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Dong He and Honglin Wang

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Dong He*

Hong Kong Monetary Authority

Hong Kong Institute for Monetary Research

and

Honglin Wang*

Hong Kong Monetary Authority

Hong Kong Institute for Monetary Research

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Abstract

China has a dual-track interest-rate system: bank deposit and lending rates are regulated, but money and bond market rates are market-determined. At the same time, the central bank also imposes an indicative target, which may not be binding at all times, on total credit in the banking system. We develop and calibrate a theoretical model to illustrate the conduct of monetary policy within the framework of dual-track interest rates and a juxtaposition of both price- and quantity-based policy instruments. We model the transmission of monetary policy instruments to market interest rates, which, together with the quantitative credit target in the banking system, ultimately serve as the lever by which monetary policy affects the real economy. The model shows that market interest rates are most sensitive to changes in the benchmark deposit interest rates, significantly responsive to changes in the reserve requirements, but not particularly reactive to open market operations. These theoretical predictions are verified and supported by both linear and GARCH models using daily money and bond market data. Overall, the results of this study help us understand why the central bank conducts monetary policy in China the way it does: a combination of price and quantitative instruments, with various degrees of potency in terms of their influence on the cost of credit.

Keywords: Monetary Policy, People's Bank of China, Dual-Track Interest Rates, Interest Rate Liberalization

JEL Classification: E52, E58, C25, C32

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* Research Department of the Hong Kong Monetary Authority.
Author's email address: dhe@hkma.gov.hk; hwang@hkma.gov.hk

1. Introduction

The conduct of monetary policy is little understood by observers of the Chinese economy. Unlike in the advanced market economies where monetary policy typically has "one target and one instrument," the monetary policy framework in China is regarded as having multiple targets and multiple instruments. However, it is unclear through which channels instruments operate to move target variables. It is also unclear how price- and quantity-based instruments are chosen or combined to influence the availability and/or the cost of credit.

Key to a good understanding of China's monetary policy framework is the "dual-track" interest-rate system: on the one hand, bank deposits and lending rates are regulated by the central bank (i.e., the imposition of a deposit-rate ceiling and a lending-rate floor); on the other hand, interest rates in money and bond markets are market-determined (Porter and Xu, 2009)[1]. This system is considered to be part of the process of transitioning from a planned economy to a market economy and is consistent with the overall approach to economic reform. At the heart of China's gradualist approach to economic reform is the "dual-track" price system: prices at the margin are allowed to be set by market forces, while a large segment of the demand and supply system continues to function based on controlled prices (Qian, 1999). The controlled or regulated sector shrinks over time, and the whole system then becomes market-based. During the transition process, regulated and market prices interact with each other in a complex fashion: while changes in the regulated prices invariably affect market prices due to the forces of arbitrage, movements in market prices also provide useful information to the authorities that are in charge of setting regulated prices about changes in the underlying condition of demand and supply.

The objective of this paper is to provide a framework that allows us to have a better understanding of the conduct of monetary policy in China under the dual-track interest-rate system and a juxtaposition of both price-based and quantity-based policy instruments. We model the transmission of monetary policy instruments to market interest rates, which we take as indicators of monetary conditions and the cost of credit and, together with an indicative quantitative credit target in the banking system, ultimately serve as the lever by which monetary policy affects the real economy.

The existing literature on China's monetary policy typically focuses on various weaknesses of the financial system and evaluates links between monetary policy and macroeconomic performance (Qin *et al.*, 2005; Geiger, 2006; Laurens and Maino, 2007; Dickinson and Liu, 2007; Fan and Zhang, 2007; He and Pauwels, 2008; Shu and Ng, 2010, among others). Although many studies point out that regulated interest rates might hamper monetary policy transmission, few studies pay attention to how the

[1] There are still a few regulations on issuing rates in the bond market. For example, the issue rate on a corporate bond cannot be 40% higher than the term deposit rate at the same maturity. However, these regulations have not been binding, as markets have resorted to other instruments that do not fall under the regulation (Wu, 2011). Therefore, wholesale interest rates are basically market-determined in the money and bond market.

transmission works under the dual-track system. Empirical models in those studies either assume that the transmission mechanism in China is the same as that in advanced economies or simply treat it as a black box.

