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ABSTRACT

In well-developed financial markets, wholesale funding comoves negatively with retail deposits in response to interest rate changes, thereby weakening monetary policy transmission. By contrast, our study finds that in economies such as China where deposit rate ceilings are regulated, (i) retail deposits and wholesale funding comove positively as the policy rate changes, and (ii) wholesale funding strengthens the transmission of the policy rate to bank lending. We develop a theoretical model underscoring the role of deposit market regulation for the impact of monetary policy on bank funding composition in the context of the world's largest emerging market economy.

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I. Introduction

Understanding the role of wholesale funding in 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 to retail deposits. When the monetary authority reduces its interest rate (the policy rate), banks often substitute retail deposits for wholesale funding, and the opposite occurs when the interest rate is raised. This substitution effect leads to a negative comovement between retail deposits and wholesale funding in response to changes in the policy rate. Such dynamics are supported by the classical bank lending channel literature (e.g., Stein (1998) and Bianchi and Bigio (2022)), which discusses how the Federal Reserve influences banks' ability to create deposits, as well as by the more recent deposits channel literature (e.g., Drechsler, Savov, and Schnabl (2017) and Wang, Whited, Wu, and Xiao (2022)), focusing on the impact of federal fund rate changes on banks' deposit market power.

While past studies have primarily focused on economies with liberalized financial markets, China—the largest emerging-market economy—presents a different scenario. China continues to impose deposit rate ceilings as part of its banking regulation (Brunnermeier, Sockin, and Xiong, 2022). In such an economy, the relationship between changes in the policy rate and banks' funding composition, as well as the role of wholesale funding in the transmission of monetary policy to bank lending, may qualitatively differ from economies without such regulatory restrictions. In particular, wholesale funding in the Chinese banking system has emerged as an important source of external funding. In 2017, for instance, wholesale funding constituted nearly 30% of total liabilities on average for all publicly listed banks.[1]

In this study, we explore how monetary policy affects wholesale funding and bank lending in China by explicitly incorporating deposit rate ceilings into a standard banking model. To motivate our theoretical model, we first provide evidence using bank-level data from China, a country that has long been subject to deposit rate ceilings. We then develop a theoretical model to account for our motivating evidence. Both our empirical and theoretical results reveal that in economies with deposit rate ceilings, wholesale funding comoves positively with retail deposits in response to changes in the policy rate, thus enhancing the transmission

[1]In the Chinese banking system, wholesale funding includes borrowings from banks and other financial institutions, borrowings from the central bank, bonds payable, financial assets sold for repurchase, and dues to banks and other financial institutions.

of monetary policy to bank lending. This finding contrasts with the result for economies without such ceilings.

Our theoretical model, guided by our motivating evidence, constitutes the main contribution of our paper. A key innovation of our model is that it allows the capital constraint faced by an individual bank to change in response to policy rate fluctuations. This element allows wholesale funding and retail deposits to comove positively in response to policy rate changes when a regulatory ceiling is imposed on deposit rates. As the policy rate falls, the bank's equity rises, relaxing the capital constraint. This relaxation enables banks to expand their funding sources through wholesale funding, as deposit rate ceilings constrain the amount of retail deposits they can supply. Consequently, wholesale funding and retail deposits move in the same direction, strengthening the transmission of the policy rate to bank loans. Conversely, when the policy rate rises, both retail deposits and wholesale funding decline due to the regulatory ceiling on deposit rates and the tightening of capital constraints.

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, Savov, and Schnabl (2017), Drechscher, Savov, and Schnabl (2021), Xiao (2020), and Wang, Whited, Wu, and Xiao (2022)). Existing literature consistently finds that wholesale funding weakens the monetary policy transmission because of its movements opposite of 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, can enhance monetary policy transmission (Choi and Choi (2021)). Our study, however, departs from previous work by showing that in China where regulation places deposit rate ceilings, wholesale funding complements retail deposits in the transmission of the policy rate to the loan market. As a result, the Basel III liquidity regulation may hinder the monetary policy transmission in China, a pivotal player in the global economy and the second largest economy in the world. To the best of our knowledge, our study is the first to explore how deposit market regulations affect the impact of the policy rate on banks' funding composition.

Our model emphasizes that the capital constraint, largely ignored in the literature on the deposits channel of monetary policy, is crucial for generating a positive comovement between wholesale funding and retail deposits. In existing models, such as that of Drechsler, Savov, and Schnabl (2017), the capital constraint does not change when the policy rate changes. As a result, banks substitute retail deposits for wholesale funding when the policy rate falls, even in an economy with binding deposit rate ceilings. This substitution effect always results in a negative comovement between the two sources of external funding. Even with capital constraints that endogenously respond to changes in the policy rate, retail deposits still move in the opposite direction of wholesale funding (Wang, Whited, Wu, and Xiao, 2022). Thus, allowing capital constraints to change with the policy rate is a necessary but not sufficient condition for positive comovement of these funding sources. Moreover, our paper examines the transmission of the policy rate to bank lending in the Chinese context. This focus contributes to the emerging literature on the effects of monetary policy on China's banking system (Cong, Gao, Ponticelli, and Yang, 2019).[2]

II. Motivating evidence

In this section, we present two important findings as empirical evidence motivating our theoretical work in Section III. (1) For banks with binding deposit rate ceilings, there is a positive correlation between wholesale funding and retail deposits in response to changes in the interest rate. In contrast, for banks not constrained by deposit rate ceilings, the opposite is true. (2) While wholesale funding weakens the transmission of monetary policy to bank lending for banks not constrained by deposit rate ceilings, it strengthens the transmission for banks with binding deposit rate ceilings.

