour is the capital constraint, with the slope at each point given by

$$\frac{\partial w}{\partial d} = -\frac{\theta - \mu_d}{\theta + 2\theta\varphi w - \mu_w}. \tag{18}$$

Point A in Figure 1, where the two curves are tangent, represents the optimal funding composition without deposit rate ceilings. In this case, wholesale funding is determined by equation (14). When there is a deposit rate ceiling, the deposit supply by the bank is constrained in equilibrium, which moves the optimal funding mix to point B, with a higher w compared to the case without deposit rate ceiling.

A loosening of monetary policy has two opposite effects on wholesale funding, as captured by the left-hand side (LHS) and RHS of equation (12). On the one hand, a decrease in the policy rate increases the effective net returns to deposits (μ_d) relative to wholesale funding (μ_w), encouraging banks to substitute deposits for wholesale funding. This effect, called "substitution effect," is shown by a steeper indifference curve in Figure 1. On the other hand, a decrease in the policy rate relaxes the capital constraint by increasing the bank's equity, leading to a larger feasible set of d, w and enabling banks to expand their sources of funds through an increase in the supply of wholesale funding. This effect is called the "wealth effect."

The relative magnitudes of these effects depend on whether the deposit rate ceiling is binding or not. Without deposit rate ceilings, the substitution effect dominates, and the new optimal point is A'. As deposits become relatively more profitable, the optimal value of w

declines. With deposit rate ceilings, however, the new optimal point becomes B' with a higher w, despite the fact that a decrease in r_b increases deposits d by relaxing the deposit ceiling constraint. In other words, wholesale funding and deposits comove positively in response to changes in the policy rate. Internet Appendix A.3 shows that our theoretical predictions remain valid even if we consider banks to be monopolistically competitive in deposit markets, as in Drechscher et al. (2017). This result follows from the fact that bank market power magnifies the positive response of the deposit spread—the cost of retail deposits—to changes in policy interest rates. Consequently, households have a greater motivation to replace retail deposits with wholesale funding, which induces a negative comovement between deposits and wholesale funding in the absence of deposit rate ceilings. The presence of such ceilings renders the lower bound of the deposit spread more binding when the policy rate falls. Accordingly, banks have a stronger incentive to utilize wholesale funding to diversify their funding sources, primarily driven by wealth effects discussed in the benchmark model.

In summary, Proposition 1 provides theoretical results regarding the responses of banks' funding composition to changes in the policy rate and in particular, the role of deposit rate ceilings in such responses. In the next section, we examine the role of wholesale funding in the monetary transmission to bank lending.

II.3. **Role of wholesale funding in the monetary transmission.** In this section, we discuss the transmission of monetary policy to the real economy and provides theoretical results on the significance of wholesale funding in this process. By comparing economies with and without wholesale funding, we establish the following proposition.

Proposition 2. Let $|_{w>0}$ denote the case in which banks can borrow via wholesale funding and $|_{w=0}$ denote the case in which banks cannot borrow in the wholesale funding market.

(1) Without deposit rate ceilings and under $\frac{\theta-\mu_d}{2\theta\varphi w+\theta-\mu_w} > 1-\rho r_b$,

$$\frac{\partial l}{\partial r_b}\Big|_{w>0} > \frac{\partial l}{\partial r_b}\Big|_{w=0}.$$

(2) When deposit rate ceilings are binding,

$$\frac{\partial l}{\partial r_b}\Big|_{w>0} < \frac{\partial l}{\partial r_b}\Big|_{w=0} < 0.$$

Proof of Proposition 2.

(1) When there are no ceilings on deposit rates, we first consider the case in which banks do not have access to wholesale funding, i.e., $w = 0$. The flow-of-funds constraint (6)

is simplified to

$$l = (1 - \rho r_b)d - [\kappa + r_b(\tau - \kappa)] \tag{19}$$

It follows from equation (19) that

$$\frac{\partial l}{\partial r_b}|_{w=0} = (1 - \rho r_b)\frac{\partial d}{\partial r_b} - \rho d - (\tau - \kappa). \tag{20}$$

With $w = 0$, the bank's capital constraint becomes

$$d = \frac{\mu_a \kappa + \upsilon_l}{\theta - \mu_d}, \tag{21}$$

which implies

$$\frac{\partial d}{\partial r_b} = \frac{(\kappa - \tau)\, R_l\, (\theta - \mu_d) + (\mu_a \kappa + \upsilon_l)\, \partial \mu_d / \partial r_b}{(\theta - \mu_d)^2} < 0.$$

Hence, $\partial l / \partial r_b|_{w=0} < 0$.

Now consider the case in which banks can have access to wholesale funding. We rewrite equation (13) as

$$d = h(w) + d^0, \tag{22}$$

where $h(w) = \frac{-\theta \varphi w^2 - (\theta - \mu_w)w}{\theta - \mu_d} < 0$ and $d^0 \equiv \frac{\mu_a \kappa + \upsilon_l}{\theta - \mu_d}$. Substituting (22) into equation (6), we have

$$l = (1 - \rho r_b)h(w) + w + (1 - \rho r_b)d^0 - [\kappa + r_b(\tau - \kappa)], \tag{23}$$

and thus

$$\begin{aligned} \frac{\partial l}{\partial r_b}\Big|_{w>0} &= [(1 - \rho r_b)h'(w) + 1]\frac{\partial w}{\partial r_b} - \rho h(w) + \frac{\partial (1 - \rho r_b)d^0 - [\kappa + r_b(\tau - \kappa)]}{\partial r_b} \\ &= [1 - (1 - \rho r_b)\frac{2\theta \varphi w + \theta - \mu_w}{\theta - \mu_d}]\frac{\partial w}{\partial r_b} - \rho h(w) + \frac{\partial l}{\partial r_b}\Big|_{w=0}. \end{aligned} \tag{24}$$

Because $\partial w / \partial r_b > 0$ and $\rho h(w) < 0$, the term in the solid bracket on the right-hand side of the above equation must be positive so that $\frac{\partial l}{\partial r_b}|_{w>0} > \frac{\partial l}{\partial rb}|_{w=0}$. Thus,

$$\frac{\theta - \mu_d}{2\theta \varphi w + \theta - \mu_w} > 1 - \rho r_b.$$

This condition suggests that a decrease in the policy rate results in a reduction in wholesale funding, leading to a negative impact on bank lending. Consequently, banks that have access to wholesale funding increase their lending less than those without such access. Therefore, wholesale funding weakens the transmission of monetary policy.