In contrast, three recent studies pay explicit attention to the transmission mechanism of monetary policy under regulated interest rates. Feyzioglu *et al.* (2009) study the behavior of Chinese banks under regulated interest rates, and they argue that interest-rate liberalization will likely result in higher interest rates. Porter and Xu (2009) construct a stylized model of China's interbank market, based on Freixas and Rochet (2008), and argue that raising the regulated lending rate will lead to a rise in the interbank rate but that raising the regulated deposit rate will instead lead to a fall in the interbank rate, provided the deposit-rate ceiling is binding and the lending-rate floor is not binding. Chen *et al.* (2011) extend the theoretical work of Porter and Xu (2009) and illustrate that regulated deposit and lending rates either have a negative impact, or have no impact, on the interbank rate. This result is troubling because it implies that regulated interest rates are not effective as monetary policy instruments in China. Nevertheless, the result may be due to the particular structure of the model, which is a partial-equilibrium model that does not take into account interactions between the banking sector and the money and bond markets.

In this paper, we develop a new theoretical model based on Porter and Xu (2009) and Chen *et al.* (2011) and extend their earlier analyses by taking into account fund flows between the banking sector and the bond market. Our new model shows that monetary policy instruments work reasonably well under the dual-track system, in the sense that their effects on the cost of credit are predictable both qualitatively and empirically. We conduct a simple calibration of the theoretical model to compare the relative potency of various policy instruments. We then estimate two empirical models to test the predictions of the theoretical model.

The theoretical model shows that raising the deposit-rate ceiling would lead to a rise in market rates if the deposit-rate ceiling is binding and the lending-rate floor is non-binding. Under this scenario, the lending-rate floor has no impact on market rates because moving the floor would not affect market equilibrium. Raising the Reserve Requirement Ratio (RRR) will also lead to a rise in market rates, as will issuing Central Bank Bills (CBB). If both the deposit-rate ceiling and the lending-rate floor are binding, then raising the deposit-rate ceiling will still lead to a rise in market rates; however, the impact of changing the lending-rate floor is indeterminate.

We also discuss the role of a quantitative target on credit and its impact on monetary policy transmission. A credit target is necessary when the deposit-rate ceiling is much lower than the equilibrium rate, although the target may not be binding, particularly when the demand for credit is weak. The use of the credit target also implies that most loans are made at rates above the floor. We conduct a simple calibration under this scenario and discover that the impact of changing the deposit-rate ceiling is approximately twice as large as the impact of changing the RRR, which in turn is much larger than the impact of changing the issuing rate of central bank bills.

The empirical section of this study aims to test the prediction of the theoretical model and the calibration. To do so, we employ daily data from the interbank market, covering the period from 30 October 2004 to 15 November 2010. The empirical results are consistent with the predictions of the theoretical models and the calibration: changes in regulated interest rates and other policy instruments have a predictable influence on market interest rates. For the People's Bank of China (PBC), setting the benchmark deposit rate is the most powerful instrument to influence market rates, and setting the RRR is the second-most important instrument to affect market rates. The relative potency of setting the benchmark deposit rate and the RRR is not constant over time, depending on the supply elasticity of deposits. However, setting the issuing rate of central bank bills does not have a significant impact on market rates, presumably due to the relatively small size of such bills on the PBC balance sheet.

The rest of the paper is organized as follows. The next section briefly reviews China's monetary policy framework, then describes the structure of the interbank bond markets. Section 3 derives the theoretical model and discusses several scenarios under the framework. A simple calibration is conducted to compare the relative potency of various policy instruments. Section 4 discusses specifications of the empirical models and estimation strategy. Section 5 reports estimation results and discusses two caveats, wherein we also provide an estimate of the equilibrium interest rate in China, which allows us to judge whether the deposit-rate ceiling is binding or not. Section 6 concludes the paper.

2. Institutional Background

2.1 The Monetary Policy Framework in China[2]

According to the *Law on the People's Bank of China,* "the aim of monetary policies shall be to maintain the stability of the currency and thereby promote economic growth." Thus, the PBC has a dual mandate, similar to that of the US Federal Reserve. Even though it is not explicitly stated in the law, there is also an understanding that the PBC has the mandate to maintain the stability of the Chinese financial system, reflecting its role as the lender of last resort. The policy implementation framework has evolved since the mid-1990s from relying on quantity-based instruments into a mixture of both quantity- and price-based instruments. Although the PBC does not appear to have an official articulation of its policy framework, it can be described as follows:

2 This section draws on He and Pauwels (2008).

- (Implicit) final targets: inflation, growth, and financial stability
- (Indicative) intermediate targets: M2, banking-system credit, and fundraising in money and capital markets
- (Implicit) operating targets: reserve money, and money- and bond-market interest rates
- Policy instruments: various policy interest rates (including rediscount, re-lending, banks' benchmark lending and deposit rates), reserve requirements, open market operations, foreign-exchange intervention, and "window guidance"

In terms of the frequency of policy adjustment, the reserve requirement ratio appears to be the most frequently used instrument. Adjustments of the benchmark deposit and lending rates of banks are less frequent but are perceived to carry a larger weight than adjustments of the RRR in signaling the strength of policy change. Open market operations, including issuance of new central bank bills and notes, repos and reverse-repos of such bills and notes, appear to be used for "fine-tuning" market liquidity to avoid excessive volatility in market interest rates. Other policy instruments that cannot be easily observed by the public include foreign-exchange interventions, window guidance and administrative measures. Foreign-exchange interventions are used by the PBC to influence the level of the renminbi exchange rate. Window guidance gives nonbinding direction to financial institutions on credit growth and sector allocation. Credit quotas are specifically targeted at commercial banks when the loan growth is judged to be too rapid. In this paper, we concentrate on major policy instruments used frequently by PBC: RRR, benchmark deposit and lending rates, and central bank bills.

2.2 Dual-Track Interest Rates and Credit Target

After years of reform, China has made substantial progress in liberalizing its financial markets and interest rates (Feyzioglu *et al.*, 2009; PBC, 2005). Wholesale transactions among financial institutions in money and bond markets, as well as interest rates on foreign-currency-denominated instruments, have been liberalized since 1996. In retail lending and deposit markets, the deposit-rate floor and the lending-rate ceiling were removed in October 2004, except for those of credit cooperatives.[3]

On the other hand, there still exists a deposit-rate ceiling and a lending-rate floor in retail banking operations. Nevertheless, the ceiling or floor may not necessarily be binding in practice. If not binding, they would not create distortions that cause market rates to deviate from equilibrium rates. Therefore, it is important to discuss whether the ceiling or the floor is binding.

The deposit-rate ceiling is generally considered binding (PBC, 2009; Feyzioglu *et al.*, 2009). In Section 5, we set up a model to estimate the equilibrium real interest rate and show that, in practice, the real deposit rate has been significantly below the equilibrium rate, suggesting that the deposit-rate ceiling is indeed

3 The ceiling on lending rates for credit cooperatives remains at 2.3 times the benchmark lending rate.

binding. One consequence of imposing a deposit-rate ceiling is low and often negative real returns on household deposits, which implies an implicit tax on households to subsidize debtors (firms and banks). The distribution of this subsidy between banks and non-bank borrowers is determined by the lending-rate floor, which is designed to keep the interest-rate margin of banks sufficiently large to maintain the profitability of the whole banking system.

A more controversial issue is whether the lending-rate floor is binding. The data of actual lending rates since 2004 (the year when the ceiling was removed) show that the percentage of loans made at the floor fluctuated from 16% to 32% (the floor is 90% of the benchmark lending rate), which suggests that most loans were made at above the floor rate (Column 2, Table 1). In other words, the lending-rate floor has not been particularly binding in practice.

However, the fact that the lending-rate floor is non-binding might not be driven by market forces. The reason is that the loan supply, in practice, is subject to an aggregate quantitative target on credit by the PBC. Lardy (2008) argues that the price of capital in China is far too low, resulting in excess demand for bank loans and increasing use of quantitative instruments to control credit growth. However, an interesting question is why banks do not charge higher prices for loans if they face excess demand for loans and are free to raise loan interest rates.

To understand this issue, we need to consider an additional perspective of the Chinese banking sector: competition among banks. Because the deposit rate is capped at a low level by the ceiling, competition among banks motivates each bank to push out loans as long as the marginal cost of loans (the deposit rate plus managing costs) is lower than the lending rate. On the demand side, firms have excess demand for loans because the loan rate is lower than the equilibrium rate. Thus, without a lending-rate floor, the loan market would be cleared at a lower lending rate and a much larger amount of loans, which would result in too much credit in the economy. To fix this distortion (excess loan demand), two additional regulations (distortions) are added into the loan market. The first one is the lending-rate floor, which limits competition among banks and guarantees the profitability (stability) of the whole banking sector. The second one is a quantitative target on credit (credit quota), which limits the total amount of credit in the economy.