Our findings are based on 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). For detailed descriptions of the variables used in this section, see Internet Appendix A. We manually collected deposit interest rates from each bank's daily listing; macroeconomic data are collected from the National Bureau of Statistics of China and the People's Bank of China (PBC). Our bank-quarter dataset covers the period from the first quarter of 2013 (2013Q1) to the fourth quarter of 2019 (2019Q4).

II.1. **Banks' funding composition: positive comovements between deposits and wholesale funding.** We now estimate the impact of changes in the interest rate on the composition of retail deposits and wholesale funding for banks constrained by deposit rate ceilings. Using the difference-in-differences (DID) approach, we find that in response to changes in monetary policy rates, retail deposits comove positively with wholesale funding in banks subject to binding deposit rate ceilings (hereafter, BBs—binding banks), while this

[2]See also Chen, Ren, and Zha (2018), Chen, He, and Liu (2020), Li, Liu, Peng, and Xu (2020), and Chen, Gao, Higgins, Waggoner, and Zha (2023), among others.

correlation is negative in banks not constrained by these ceilings (hereafter, NBBs—non-binding banks).

Our sample includes two groups of banks: BBs and NBBs. We define the "deposit ceiling spread" as the difference between the deposit rate and its regulatory ceiling. For BBs, this spread is zero, indicating that their deposit rates are bound by the regulatory ceiling. For NBBs, by contrast, this spread is negative, reflecting that their deposit rates are not constrained by the regulatory ceiling. To mitigate the influence of other macroeconomic factors on the deposit ceiling spread, we consider an individual bank's spread one quarter after the China Banking Regulatory Commission's first-time relaxation of the deposit ceiling regulation on June 8, 2012, which predates our sample period. This regulatory change, unanticipated by banks, marked the PBC's first increase in the deposit rate ceiling, from the benchmark deposit rate to 1.1 times that rate. Therefore, if a bank is subject to or bound by the binding deposit rate ceiling imposed by the regulation, the bank's deposit ceiling spread will be zero following the relaxation of deposit rate ceiling regulation. Conversely, if such regulation does not affect a particular bank, this bank's deposit ceiling spread will be negative.

Wholesale funding supplies a bank with an alternative source of external finance. Loan demand and the availability of banks' internal funds may affect how banks rely on retail deposits and wholesale funding as external sources of funding. To control for these factors, we include in our regression three alternative measures of liquidity: the ratio of net increase of cash (and cash equivalents) to total assets (LIQ), earnings per share (EPS), and the ratio of proceeds from issuing shares to total assets (STK). With these variables controlled for, we run an unbalanced bank-quarter panel regression as follows:

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

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 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); $I(BB_b)$ is a dummy variable equal to 1 if bank b is a BB and zero otherwise; $X_{b,t-1}$ represents a set of bank-level variables, including the 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 to changes in the policy rate for NBBs. The coefficient β measures the *marginal* impact of a change in the policy rate on deposits or wholesale funding for BBs, so that its overall impact on BBs is measured by $\alpha + \beta$.

Table 1 presents the responses of retail deposits and wholesale funding to changes in the policy rate. In column (1), the estimated coefficient α, representing the response of NBBs' deposits or wholesale funding to policy rate changes, is negative and statistically significant. This estimate implies that for NBBs, a one-percentage-point decrease in the policy rate corresponds to a 1.7 percentage-point increase in retail deposits (as a share of total liabilities). The estimated coefficient β, which measures the marginal impact of policy rate changes on BBs, is significantly positive, indicating that the response of retail deposits in BBs is weaker than that in NBBs. Accordingly, the increase in retail deposits in response to a one-percentage-point decrease in the policy rate is only 0.65 percentage point for BBs, as indicated by the estimated value of $\alpha+\beta$. Thus, BBs experience a less pass-through from changes in the policy rate into retail deposits than NBBs, but nonetheless their deposits rise. This result remains robust when we include time-varying bank-specific controls, as shown in column (2).

Column (3) presents the estimated results for wholesale funding. The estimated coefficient α is positive and statistically significant. The estimate indicates that a one-percentage-point decrease in the policy rate leads to a 0.59 percentage-point decrease in wholesale funding, consistent with existing literature. Intuitively, a policy rate cut reduces the cost of deposit funding, encouraging banks to substitute retail deposits for wholesale funding.[3] By contrast, the estimated coefficient β is negative and statistically significant, indicating that wholesale funding in BBs increases by 2.27 percentage points relative to NBBs in response to a one-percentage-point decrease in the policy rate. The overall impact of a policy rate cut on BBs' wholesale funding, captured by $\alpha + \beta$, is negative and highly significant statistically. Again, our findings are robust to the inclusion of time-varying bank-specific controls (column (4)).