(2) When deposit rate ceilings are binding, we first consider the case where banks cannot borrow via wholesale funding, i.e., $w = 0$. The flow-of-funds constraint (6) becomes

$$l = (1 - \rho r_b)\bar{d} - [\kappa + r_b(\tau - \kappa)]. \tag{25}$$

Hence, $\frac{\partial l}{\partial r_b} \mid_{w=0} = -\rho\bar{d} + (1 - \rho r_b)\frac{\partial \bar{d}}{\partial r_b} - (\tau - \kappa) < 0$.

We now consider the case where banks have access to wholesale funding. Equation (19) becomes

$$l = (1 - \rho r_b)\bar{d} + w - [\kappa + r_b(\tau - \kappa)] \tag{26}$$

Hence, we have

$$\begin{aligned} \frac{\partial l}{\partial r_b} \mid_{w>0} &= \frac{\partial w}{\partial r_b} + [-\rho\bar{d} + (1 - \rho r_b)\frac{\partial \bar{d}}{\partial r_b} - (\tau - \kappa)] \\ &= \frac{\partial w}{\partial r_b} + \frac{\partial l}{\partial r_b} \mid_{w=0} < \frac{\partial l}{\partial r_b} \mid_{w=0} < 0, \end{aligned} \tag{27}$$

where the last inequality is established by the fact that $\partial w / \partial r_b < 0$.

□

According to Proposition 2, when deposit rate ceilings are binding, a policy rate reduction relaxes banks' capital constraint and thus allows them to increase their loan supply via wholesale funding. As a result, banks will increase their loan supply in response to a reduction in the policy rate when they have access to the wholesale funding market more than when they do not. Access to wholesale funding provides banks with an alternative source of funding for their lending.

III. Evidence on the impacts of monetary policy on banks' balance sheets

In this section, we present empirical evidence with the following findings: (1) For banks with binding deposit rate ceilings, there is a positive correlation between wholesale funding and retail deposits in response to monetary policy, whereas for banks that are not constrained by deposit rate ceilings, the opposite holds true. (2) Wholesale funding facilitates the transmission of monetary policy to bank lending for banks with binding deposit rate ceilings.

For our empirical work, we construct a sample of all listed banks on the Shanghai and Shenzhen Stock Exchanges using quarterly data obtained from the China Stock Market and Accounting Research Database (CSMAR).[9] We manually collect deposit interest rates from

[9]For detailed descriptions of the variables used for this section, see Internet Appendix B.

each bank's biannual report, and the macroeconomic data are from the National Bureau of Statistics of China and the People's Bank of China (PBC). Our bank-quarter dataset covers the period from 2013Q4 to 2019Q1, while our biannual data sample period ranges from 2011H1 to 2019H2, where "H" refers to a half-year.

III.1. **Evidence on deposit rate ceilings.** To quantify the role of deposit rate ceilings in the transmission of monetary policy, we distinguish two groups of banks in our sample: one consisting of banks with binding deposit rate ceilings and the other consisting of banks not constrained by deposit rate ceilings. Smaller banks, such as non-state banks (NSBs), typically operate on a local scale with fewer branches in comparison to larger banks, such as state banks (SBs). In some cases, NSBs may only have branches within the province where their headquarters are located. These factors make NSBs less competitive in attracting deposits and more vulnerable to the effects of binding deposit rate ceilings than SBs.

To substantiate this argument, we examine the response of deposit interest rates by these two groups of banks to China's regulatory changes in deposit rate ceilings. For banks that are subject to binding deposit rate ceilings (i.e., NSBs), their deposit interest rates are expected to respond positively to a relaxation of deposit ceiling regulations. By contrast, for banks that are not subject to binding deposit rate ceilings (i.e., SBs), their deposit interest rates are expected not to respond to such regulatory changes.

We use the following bank-biannual panel regression to analyze the impact of regulatory relaxation on deposit rates for NSBs and SBs:

$$R_{d,t} = \alpha Ceiling_t + \beta Ceiling_t \times I\left(NSB_b\right) + \alpha_b + \tau_y + \tau_h + \epsilon_{b,t},$$

where $R_{d,t}$ is an individual bank's deposit interest rate, $Ceiling_t$ is a dummy variable indicating whether the deposit rate ceiling regulation was relaxed during the biannual period. We set the policy dummy variable to one for the three periods when the deposit rate ceiling was relaxed by the PBC: 2012H1, 2014H2, and 2015H1.[10] The indicator variable $I(NSB_b)$ returns 1 if the issuing bank is an NSB and 0 otherwise. The coefficient α_b represents the

[10]On June 8, 2012, the PBC announced the lifting of the deposit ceiling, increasing it from the benchmark deposit rate to 1.1 times the benchmark deposit rate. Subsequently, on November 22, 2014, the PBC further raised the deposit rate ceiling to 1.2 times the benchmark deposit rate. On March 1 and May 11, 2015, additional increases occurred, elevating the deposit rate ceiling from 1.2 to 1.3 and then to 1.5 times the benchmark deposit rate, respectively. Although the official ceiling was abolished on October 24, 2015, the PBC maintained de facto deposit rate ceilings ranging from 1.3 to 1.5 times the benchmark deposit rate through self-regulatory measures for deposit interest rates.

bank fixed effect, controlling for time-invariant unobserved heterogeneity across banks;[11] τ_y represents the year fixed effect; and τ_h represents the biannual fixed effect, controlling for macroeconomic shocks other than regulatory changes in deposit rate ceilings. The coefficient α captures the response of SBs' deposit interest rates to regulatory changes in deposit rate ceilings, while the coefficient β is the marginal impact of such a regulatory change on NSBs' deposit rates.

The estimate of α is insignificant at 0.024 with a standard error of 0.027, indicating that a relaxation of deposit rate ceilings does not affect SBs' deposit rates. By contrast, the estimate of β is significant at 0.094 with a standard error of 0.044, indicating that a relaxation of deposit rate ceilings increases NSBs' deposit rates. The overall effect of a regulatory relaxation of deposit rate ceilings on NSBs, measured by $\alpha + \beta$, is 0.118, which is statistically significant at the 1% level. The regression has a sample size of 360 with $R^2 = 0.89$. These findings remain robust even when we control for bank size. The regression with this added control variable has a sample size of 325 with $R^2 = 0.90$. The estimates of α and β are 0.022 with a standard error of 0.022 and 0.099 with a standard error of 0.04, respectively; the estimate of $\alpha + \beta$ is 0.121 with the 1% statistical significance.

These findings offer evidence of NSBs being constrained by binding deposit rate ceilings, while SBs are not. Consequently, in further analyses, we consider NSBs as the treated group and SBs as the control group to evaluate the impact of deposit rate ceilings on the response of bank funding composition to monetary policy and the transmission of monetary policy to bank loans.

III.2. **The role of deposit rate ceilings in the impact of monetary policy on banks' funding composition.** In this section, we estimate the impact of monetary policy on the composition of retail deposits and wholesale funding for banks constrained by deposit rate ceilings. Using the difference-in-difference (DID) approach for our estimation, we find that when monetary policy rates change, the comovement of retail deposits and wholesale funding is positive for NSBs, but negative for SBs.

NSBs may be more sensitive to loan demand induced by monetary policy or have less access to internal sources of funds than SBs, and thus rely more on wholesale funding to expand their funding base. To control for loan demand and the availability of internal funds, both of which may affect banks' reliance on retail deposits and wholesale funding as external sources of funding, we include in our regression the ratio of net profit to total assets (ROA)

[11] For example, SBs and NSBs face different required reserve ratios.

to capture banks' loan demand as well as three alternative measures of liquidity, namely the ratio of liquidity assets to total assets (LIQ), the ratio of non-loan financial assets to total assets (FIN), and the ratio of cash flow from stock issuance to total assets (STK).

With these variables controlled for, we run an unbalanced bank-quarter panel regression as follows:

$$\Delta y_{b,t} = \alpha R_{t-1} + \beta R_{t-1} \times I(NSB_b) + \gamma X_{b,t-1} + \alpha_b + \tau_y + \tau_q + \epsilon_{b,t}, \tag{28}$$

where $\Delta y_{b,t}$ is the year-over-year change in retail deposits or wholesale funding in bank b in quarter t, scaled by one-quarter-lagged total liabilities; R_{t-1} is the policy interest rate lagged by one quarter, measured as the 7-day reverse repo rate for all financial institutions (R007); $X_{b,t-1}$ represents a set of bank-level variables, including the aforementioned control variables and their interaction with the lagged policy interest rate; τ_y is the year fixed effect to control for macroeconomic shocks other than changes in the policy rate; and τ_q represents quarter-of-year fixed effects to account for seasonality. The coefficient α captures the response of deposits or wholesale funding in SBs to changes in the policy rate. The key coefficient is β on the interaction between the policy rate and the dummy for NSBs, which measures the differential impact of a change in the policy rate on deposits or wholesale funding in NSBs.

Table 1 presents the responses of retail deposits and wholesale funding to changes in the monetary policy rate. In column (1), the estimated coefficient α is negative and significant. The estimate implies that for banks facing no constraint on deposit rate ceilings (i.e., SBs), a one-percentage decrease in the policy rate corresponds to a 2.2 percentage-point (pp) increase in retail deposits as a share of total liabilities. The estimated coefficient β, however, is significantly positive, indicating that the response of retail deposits in NSBs is weaker than that in SBs. Accordingly, the increase in retail deposits as a share of total liabilities in response to a one-percentage-point decrease in policy rates is only 1.47 percentage points (pps) for NSBs, as indicated by the estimated value of $\alpha + \beta$. Thus, we find that NSBs, which face binding deposit rate ceilings, experience less pass-through from monetary policy into retail deposits than SBs. Our estimate remains robust when we include quarter-of-year (seasonal) fixed effects, as shown in column (2).

Column (3) presents the estimated results for wholesale funding. The first row shows that the estimated coefficient α is positive and significant. The estimate indicates that a one-percentage-point decrease in the policy rate leads to a 0.73 pp decrease in wholesale funding as a share of total liabilities. Intuitively, a loosening of monetary policy reduces the cost of deposit funding, encouraging banks to substitute retail deposits for wholesale funding. Conversely, when monetary policy is tightened and deposits become more expensive, SBs turn to wholesale funding. By contrast, the estimated coefficient β is negative and significant at the 1% level, indicating that wholesale funding in NSBs increases by 1.66 pps *relative to* SBs in response to a one-percentage-point decrease in the policy rate. The overall effect of monetary policy on NSBs' wholesale funding, captured by $\alpha + \beta$, is negative and statistically significant. Again, our findings are robust to the inclusion of seasonal fixed effects (column (4)).

These results shed light on the comovement between retail deposits and wholesale funding when the policy rate changes. A comparison of the sign of α between columns (1) and (3) (or columns (2) and (4)) shows that, when banks are not constrained by deposit rate ceilings, there is a negative comovement between retail deposits and wholesale funding in response to changes in the policy rate. This finding is consistent with empirical evidence from the U.S. (Drechscher et al., 2017; Choi and Choi, 2021). By contrast, when banks face binding deposit rate ceilings, wholesale funding and retail deposits comove positively when the policy rate changes, as shown by comparing the sign of β or $\alpha + \beta$ between columns (1) and (3) (or columns (2) and (4)).

III.3. **The role of wholesale funding in the transmission of monetary policy.** In this section, we provide empirical evidence on the impact of wholesale funding on the transmission of monetary policy for banks constrained by deposit rate ceilings. We find that among NSBs, the sensitivity of bank lending to changes in the policy rate increases with their exposure to wholesale funding.

In our regression, we control for loan demand as well as banks' liquidity on their balance sheets. We include the same bank-specific characteristics and their interaction with the policy rate as in regression (28), except that we replace the ratio of non-loan financial assets to total assets (FIN) with the ratio of short-term financial liabilities to total liabilities (FIL). We also perform an initial analysis without controlling for bank-specific characteristics, but with an inclusion of bank-year fixed effects to control for unobserved time-varying bank characteristics.