These results reveal significant comovement between retail deposits and wholesale funding when the policy rate changes. Comparing the sign of α between columns (1) and (3), as well as between columns (2) and (4), confirms that in the absence of deposit rate ceilings, as in most developed economies, there is a negative comovement between retail deposits and wholesale funding in response to policy rate changes. This result is consistent with empirical

[3]Conversely, when the monetary authority increases its interest rate and deposits become more expensive, NBBs turn to wholesale funding.

evidence from the United States. When banks face binding deposit rate ceilings, by contrast, wholesale funding and retail deposits comove positively in response to policy rate changes, as indicated by the same sign of $\alpha + \beta$ in columns (1) and (3), and in columns (2) and (4).

II.2. **The role of wholesale funding in the transmission of the policy rate.** In this section, we provide empirical evidence on the impact of wholesale funding on the transmission of changes in the policy rate to bank loans for BBs by estimating the following regression, using a subsample that contains only BBs:

$$\Delta L_{b,t} = \alpha W_{b,t-1} + \beta R_{t-1} \times W_{b,t-1} + \gamma R_{t-1} + \kappa X_{b,t-1} + \alpha_b + \tau_y + \tau_q + \epsilon_{b,t},$$

where $\Delta L_{b,t}$ represents the year-over-year changes in bank loans for bank b in quarter t, and $W_{b,t-1}$ denotes the wholesale funding in the previous quarter, both scaled by total liabilities. A vector of control variables, $X_{b,t-1}$, includes the ratio of net profit to total assets (ROA) to control for the effects of loan demand, and the ratio of total liabilities to equity (LEV) to control for the effects of bank leverage. The term α_b denotes bank fixed effects, τ_y year fixed effects, and τ_q quarter (seasonal) fixed effects. Our primary focus is on the coefficient β, which captures the role of wholesale funding in transmitting the monetary policy rate to bank lending.

Table 2 reports the estimation results. The estimated coefficient α is positive and statistically significant, suggesting that banks with higher exposure to wholesale funding experience a larger increase in bank lending. The estimated value of β is negative and statistically significant, indicating that for every one-percentage-point increase in wholesale funding, there is a corresponding 0.05 percentage point increase in the elasticity of bank lending to the policy rate. Our findings are robust to the inclusion of macroeconomic factors such as quarterly year-over-year GDP growth and inflation rates, as well as their interactions with bank-specific variables, as additional control variables. Moreover, our results hold under a different specification that includes bank, year, and seasonal fixed effects to control for unobserved time-varying bank characteristics.

In summary, our results for BBs are twofold. First, we observe that for BBs, wholesale funding comoves positively with retail deposits when the policy rate changes. Second, the higher a bank's exposure to wholesale funding, the more sensitive its lending is to changes in the policy rate. These findings not only shed light on the effects of a policy rate change to bank funding composition and lending, but also provide empirical motivation to develop a theoretical model that explicitly considers the role of financially repressive regulations such as deposit rate ceilings.

III. A banking model with deposit market regulation

In this section, we develop a simple model to illustrate how regulatory ceilings on deposit interest rates affect the transmission of monetary policy to banks' funding composition. Our model assumes that banks are subject to imperfect competition in the deposit market, which is a key aspect of the deposit channel for monetary policy transmission. In addition, banks are subject to a capital constraint, and monetary policy influences the tightness of this constraint. In our model, deposit market regulation is characterized by a ceiling on deposit rates, effectively placing a lower bound on the spread between the policy rate and the deposit rate. We demonstrate that under these conditions, wholesale funding can enhance the transmission of policy rate changes through bank lending, a novel finding that has not been previously explored.

III.1. **Environment.** The economy has two types of agents: a set of N monopolistically competitive banks and the representative household. Banks have the option to borrow through deposits (d) or wholesale funding (w). Deposits are subject to monopolistic competition, whereas wholesale funding is not. On the other hand, the marginal cost of raising funds via wholesale funding increases in the amount borrowed, capturing the fact that unlike deposits, wholesale funding is uninsured. 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.

III.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. 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

$$C + \beta_m \log D$$

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 deposit market regulation, 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:

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

The aggregate deposits are a composite good produced by a set of N banks:

$$D = \left(\frac{1}{N} \sum_{i=1}^{N} D_i^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}}, \tag{4}$$

where η is the elasticity of substitution across banks, which is $1 < \eta < \infty$. Each bank has mass $\frac{1}{N}$ and produces deposits at rate D_i. As in Drechsler, Savov, and Schnabl (2017), we normalize the mass of each bank to $\frac{1}{N}$ so that the total size of banking sector is 1 regardless of N. A larger N means higher deposit competition.

The representative household chooses deposits across banks to minimize the opportunity cost of holding deposits:

$$\min_{D_i} \sum_{i=1}^{N} \frac{1}{N} D_i S_i, \tag{5}$$

subject to equation (4).