We estimate the following regression for NSBs to examine the role of wholesale funding in the pass-through of the policy rate to bank lending when banks face binding deposit rate ceilings:

$$\Delta L_{b,t} = \alpha W_{b,t-1} + \beta R_{t-1} \times W_{b,t-1} + \gamma R_{t-1} + \kappa X_{b,t-1} + \alpha_{b,y} + \epsilon_{b,t}, \tag{29}$$

where $\Delta L_{b,t}$ represents the year-over-year changes in bank loans for bank b in quarter t, scaled by the total assets lagged by one quarter, and $W_{b,t-1}$ denotes the wholesale funding from the previous quarter, adjusted by the total liabilities also lagged by one quarter. The term $\alpha_{b,y}$ denotes bank-year fixed effects, and $X_{b,t-1}$ is a vector of control variables. The coefficient of primary interest is β, which captures the role of wholesale funding in transmitting the policy rate to bank lending.

Table 2 presents the impact of wholesale funding exposure on the sensitivity of bank lending to the interest rate. In column (1), the estimated coefficient α is positive and statistically significant at the 1% level, indicating that banks with higher exposure to wholesale funding experience a larger increase in bank lending as a share of total assets. The estimated value of β is negative and significant at the 5% level, suggesting that a one-standard-deviation increase in the ratio of wholesale funding to total liabilities corresponds to a 0.5 pp increase in the elasticity of bank lending to the policy rate. Column (2) shows that our findings are robust to the inclusion of bank-specific variables and their interactions with the policy rate, with the estimated value of β very similar to the value reported in column (1).

To control for other macroeconomic shocks that may confound the effects of changes in the policy rate, we include lagged quarterly year-over-year GDP growth and inflation rates, as well as their interactions with bank-specific variables, as additional control variables. Columns (3) and (4) report the estimates when these macroeconomic variables are controlled for. Our finding of a significantly negative β holds, and the estimate of β is similar in magnitude to the value reported in column (2).

In summary, our results for banks that are constrained by deposit rate ceilings are twofold. First, wholesale funding comoves positively with retail deposits when the policy rate changes, while the opposite is true for banks that do not face binding deposit rate ceilings. Second, the higher the exposure to wholesale funding, the more sensitive bank lending is to changes in the policy rate. These findings provide empirical support for the theoretical results presented in Section II.

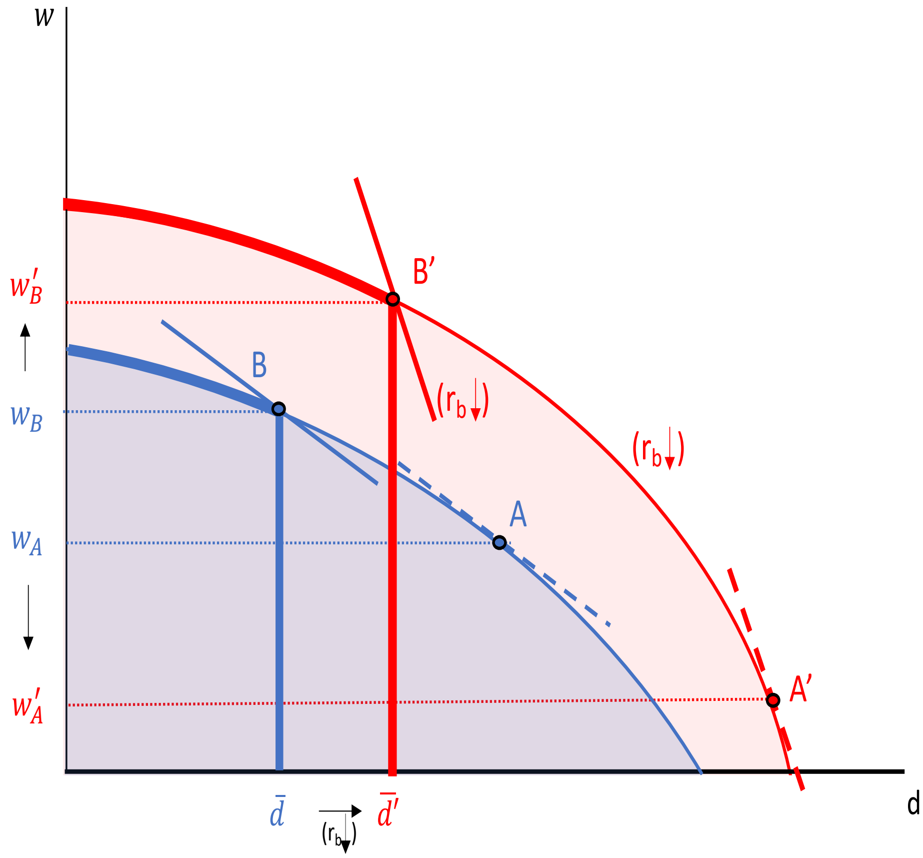
IV. Conclusion

The conventional view of monetary policy transmission through the banking system suggests that wholesale funding, as an alternative external funding source to retail deposits, moves inversely with retail deposits when the policy rate changes. This negative correlation implies that the presence of wholesale funding weakens the effectiveness of monetary policy transmission. In economies with financial repression, however, we argue that wholesale funding moves positively with retail deposits in response to changes in the policy rate, thus enhancing the transmission of monetary policy to bank lending.

We demonstrate this point using a simple banking model with deposit rate ceilings. A loosening of monetary policy not only leads to a substitution effect of retail deposits for wholesale funding by reducing the cost of funding via retail deposits (the standard bank lending channel), but also to a wealth effect by expanding the borrowing capacity of individual banks since it relaxes the capital constraint. In the absence of deposit rate ceilings, the substitution effect dominates, and banks increase retail deposits while reducing wholesale funding to increase lending. When banks are constrained by deposit rate ceilings, however, the wealth effect resulting from the relaxation of the capital constraint allows banks to increase both wholesale funding and retail deposits altogether. Our theoretical results suggest that access to wholesale funding enhances the transmission of monetary policy to bank lending in the presence of deposit rate ceilings, while the opposite is true when there are no such financial repressions. We provide empirical evidence in support of our model's results using bank-level data from China.

Our findings have significant implications for liquidity regulations. Basel III introduced the LCR requirement to address banks' global vulnerability due to overreliance on wholesale funding, heavily penalizing the use of unsecured wholesale funding for liquidity. While such liquidity regulations may help mitigate the banking system's exposure to systemic risks, both our theoretical and empirical results suggest that they reduce the effectiveness of monetary policy transmission in economies with financial repression. There is a need, therefore, to strike a balance between the effectiveness of monetary policy transmission and banks' exposure to systemic risks in designing liquidity regulations. This topic warrants further research in the future.

Figure 1. Impacts of changes in the monetary policy rate on banks' funding composition



Note: The vertical axis represents wholesale funding denoted by "W", and the horizontal axis represents deposits denoted by "d".

Table 1. Effect of monetary policy on retail deposits and wholesale funding

	Deposits		Wholesale funding	
	(1)	(2)	(3)	(4)
R_{t-1}: α	-2.166***	-1.966***	0.727**	0.833**
	(0.508)	(0.520)	(0.337)	(0.323)
$R_{t-1} \times I(NSB_b)$: β	0.695*	0.690*	-1.660***	-1.694***
	(0.382)	(0.373)	(0.247)	(0.226)
$R_{t-1} \times ROA_{t-1}$	-0.432	-0.463	0.555*	0.424*
	(0.632)	(0.562)	(0.321)	(0.227)
$R_{t-1} \times LIQ_{t-1}$	0.176***	0.179***	-0.0836**	-0.0758**
	(0.0604)	(0.0577)	(0.0394)	(0.0358)
$R_{t-1} \times FIN_{t-1}$	-0.0752	-0.0753	-0.0202	-0.0187
	(0.0700)	(0.0683)	(0.0351)	(0.0336)
$R_{t-1} \times STK_{t-1}$	0.243	0.311	-1.330**	-1.288**
	(0.901)	(0.921)	(0.542)	(0.505)
$\alpha + \beta$	-1.4710^{***}	-1.2753^{**}	-0.9328^{**}	-0.8611^{**}
Bank FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Seasonal FE	YES	NO	YES	NO
N	397	397	390	390
R^2	0.4946	0.4921	0.6098	0.6079

Note: This table presents regression results with year-over-year changes in deposits and wholesale funding for each bank, scaled by lagged total liability, as the dependent variables. The independent variables include the lagged monetary policy interest rate (R_{t-1}) measured as R007, and its interaction with a dummy variable that equals one if a bank is a NSB and zero otherwise ($I(NSB_b)$). Bank-level control variables include net profit scaled by lagged total assets (ROA_{t-1}), the ratio of liquid assets to lagged total assets (LIQ_{t-1}), the year-over-year change of financial assets scaled by one-quarter-lagged total assets (FIN_{t-1}), and the ratio of cash flow from stock to lagged total liability of the last period (STK_{t-1}), along with their interaction terms with R_{t-1}. Regressions for columns (1) and (3) control for bank, year, and seasonal fixed effects, while regressions for columns (2) and (4) control for bank and year fixed effects. Robust standard errors clustered by bank type are reported in parentheses. Statistical significance is denoted by ***, **, and * at the 1%, 5%, and 10% levels, respectively.

Table 2. Effect of exposure to wholesale funding on monetary transmission to NSB lending

	(1)	(2)	(3)	(4)
W_{t-1}: α	1.976***	2.026***	1.324*	1.835***
	(0.630)	(0.668)	(0.638)	(0.636)
$R_{t-1} \times W_{t-1}$: β	-0.500**	-0.482**	-0.363*	-0.495**
	(0.210)	(0.197)	(0.197)	(0.218)
R_{t-1}: γ	-0.244	-0.384	-0.0893	1.004**
	(0.204)	(0.568)	(0.474)	(0.418)
$R_{t-1} \times ROA_{t-1}$		-0.123	-0.838*	-1.308**
		(0.279)	(0.449)	(0.471)
$R_{t-1} \times LIQ_{t-1}$		0.0402	0.0784	-0.0255
		(0.0518)	(0.0696)	(0.0653)
$R_{t-1} \times FIL_{t-1}$		-0.916***	-0.00188	-0.825
		(0.319)	(0.279)	(0.572)
$R_{t-1} \times STK_{t-1}$		0.708	0.773*	1.635
		(0.693)	(0.399)	(1.100)
Bank × Year FE	YES	YES	NO	YES
Bank FE	NO	NO	YES	NO
Macro Controls	NO	NO	YES	YES
N	287	276	276	276
R^2	0.7111	0.7153	0.4321	0.7655

Note: This table presents regression results in which the dependent variable is the bank-quarter observation of the year-over-year change of outstanding bank loans scaled by lagged total assets. The independent variables include the standardized ratio of wholesale funding to the lagged total liability of the last period (W_{t-1}) and its interaction with the lagged monetary policy interest rate (R_{t-1}), measured as R007. The bank-level control variables include net profit scaled by lagged total assets of the last period (ROA_{t-1}), the ratio of liquid assets to lagged total assets (LIQ_{t-1}), the year-over-year change of financial liability scaled by lagged total liabilities (FIL_{t-1}), the ratio of cash flow from stock scaled by lagged total liability (STK_{t-1}), and their interaction terms with R_{t-1}. Macro control variables include the lagged year-over-year GDP growth rate (GDP_{t-1}), the lagged year-over-year GDP deflator inflation rate (INF_{t-1}), and their interactions with bank-specific variables. We report robust standard errors clustered by bank in parentheses. Significance levels are denoted by ***, **, and * for the 1%, 5%, and 10% levels, respectively.

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Internet Appendices

Not Intended for Publication

Appendix A. Additional Details of the Model

A.1. **Bindingness of deposit rate ceiling.** In this section, we discuss the parameter restrictions under which deposit rate ceilings are not binding for state banks, but binding for non-state banks. Without loss of generality, we assume that liquidity service of deposit follows CRRA utility. The household chooses consumption, deposit and bonds, $\{C, D, B\}$, to maximize the sum of consumption and the liquidity value

$$C + \beta_m \frac{D^{1-\gamma} - 1}{1 - \gamma}$$

subject to

$$C \leq W_0 R_b - DS = BR_b + DR_d$$

where β_m is the weight parameter between consumption and liquidity services and R_d denotes the gross return of deposit. $W_0 = B + D$, $S = R_b - R_d$ is the deposit spread, capturing the household's cost of holding deposits instead of bonds. The first order condition implies the following key equation regarding the household's demand of bank deposit, which is downward sloping in deposit spread:

$$D^{\gamma} = \frac{\beta_m}{S} \tag{S1}$$

The larger γ is, the less elastic the household's demand of deposit is to deposit spread. For simplicity, we assume $\gamma = 1$ for non-state banks, and $\gamma = 0$ for state banks. The deposit demand curve for state banks is

$$S = \beta_m \tag{S2}$$

For state banks always not be constrained by the deposit ceiling, it is sufficient that the the equilibrium deposit spread is higher than the lower bound, which implies $\lambda < \frac{\beta_m}{R_b}$.