In the symmetric equilibrium, we have $S_i = S$. We can show that in a symmetric equilibrium the elasticity of demand for bank is deposits is given by

$$-\frac{\partial log D_i}{\partial log S_i} = \frac{N-1}{N}\eta \tag{6}$$

We define $M = -1 - \frac{1}{\frac{\partial log D_i}{\partial log S_i}} = \frac{N}{(N-1)\eta} - 1$ as the market power of bank i.[4]

III.1.2. *Banks.* Banks consume all of their profit at the end of the period. The profit of bank i at the end of the period is denoted as Π^i, and it represents the sum of the gross return on bank loans, net of the cost of retail deposits and wholesale funding. We follow Wang, Whited, Wu, and Xiao (2022) and assume that lending involves a maturity transformation between assets and liabilities. Specifically, loans mature in two periods for simplicity (i.e., a portion α of loans mature in the first period, and the remaining $1-\alpha$ mature in the second period). Both retail deposits and wholesale funding are short-term and mature for one period.

Therefore, the bank's profit at the end of the period is:

$$\Pi^i = (1-\alpha)L_{i,-1}r^l_{-1} + \alpha(R_b + l_0)L_i - (R_b + \psi W_i)W_i - (R_b - S_i)D_i, \tag{7}$$

where $L_{i,-1}$ represents existing loans from the last period, r^l_{-1} is the pre-fixed loan interest rate associated with $L_{i,-1}$, $L_i = D_i + W_i$ the total loans of the current period. Parameters $\psi > 0$ and l_0 control the bank's wholesale funding cost and loan spreads, which together capture their marginal cost of loan services.

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

$$\theta(W_i + D_i) \leq \Pi^i, \tag{8}$$

where $0 < \theta \leq 1$. Thus, the bank's profit must exceed a certain fraction of its total liability. Note that the maturity mismatch (i.e., the difference in time-to-maturity between assets and liabilities) makes the tightness of the capital constraint respond endogenously to the policy rate. Because deposit and wholesale funding are short-term, both the deposit rate and interest rate for wholesale funding adjust instantaneously with the policy rate. Loans are long-term, so only a fraction of loans mature, while the remaining $1-\alpha$ of loans carry the same pre-fixed interest rate. Hence, a decrease in the policy rate, by reducing funding

[4] From (12), M should be positive, hence $1 < \eta < \frac{N}{N-1}$. When $N \to \infty$, $M \to 0$; when $N \geq 2$, $M < 1$. Therefore, M is between 0 and 1.

costs more than average returns to total bank lending, increases bank capital and relaxes the bank capital constraint.[5]

III.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 assumption.

Assumption 1.

$$\alpha < \frac{\theta}{l_0}. \tag{9}$$

Constraint (9) ensures that, ceteris paribus, an increase in either deposit or wholesale funding tightens the capital constraint.

Proposition 1. Under Assumption 1, in response to changes in the monetary policy rate:

(1) When there are no deposit rate ceilings, equilibrium wholesale funding and retail deposits move in opposite directions, i.e.,

$$\frac{\partial W}{\partial R_b} > 0, \frac{\partial D}{\partial R_b} < 0;$$

if the aggregate supply of deposit $\hat{D}$ from banks is upward sloping in deposit rate spread S.

(2) When deposit rate ceilings are binding, equilibrium wholesale funding and retail deposits move in the same direction, i.e.,

$$\frac{\partial W}{\partial R_b} < 0, \frac{\partial D}{\partial R_b} < 0;$$

iff

$$(1-\alpha)W > (\theta - \alpha l_0)\frac{\bar{D}}{R_b} \tag{10}$$

Proof of Proposition 1.

(1) When there is no deposit rate ceiling, the FOCs over W_i and D_i are

$$\begin{aligned} \frac{\partial L}{\partial W_i} &= [\alpha l_0 - (1-\alpha)R_b - 2\psi W_i](1+\mu) - \mu\theta = 0 \\ \frac{\partial L}{\partial D_i} &= [\alpha l_0 - (1-\alpha)R_b + S_i(1 + \frac{\partial S_i/S_i}{\partial D_i/D_i})](1+\mu) - \mu\theta = 0 \end{aligned} \tag{11}$$

[5]The capital constraint, represented by equation (8), reflects regulatory requirements on banks' equity or capital. This constraint, discussed in Wang, Whited, Wu, and Xiao (2022), is a commonly used feature in the literature.

where μ is the Lagrangian multiplier for capital constraint (8).[6]

From (11) one can solve

$$W_i = \frac{-(1+\frac{\partial log S_i}{\partial log D_i})}{2\psi} S_i = \frac{M}{2\psi} S_i \tag{12}$$

Putting the above equation into (8), we solve the supply of deposit D_i as a function of deposit interest rate spread S_i:

$$D_i = \frac{-[\theta + (1-\alpha)R_b - \alpha l_0 + \psi \frac{M}{2\psi} S_i]\frac{M}{2\psi} S_i + (1-\alpha)L_{-1} r^l_{-1}}{\theta + (1-\alpha)R_b - \alpha l_0 - S_i} \tag{13}$$