Given that state banks are not subject to binding deposit rate ceilings, for non-state banks that are subject to such ceilings, the equilibrium deposits for non-state banks without deposit rate ceilings, denoted as D^*, must exceed the intersection of the household demand curves for state and non-state banks, which are one. If not, the equilibrium deposit spread of non-state banks would be greater than or equal to that of state banks, rendering the non-state banks unconstrained by the deposit rate ceilings. Hence, we assume that $D^* > 1$.[12]

[12] In combination with non-state banks' incentive constraint, we can solve for the equilibrium deposits in the absence of deposit rate ceilings as

$$D^* = \frac{(\theta - \mu_w)^2 - \mu_w^2 (\theta/\mu_d - 1)^2}{4\theta\varphi(\theta - \mu_d)} + \frac{\mu_a \kappa + v_l}{\theta - \mu_d}.$$

For non-state banks, the equilibrium deposit spread without deposit ceiling is

$$S^* = \frac{\beta_m}{D^*} \tag{S3}$$

Again we need $S^* \leq \lambda R_b$ for non-state banks to be constrained, which implies $\lambda \geq \frac{\beta_m}{D^* R_b}$ To summarize, if $\frac{\beta_m}{D^* R_b} \leq \lambda < \frac{\beta_m}{R_b}$, non-state banks are binded by the deposit rate ceiling, while state banks are not.

A.2. **Characteristics of Banks' Problem.** Let λ and λ_d denote the Lagrangian multipliers corresponding to the incentive constraint and the deposit rate ceiling constraint, respectively. This yields the Lagrangian as follows:

$$\mathcal{L} = (1+\lambda)(\mu_a a + \mu_d d + \mu_w w + \upsilon_l) - \lambda\theta[d + w + \varphi w^2]$$
$$- \lambda_d(d - \bar{d}) + \lambda_a(a - \kappa)$$

The first-order condition with respect to a is given by:

$$\frac{\partial \mathcal{L}}{\partial \psi_a} = (1+\lambda)\mu_a + \lambda_a = 0$$

Given that $-\mu_a > 0$, which denotes the positive opportunity cost of holding cash, it follows that $\lambda_a > 0$. Thus, the optimal choice of a is κ.

The first-order conditions for w and d are:

$$(1+\lambda)\mu_w = \lambda\theta(1 + 2\varphi w) \tag{S4}$$

$$(1+\lambda)\mu_d = \lambda\theta + \lambda_d \tag{S5}$$

The capital constraint should be binding ($\lambda > 0$); otherwise, if $\lambda = 0$, it follows from equation (S4) that banks would be incentivized to secure infinite wholesale funding.

Equation (S4) leads to:

$$\theta + 2\theta\varphi w = \frac{1+\lambda}{\lambda}\mu_w > \mu_w. \tag{S6}$$

Equation (S5) implies:

$$\mu_d = \frac{\lambda\theta + \lambda_d}{1+\lambda} \tag{S7}$$

Specifically, if the deposit rate ceiling is non-binding, $\mu_d = \frac{\lambda\theta}{1+\lambda} < \theta$.

Now consider the binding capital constraint:

$$(\theta - \mu_d)d + (\theta + \theta\varphi w - \mu_w)w = \mu_a\kappa + \upsilon_l$$

Since both w and d are positive, it must be the case that $\mu_d < \theta$ and $\mu_w < \theta + \theta\varphi w$ to prevent banks from securing infinite deposits and wholesale funding. Note that $\mu_w < \theta + \theta\varphi w$ is consistent with equation (S6).

A.3. **Robustness of Theoretical Predictions to Banks' Power in Deposit Markets.** In this section, we enhance our model by incorporating the deposits channel of monetary policy vis banks' market power. We demonstrate that the introduction of this additional channel does not affect the robustness of our primary theoretical predictions about the comovement of retail deposits and wholesale funding.

The economy in our model comprises two types of agents: the representative household that demands retail deposits, and N banks, each with a mass of $1/N$. These banks can fund their lending activities through both retail deposits and wholesale funding. In accordance with existing literature, we posit that while individual banks exert market power in the deposit market, they face competitive interest rates when it comes to wholesale funding.

A.3.1. *Household Deposit Demand.* Similarly to our benchmark economy, the representative household chooses consumption, aggregate deposit demand and bond to maximize the sum of consumption and liquidity value. The optimal aggregate deposit demand D is the same as its counterpart in the benchmark economy, characterized by Equation (1). Aggregate deposits are made up of individual bank deposits that are imperfect substitute from each other with the elasticity of substitution $\eta > 1$.

$$D = \left(\frac{1}{N} \sum\nolimits_{i=1}^{N} d_i^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \tag{S8}$$

Given the aggregate deposit, the household distributes his deposit holdings across banks to minimize the average cost of holding deposits, by solving the following cost minimization problem

$$\min_{\{d_i\}_{i=1}^{N}} \sum\nolimits_{i=1}^{N} \frac{1}{N} d_i s_i$$

subject to (S8).

The first-order condition implies

$$\frac{\partial \log d_i}{\partial \log s_i} = -\frac{\eta \left(N-1\right)}{1+\left(N-1\right)\left(\frac{s_i}{s}\right)^{\eta-1}} \left(\frac{s_i}{s}\right)^{\eta-1}$$

By symmetry, $s_i = s$ in equilibrium. The deposit demand elasticity, denoted as e, equals

$$e = -\frac{\partial \log d_i}{\partial \log s_i} = \frac{N-1}{N}\eta \tag{S9}$$

A.3.2. *Bank Funding Composition.* To compare with our benchmark economy, we first solve banks' optimal funding problem without deposit rate ceilings. Since the deposit market is monopolistic competitive, individual banks are subject to its deposit demand function (S9) when solving its optimal funding problem. The optimization problem of an individual bank i is

$$E = \max_{d_i, w_i}(\mu_{d,i} d_i + \mu_w w_i + \mu_a \kappa + \upsilon_l) \tag{S10}$$

subject to the deposit ceiling constraint (9), ($S9$) and

$$\theta[d_i + w_i + \varphi w_i^2] \leq \mu_{d,i} d_i + \mu_w w_i + \mu_a \kappa + \upsilon_l, \tag{S11}$$

where the definition of μ_a, μ_w and υ_l is the same as in our benchmark economy and

$$\begin{aligned} \mu_{d,i} &= R_l(1 - \rho r_b) - (1 + r_b) + s_i \\ &\equiv \mu'_d + s_i \end{aligned} \tag{S12}$$

where $\mu'_d \equiv R_l(1-\rho r_b)-(1 + r_b)$ is exogenous to d_i. Note that unlike our benchmark economy, here the choice of deposit d_i will affect the $\mu_{d,i}$ via s_i.

Since banks are symmetric, in equilibrium $d_i = d_j = d, w_i = w_j = w$. To simplify notation, in the following analysis, we drop the subscript i and use d and w to denote the optimal choice of deposit and wholesale fund for individual banks. Equation ($S11$) defines an implicit function of w in terms of $d : w = w\left(d; \mu_d\left(d\right)\right)$. The first-order condition is

$$\mu'_d + (1 - \frac{1}{e})s = -\mu_w \frac{dw}{dd} \tag{S13}$$

where $\frac{dw}{dd}$ denotes the total derivative of w with respect to d. The LHS of ($S13$) is the marginal benefit of deposit increase, taking into accounts the effect of deposit increase on deposit spread. The RHS is the marginal cost of deposit increase via its impacts on wholesale funding under the capital constraint.

Note that dw/dd is the slope of the concave contour of the capital constraint and can be decomposed into two components:

$$\frac{dw}{dd} = \frac{\partial w}{\partial d} + \frac{\partial \mu_d}{\partial d}\frac{\partial w}{\partial \mu_d} \tag{S14}$$

The first argument on the RHS of (S14) corresponds to the direct effect of retail deposit on wholesale funding (i.e., with μ_d exogenous to d), which follows (18) and is negative. The second argument on the RHS of (S14) captures the indirect effect of retail deposit on wholesale funding via μ_d. Equation ($S11$) implies

$$\frac{\partial w}{\partial \mu_d} = \frac{d}{\theta + 2\theta\varphi w - \mu_w} > 0. \tag{S15}$$

Equation ($S12$) implies

$$\frac{\partial \mu_d}{\partial d} = \frac{\partial s}{\partial d} = -\frac{1}{e}\frac{s}{d} < 0. \tag{S16}$$

Plugging (18), $(S15)$ and $(S16)$ into $(S14)$, we have

$$\frac{dw}{dd} = -\frac{\theta - \mu_d' - \left(1 - \frac{1}{e}\right) s}{\theta + 2\theta\varphi w - \mu_w} < 0. \tag{S17}$$

Note that our benchmark model is a special case of this extended model, in which $e \to \infty$. and $\mu_d' + (1 - \frac{1}{e})s = \mu_d$. Accordingly, $\partial \mu_d / \partial d = 0$ and $dw/dd = \partial w / \partial d$. And Equation (S13) becomes $-\partial \mu_d / \partial \mu_w = \partial w / \partial d$, which chatacterizes the optimal bank funding composition in the benchmark model.

Plugging $(S17)$ into equation (S13) and rearranging, we get optimal deposit supply of individual banks

$$\frac{\mu_d' + \left(1 - \frac{1}{e}\right) s}{\mu_w} = \frac{\theta - [\mu_d' + \left(1 - \frac{1}{e}\right) s]}{\theta + 2\theta\varphi w - \mu_w} \tag{S18}$$

We can rearrange $(S18)$ and obtain the aggregate deposit supply curve by $s = S$, $d = \widehat{D}$ and $w = W$.

$$\mu_d' + \left(1 - \frac{1}{e}\right) S = \frac{\mu_w}{1 + 2\varphi W \left(\widehat{D}; \mu_d\right)} \tag{S19}$$

Since $\frac{dW}{dD} < 0$, the RHS of $(S19)$ increases with deposit supply $\widehat{D}$.

A.3.3. *Impacts of Monetary Policy on Banks' Funding Composition.* This section shows that our theoretical predictions regarding the comovement of retail deposits and wholesale funding when monetary policy changes still hold in this extended model. We establish the following lemma

Lemma S1. Without deposit rate ceilings, in equilibrium, individual banks' retail deposit and wholesale fund comove negatively when the policy rate changes,

$$\frac{\partial d^*}{\partial r_b} < 0; \ \frac{\partial w^*}{\partial r_b} > 0.$$

Proof. Plugging (1), the aggregate demand for deposit, into $(S19)$, the equilibrium deposit quantity satisfies

$$\mu_d' + \left(1 - \frac{1}{e}\right) \frac{\beta_m}{D^*} = \frac{\mu_w}{1 + 2\varphi w \left(D^*\right)}$$

To obtain $\frac{\partial S^*}{\partial r_b}$, note that in equilibrium

$$D\left(S\right) = \widehat{D}\left(S, r_b\right)$$

Taking total derivative with respect to S and r_b, we have

$$\frac{\partial D}{\partial S}\frac{\partial S}{\partial r_b}=\frac{\partial \widehat{D}}{\partial S}\frac{\partial S}{\partial r_b}+\frac{\partial \widehat{D}}{\partial r_b}$$

Reodering the above equation, we obtain

$$\frac{\partial S^*}{\partial r_b}=\frac{-\frac{\partial \widehat{D}}{\partial r_b}}{\frac{\partial \widehat{D}}{\partial S}-\frac{\partial D}{\partial S}} \tag{S20}$$

Equation $(S19)$ implies that

$$\frac{\partial \widehat{D}}{\partial S}=-\frac{1-\frac{1}{e}}{\frac{2\mu_w\varphi}{(1+2\varphi W)^2}\frac{dW}{d\widehat{D}}}>0 \tag{S21}$$