By imposing symmetry across banks, i.e. $D_i = D$ (which leads to $S_i = S$ and $W_i = W = \frac{M}{2\psi}S$), we obtain the aggregate supply of deposit:

$$\hat{D}(S, R_b) = \frac{-[\theta + (1-\alpha)R_b - \alpha l_0 + \psi \hat{W}]\hat{W} + (1-\alpha)L_{-1} r^l_{-1}}{\theta + (1-\alpha)R_b - \alpha l_0 - S} \tag{14}$$

And the slope of the aggregate deposit supply curve is

$$\frac{\partial \hat{D}}{\partial S} = \frac{D - [\theta + (1-\alpha)R_b - \alpha l_0 + 2\psi \hat{W}]\frac{\partial \hat{W}}{\partial S}}{\theta + (1-\alpha)R_b - \alpha l_0 - S} \tag{15}$$

By Assumption 1, the following condition needs to be hold in order to have an upward sloping aggregate supply of deposit ($\frac{\partial \hat{D}}{\partial S} > 0$):

$$[\theta + (1-\alpha)R_b - \alpha l_0 + 2\psi \hat{W}]\frac{\partial \hat{W}}{\partial S} < D. \tag{16}$$

With the demand for deposits from households (equation (1)) and the supply of deposits from banks (equation (14)), we solve for the equilibrium quantity and cost using the market-clearing conditions,

$$D(S) = \hat{D}(S, R_b). \tag{17}$$

Taking the derivative of R_b on both sides of (17) and reordering, we obtain

$$\frac{\partial S}{\partial R_b} = \frac{-\frac{\partial \hat{D}}{\partial R_b}}{\frac{\partial \hat{D}}{\partial S} - \frac{\partial D}{\partial S}}. \tag{18}$$

Since $\frac{\partial \hat{D}}{\partial R_b} = -\frac{(1-\alpha)(D+W)}{\theta+(1-\alpha)R_b - \alpha l_0 - S} < 0$, $\frac{\partial \hat{D}}{\partial S} > 0$, and $\frac{\partial D}{\partial S} = -\frac{\beta_m}{S^2} < 0$, we have

$$\frac{\partial S}{\partial R_b} > 0, \tag{19}$$

[6] α should be larger than $\frac{R_b}{R_b + l_0}$ to ensure an interior optimal choice of wholesale funding W_i. Otherwise, the bank would not like to issue any wholesale funding.

In other words, an increase in the policy rate would increase the deposit spread, a result consistent with findings by Drechscher, Savov, and Schnabl (2017). Therefore,

$$\frac{\partial W}{\partial R_b} = \frac{M}{2\psi}\frac{\partial S}{\partial R_b} > 0. \tag{20}$$

Combining (1) and (14), we solve the equilibrium D as follows:

$$D = \frac{-[\theta + (1-\alpha)R_b - \alpha l_0 + \psi W]W + (1-\alpha)L_{-1}r^l_{-1} + \beta_m}{\theta + (1-\alpha)R_b - \alpha l_0}. \tag{21}$$

When policy rate R_b increases, the numerator decreases, and the denominator increases, so $\frac{\partial D}{\partial R_b} < 0$.

(2) When there is a deposit rate ceiling, since the deposit D is constrained by $\bar{D} = \frac{\beta_m}{\lambda R_b}$, it is easy to see $\frac{\partial D}{\partial R_b} < 0$.

For the impact of policy rates on wholesale funding, we have from equation (8)

$$[\theta + (1-\alpha)R_b - \alpha l_0 - \frac{\beta_m}{\bar{D}}]\bar{D} + [\theta + (1-\alpha)R_b - \alpha l_0 + \psi W]W = (1-\alpha)L_{-1}r^l_{-1}. \tag{22}$$

We then solve

$$\frac{\partial W}{\partial R_b} = -\frac{(1-\alpha)W + (\theta - \alpha l_0)\frac{\partial \bar{D}}{\partial R_b}}{\theta + (1-\alpha)R_b - \alpha l_0 + 2\psi W}. \tag{23}$$

Hence, $\frac{\partial W}{\partial R_b} < 0$ if and only if (10) holds.

□

The intuition for Proposition 1 is illustrated by Figure 1, which plots a bank's capital constraint curve and its indifference curve between retail deposits and wholesale funding. The convex curve (solid blue) shows the bank's indifference curve prior to a change in R_b, and the solid red one shows it after R_b decreases. The marginal rate of substitution between deposit and wholesale funding, as reflected in the slope of the convex indifference curve, is

$$\frac{dW_i}{dD_i} = -\frac{\Pi^i_D}{\Pi^i_W} = -\frac{\alpha l_0 - (1-\alpha)R_b - MS_i}{\alpha l_0 - (1-\alpha)R_b - 2\psi W_i}, \tag{24}$$

where $\Pi^i_X = \partial \Pi^i / \partial X$. The concave contour is the capital constraint with the slope

$$\frac{dW_i}{dD_i} = -\frac{\theta - (\alpha l_0 - (1-\alpha)R_b - MS_i)}{\theta - (\alpha l_0 - (1-\alpha)R_b - 2\psi W_i)}. \tag{25}$$

Point A in Figure 1, where the concave curve is tangent to the dotted curve, represents the optimal funding composition without deposit rate ceilings. In this case, wholesale funding is determined by equation (12). 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 opposing effects on wholesale funding. On the one hand, a decrease in the policy rate increases the marginal returns to deposits relative to wholesale funding, shown by a steeper indifference curve in Figure 1.[7] This effect, called "substitution effect", together with a binding capital constraint, encourages banks to substitute deposits for wholesale funding in the case without deposit rate ceilings. On the other hand, a decrease in the policy rate relaxes the capital constraint by increasing the bank's equity. This leads to a larger feasible set of $\{D, W\}$ and enables banks to expand their sources of funds through an increase in the supply of wholesale funding. This effect is called the "wealth effect".

These two effects underly the overall impacts of policy rates on wholesale funding without deposit rate ceilings. Figure 1 shows that with a lower policy rate, the new optimal point is A', which suggests that the substitution effect plays a dominant role. Intuitively, because an increase in wholesale funding raises the marginal cost while an increase in retail deposits does not, it is optimal to substitute deposits for wholesale funding even if the capital constraint is relaxed.

The presence of deposit rate ceilings, however, mutes the substitution effect on wholesale funding, as the increase of deposit is constrained by the deposit rate ceiling on the policy rate. Accordingly, the overall impact of a decrease in policy rates on wholesale funding depends on two opposing effects on the tightness of the capital constraint. One is the wealth effect as captured by $(1-\alpha)W$, which increases wholesale funding by relaxing the capital constraint. The other effect, via an increase in the deposit rate ceiling and thus deposits, tends to tighten the capital constraint and thus reduce wholesale funding. Condition (10) ensures that the wealth effect outweighs the opposing effect. As illustrated by Figure 1, 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.

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.

[7] For a given pair of optimal choice (D, W), when the policy rate R_b decreases by one unit, the numerator of (24) increases by $1-\alpha+\frac{\partial S}{\partial R_b}M$, while the denominator increases only by $1-\alpha$. Hence, the tangent of the indifference curve is steeper.

III.3. **The role of wholesale funding in the transmission of the policy rate.** In this section, we discuss the transmission of the policy rate to bank credit and provide 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. Denote $|_{w>0}$ as the case with wholesale funding and $|_{w=0}$ as the case without wholesale funding. Then, under Assumption 1,

(1) without deposit rate ceilings and with $\frac{\partial S}{\partial R_b} < \frac{(1-\alpha)S}{2[\theta+(1-\alpha)R_b-\alpha l_0]}$, the equilibrium loan L satisfies:
$$\frac{\partial L}{\partial R_b}\Big|_{w>0} > \frac{\partial L}{\partial R_b}\Big|_{w=0};$$
(2) when deposit rate ceilings are binding, the equilibrium loan L satisfies:
$$\frac{\partial L}{\partial R_b}\Big|_{w>0} < \frac{\partial L}{\partial R_b}\Big|_{w=0} < 0. \tag{26}$$

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., $W = 0$. Hence, $L = D$ and $\frac{\partial L}{\partial R_b} = \frac{\partial D}{\partial R_b}$.

With $W = 0$, the bank's capital constraint becomes
$$D^0 = \frac{(1-\alpha)L_{-1}r^l_{-1} + \beta_m}{\theta + (1-\alpha)R_b - \alpha l_0} \tag{27}$$
$$\frac{\partial D^0}{\partial R_b} = -(1-\alpha)\frac{(1-\alpha)L_{-1}r^l_{-1} + \beta_m}{[\theta + (1-\alpha)R_b - \alpha l_0]^2} < 0.$$
Hence, $\partial L/\partial R_b|_{w=0} < 0$.

Now consider the case in which banks can borrow via wholesale funding. We rewrite the bank capital constraint (8) as
$$D = h(W) + D^0, \tag{28}$$
where $h(W) = -W - \frac{\psi W^2}{\theta+(1-\alpha)R_b-\alpha l_0} < 0$.

Therefore, the effect of monetary policy on bank lending can be expressed as
$$\begin{aligned}\frac{\partial L}{\partial R_b}\Big|_{w>0} &= \frac{\partial W}{\partial R_b} + \frac{\partial h(W)}{\partial R_b} + \frac{\partial D^0}{\partial R_b} \\ &= -\frac{2\psi W \frac{\partial W}{\partial S}\frac{\partial S}{\partial R_b}}{\theta + (1-\alpha)R_b - \alpha l_0} \\ &+ \frac{(1-\alpha)\psi W^2}{[\theta + (1-\alpha)R_b - \alpha l_0]^2} + \frac{\partial L}{\partial R_b}\Big|_{w=0}.\end{aligned} \tag{29}$$

Hence, $\frac{\partial L}{\partial R_b} \mid_{w>0} > \frac{\partial L}{\partial R_b} \mid_{w=0}$ if and only if

$$-\frac{2\psi W \frac{\partial W}{\partial S}\frac{\partial S}{\partial R_b}}{\theta + (1-\alpha)R_b - \alpha l_0} + \frac{(1-\alpha)\psi W^2}{[\theta + (1-\alpha)R_b - \alpha l_0]^2} > 0,$$

which requires

$$\frac{\partial S}{\partial R_b} < \frac{(1-\alpha)S}{2[\theta + (1-\alpha)R_b - \alpha l_0]} \tag{30}$$

A decrease in the policy rate tends to decrease the deposit spread, which tends to amplify the effects of the policy rate on deposits. Condition (30) ensures that in equilibrium the reduction in the amount of wholesale funding with a lower policy rate dominates the increase in the amount of deposits, 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, which is also consistent with the findings by Drechscher, Savov, and Schnabl (2017).