The household demand for deposit gives

$$-\frac{\partial D}{\partial S}=\frac{\beta_m}{S^2}>0 \tag{S22}$$

To derive $\frac{\partial \widehat{D}}{\partial r_b}$, note that given S, W is a function of both D and r_b via μ_d'. Denote the RHS of $(S19)$ as RHS. Taking total derivative of $(S19)$, we have

$$\frac{\partial \mu_d'}{\partial r_b}\partial r_b=\frac{\partial RHS}{\partial W}\left(\frac{\partial W}{\partial r_b}\partial r_b+\frac{\partial W}{\partial \widehat{D}}\partial \widehat{D}\right) \tag{S23}$$

where

$$\frac{\partial W}{\partial r_b}=\frac{\partial W}{\partial \mu_d'}\frac{\partial \mu_d'}{\partial r_b}+\frac{\partial W}{\partial(\mu_a\kappa+\nu_l)}\frac{\partial(\mu_a\kappa+\nu_l)}{\partial r_b}$$

and $\frac{\partial W}{\partial \widehat{D}}$ follows (18). Rearranging $(S23)$ leads to

$$\begin{aligned}\frac{\partial \widehat{D}}{\partial r_b} &= \frac{\partial \mu_d'/\partial r_b\times\left[\frac{1}{\frac{\partial RHS}{\partial W}}-\frac{\partial W}{\partial \mu_d'}\right]-\frac{\partial W}{\partial(\mu_a\kappa+\nu_l)}\frac{\partial(\mu_a\kappa+\nu_l)}{\partial r_b}}{\partial W/\partial \widehat{D}} \\ &= -\frac{(\rho R_l+1)\left[(1+2\varphi W)^2/(2\varphi\mu_w)+d/(\theta+2\theta\varphi w-\mu_w)+(\tau-\kappa)/(\theta+2\theta\varphi w-\mu_w)\right)\right]}{\frac{\theta-\mu_d}{(\theta+2\theta\varphi w-\mu_w)}}<0.\end{aligned} \tag{S24}$$

Plugging $(S21),(S22)$ and $(S24)$ into $(S20)$, we have

$$\frac{\partial S^*}{\partial r_b}>0.$$

The response of retail deposits to policy rates in equilibrium can be expressed as

$$\frac{\partial D^*}{\partial r_b}=\frac{\partial D^*}{\partial S^*}\frac{\partial S^*}{\partial r_b}=-\frac{\beta_m}{S^2}\frac{\partial S^*}{\partial r_b}<0, \tag{S25}$$

where the second equality is obtained by plugging the aggregate deposit demand function (1).

Finally, the response of wholesale funding to policy rates can be obtained as

$$\frac{\partial W^*}{\partial r_b} = \frac{\partial D^*}{\partial r_b}\frac{dW^*}{dD^*} > 0.$$

where the inequality is obtained from both $(S14)$ and $(S25)$. Since in equilibrium, $d^* = D^*$ and $w^* = W^*$, we have (S1). □

Lemma (S1) implies that our previous results of negative comovement between retail deposits and wholesale funding still hold when banks have market power. The intuition is as follows: As banks' deposit market power increases, the marginal impact of the policy rate on the equilibrium deposit spread become larger. This implies that when the policy rate declines, it is more likely for the deposit spread to to be bounded at its lower bound. Thus, banks have stronger incentive to use wholesale funding as an alternative source of funds to retail deposit. The following lemma establishes the comovement between retail deposits and wholesale funding when the deposit rate ceiling is binding.

Lemma S2. When deposit rate ceilings are binding, there is a positive comovement between banks' supply of wholesale funding and their supply of retail deposits, i.e.,

$$\frac{\partial w}{\partial r_b} < 0, \frac{\partial d}{\partial r_b} < 0,$$

if and only if

$$(1-\lambda)\bar{d} + R_l\left(\rho\bar{d} + \tau - \kappa\right) > (\theta - \mu_d)\frac{\bar{d}}{R_b}. \tag{S26}$$

Proof. For the case with bank deposit market power, when deposit rate ceilings are binding, $S \geq \overline{S} = \lambda R_b$ and $d = \bar{d} = h(r_b) = \frac{\beta_m}{\lambda r_b}$. Hence $\frac{\partial d}{\partial r_b} = \frac{\partial \bar{d}}{\partial r_b} = h'(r_b) < 0$. We can solve w as a solution to the following equation:

$$\theta\varphi w^2 + (\theta - \mu_w)w + \theta\bar{d} - \mu_a\kappa - (\mu_{d'} + \bar{s})\bar{d} - \upsilon_l = 0. \tag{S27}$$

Equation (S27) implies

$$\frac{\partial w}{\partial r_b} = -\left[(1-\lambda)\bar{d} + R_l\left(\tau - \kappa + \bar{d}\rho\right) + (\theta - \mu_d)\frac{\partial \bar{d}}{\partial r_b}\right]\frac{1}{2\theta\varphi w + \theta - \mu_w} \tag{S28}$$

Hence, $\partial w/\partial r_b < 0$ if and only if the condition (S26) holds. □

Appendix B. Data Sources

The following list delineates the variables employed in the main text, along with their respective sources:

- R: policy rate, measured as R007, denotes as quarterly average of 7-day interbank bond collateral repo rate. Source: CEIC.
- R_d: deposit interest rate. Source: individual banks' biannual report.
- GDP: Real GDP growth rate. Source: CEIC.
- INF: GDP deflator inflation rate. Source: CEIC.
- $I(NSB)$: Dummy variable that equals 1 if a bank belongs to the type of non-state banks.
- L: Total loan divided by total assets. Source: CSMAR.
- STK: Cash flow from stock issuance divided by total assets. Source: CSMAR.
- ROA: the ratio of net earnings after dividend payout to total assets. Source: CSMAR.
- LIQ: Cash or cash equivalents at the end of period divided by total assets. Source: CSMAR.
- FIN: Short-term non-loan financial assets (financial assets held for trading+financial assets available for sale+financial derivatives+Reverse Repo) divided by total assets of each bank. Source: CSMAR.
- FIL: Short-term financial liabilities (financial liabilities available for sale+financial derivatives) divided by total liabilities of each bank. Source: CSMAR.