(2) When deposit rate ceilings are binding, we first consider the case where banks have no access to wholesale funding, i.e., $W = 0$. Hence, $\frac{\partial L}{\partial R_b}\Big|_{w=0} = \frac{\partial \bar{D}}{\partial R_b} = -\frac{\beta_m}{\lambda R_b^2} < 0$.

Now, consider the case where banks have access to wholesale funding.

$$\frac{\partial L}{\partial R_b} \mid_{w>0} = \frac{\partial W}{\partial R_b} + \frac{\partial L}{\partial R_b} \mid_{w=0} < \frac{\partial L}{\partial R_b} \mid_{w=0} < 0, \tag{31}$$

Since a decrease in the policy rate leads to an increase in wholesale funding ($\partial W/\partial R_b < 0$) and bank lending is equal to the sum of retail deposits and wholesale funding, the overall impact on lending becomes larger in absolute term. This result establishes the first inequality in equation (26).

□

According to Proposition 2, when deposit rate ceilings are binding, a policy rate reduction relaxes banks' capital constraints. This relaxation allows them to increase their loan supply by raising funds through wholesale markets. As a result, the equilibrium loan increases more in response to a policy rate reduction when banks have access to wholesale funding than in the absence of wholesale funding. Access to wholesale funding provides banks with an alternative source of funding for their lending activities.

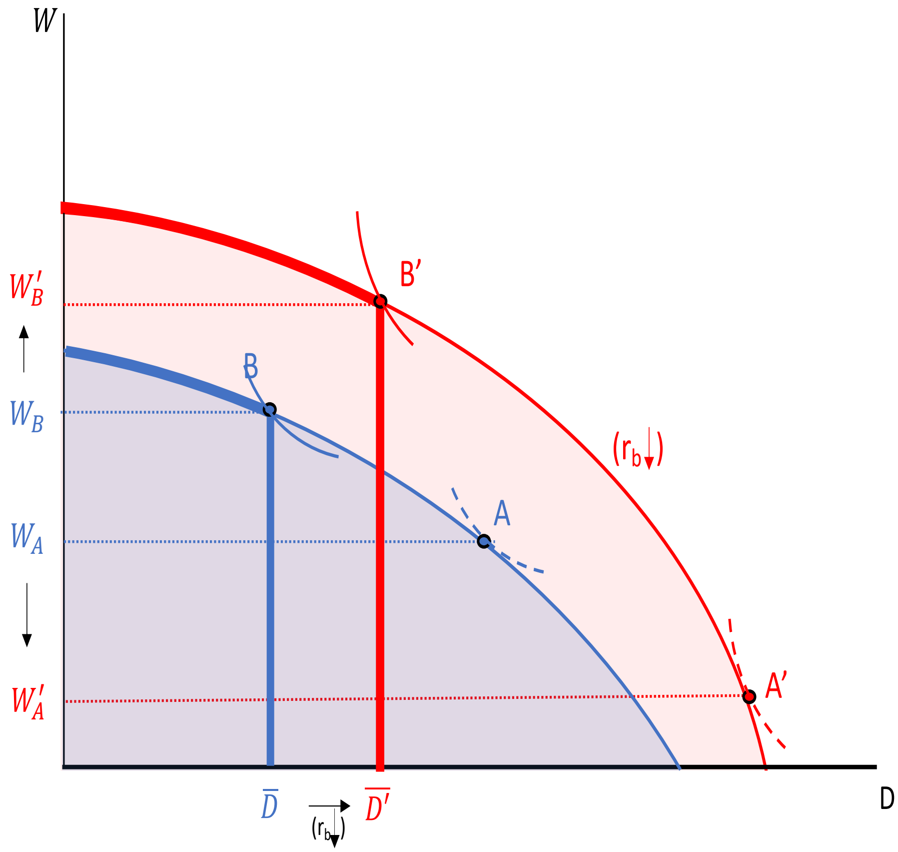
IV. Conclusion

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 China where regulations place ceilings on banks' deposit rates, 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 decrease in the policy rate leads to both a substitution effect, where retail deposits replace wholesale funding due to lower costs, and a wealth effect, where the relaxed capital constraint expands banks' borrowing capacity. 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 regulation. 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 deposit rate ceilings. 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". Point A (A') denotes the optimal funding composition without deposit rate ceilings, before (after) the monetary policy rate decreases. Point B (B') denotes the optimal funding composition with deposit rate ceilings, before (after) the monetary policy rate decreases.

TABLE 1. Effects of the policy rate on retail deposits and wholesale funding

	Deposits		Wholesale funding	
	(1)	(2)	(3)	(4)
R_{t-1}: α	-1.710^{***}	-1.829^{***}	0.593^{**}	0.847^{***}
	(0.327)	(0.369)	(0.289)	(0.308)
$R_{t-1} \times I(BB_b)$: β	1.056^{**}	0.924^{**}	-2.272^{***}	-1.937^{***}
	(0.403)	(0.392)	(0.327)	(0.429)
$R_{t-1} \times LIQ_{t-1}$		-0.0342		-0.0455
		(0.0656)		(0.0843)
$R_{t-1} \times EPS_{t-1}$		0.520^{*}		-0.466
		(0.285)		(0.296)
$R_{t-1} \times STK_{t-1}$		-1.233		-0.849
		(1.585)		(1.007)
$\alpha + \beta$	-0.65^{**}	-0.90^{***}	-1.68^{***}	-1.09^{**}
Bank FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Seasonal FE	YES	YES	YES	YES
N	546	546	547	547
R^2	0.2702	0.2988	0.3887	0.4009

Note: This table presents regression results with the year-over-year change in deposits and wholesale funding for each bank, scaled by total liabilities, as the dependent variable. Wholesale funding includes borrowings from banks and other financial institutions, borrowings from the central bank, bonds payable, and financial assets sold for repurchase. The independent variables include the policy interest rate (R_{t-1}) measured by R007, and its interaction with an indicator of whether the bank is subject to the deposit rate ceiling or not ($I(BB_b)$). Bank-level control variables include the ratio of proceeds from issuing shares to total assets (LIQ_{t-1}), earnings per share (EPS_{t-1}), and the ratio of proceeds from issuing shares to total liabilities (STK_{t-1}), along with their interaction terms with R_{t-1}. The regressions control for bank-specific, year fixed, and seasonal fixed effects. Robust standard errors, clustered by bank type, are reported in parentheses. Statistical significance is denoted by *** at the 1% level, ** at 5%, and * at 10%.

Table 2. Effects of wholesale funding exposure on monetary transmission to bank lending

	(1)	(2)	(3)	(4)
W_{t-1}: α	0.252***	0.249***	0.282***	0.258***
	(0.0740)	(0.0739)	(0.0800)	(0.0780)
$R_{t-1} \times W_{t-1}$: β	−0.0588**	−0.0590**	−0.0741***	−0.0663***
	(0.0222)	(0.0216)	(0.0216)	(0.0241)
R_{t-1}: γ	0.278	0.567	-0.304	-1.169
	(0.209)	(0.980)	(1.202)	(1.369)
$R_{t-1} \times ROA_{t-1}$		-0.0955	-0.294	-0.190
		(0.215)	(0.277)	(0.221)
$R_{t-1} \times LEV_{t-1}$		-0.0144	0.0607	0.111
		(0.0549)	(0.0738)	(0.0860)
Bank FE	YES	YES	YES	YES
Year FE	YES	YES	NO	YES
Seasonal FE	YES	YES	NO	YES
Macro Controls	NO	NO	YES	YES
N	547	547	547	547
R^2	0.1458	0.1520	0.1353	0.1788

Note: This table presents regression results in which the dependent variable is the bank-quarter observation of the year-over-year change in outstanding bank loans, scaled by total assets. The independent variables include the standardized ratio of wholesale funding to total liabilities (W_{t-1}) and its interaction with the policy rate (R_{t-1}), measured as R007. The bank-level control variables include net profit scaled by total assets (ROA_{t-1}), the ratio of total liabilities to equity (LEV_{t-1}), and their interactions with R_{t-1}. Macro control variables include the year-over-year GDP growth rate (GDP_t) and the year-over-year CPI inflation rate (INF_t), along with their interactions with bank-specific variables. Robust standard errors, clustered by bank type, are reported in parentheses. Statistical significance is indicated by *** at the 1% level, ** at 5%, and * at 10%.

Appendix A. 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.

• GDP: Real GDP growth rate. Source: CEIC.

• INF: GDP deflator inflation rate. Source: CEIC.

• $I(BB)$: Dummy variable that equals 1 if a bank is constrained by the deposit rate ceiling. Source: Financial reports and announcements of listing banks.

• D: Year-over-year change of deposits divided by total liability. Source: CSMAR.

• W: Year-over-year change of wholesale funding (includes borrowings from banks and other financial institutions, borrowings from the central bank, bonds payable, and financial assets sold for repurchase) divided by total liability. Source: CSMAR.

• L: Year-over-year change of total loan divided by total assets. Source: CSMAR.

• STK: Proceeds from issuing shares divided by total assets. Source: CSMAR.

• LIQ: Net increase of cash or cash equivalents divided by total assets. Source: CSMAR.

• EPS: Earnings per share (the current net profit attributable to ordinary shareholders divided by the weighted average number of outstanding ordinary shares). Source: CSMAR.

• ROA: The ratio of net profit to total assets. Source: CSMAR.

• LEV: The ratio of total liability to total equity. Source: CSMAR.

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