In contrast to the heavily regulated interest rates in the banking system, the other side of the dual-track system is market-determined wholesale interest rates in the interbank money and bond markets, which are now open to almost all domestic institutional investors. The development of the interbank market in China has accelerated in the past decade and has opened up an important new channel of transmission of monetary policy. It has also provided a rich source of market data, which allows researchers to study how monetary policy transmission works in China from an entirely new perspective.

2.3 The Interbank Money and Bond Market

As a key component of the Chinese financial market system, the interbank market is playing increasingly important roles in macroeconomic management, fund allocation, pricing and risk management (Zhou, 2009). It is an over-the-counter (OTC) market and consists of a domestic money market, a foreign exchange market and a domestic bond market (see Figure 1). The interbank market was originally designed as a wholesale market only for banks and other financial institutions. In recent years, almost all non-financial institutions have been allowed to participate in the interbank market; in general, individual investors cannot participate in the market directly.[4] The interbank market has grown rapidly, with the turnover of the domestic money and bond market totaling RMB 137 trillion in 2009, which was more than four times China's GDP in that year. The interbank money market consists of the non-collateralized lending market, the repo market and the bill & notes market. The repo market is the most active: repo transactions accounted for 51% of the total interbank market trading, while non-collateralized lending and bond trading accounted for 14% and 34% of the market turnover, respectively (PBC, 2010).[5]

Interest rates (yields) in the interbank money and bond markets are determined by market forces. They serve as good indicators of the cost of credit in the economy. However, because funds flow freely between the banking system and the money and bond markets, market interest rates in these markets are also influenced by the regulated interest rates in the banking system. We now turn to the question of how market interest rates are affected by various monetary policy instruments.

3. A Theoretical Model

This new model is developed based on the interbank market model of Chen *et al.* (2011), which is in turn an extended model based on Porter and Xu (2009) and Freixas and Rochet (2008). The new model focuses on how policy shocks are transmitted from the regulated retail rates to market-determined wholesale rates under the dual-track system. In contrast with the previous models, we introduce fund flows between the regulated banking market and non-regulated money and bond market and illustrate how monetary police shocks pass through from one track to the other.

We assume there are N independent banks in the banking system and that N is sufficiently large such that no individual bank has market power in the market. Each bank absorbs deposits (D_i) from households and makes loans (L_i) to firms in the loan market. The assets on the bank's balance sheet also include required reserves submitted to the central bank, according to the RRR (α) set by the PBC,

[4] Some useful notes about the repo market and non-collateralized lending can be found in Porter and Xu (2009) and Fan and Zhang (2007).

[5] Thus, the "interbank bond market" is now a misnomer in the sense that it is no longer only a market confined to banks.

and excess reserves (E_i) deposited in the central bank, which are not unusual in the Chinese banking system. Aside from loans and reserves, each bank can buy central bank bills (B_i), the interest rate of which is set by the PBC (exogenous to each bank), and each bank can also invest in bonds or other financial products (NR_i) in the money and bond market. Because it is a competitive market, each bank is a price taker in this model. Therefore, a bank's profit maximization function can be written as follows:

$$\Pi_i = \underset{Li,Di,Ei,Bi}{Max}\{r_l L_i + r_e E_i + r_r \alpha D_i + r_b B_i + r_{nr} NR_i - r_d D_i - C(D_i, L_i, E_i)\} \quad (1)$$

where r_l is the lending rate of loans, r_d is the deposit rate, r_e is the rate paid on excess reserves set by the PBC, r_r is the interest rate paid on required reserves, and r_{nr} is the market rate in the non-regulated market. $C(D_i, L_i, E_i)$ is the managing cost of the bank, which is a function of deposits, loans and excess reserves. NR_i is the net position of bank i in the non-regulated market, which is given by

$$NR_i = D_i - L_i - E_i - \alpha D_i - B_i \quad (2)$$

Inserting equation (2) into equation (1), the maximization function for bank i can be written as follows:

$$\Pi_i = \underset{Li,Di,Ei,Bi}{Max}\{r_l L_i + r_e E_i + r_r \alpha D_i + r_b B_i + r_{nr}(D_i - L_i - E_i - \alpha D - B_i) - r_d D_i - C(D_i, L_i, E_i)\} \quad (3)$$

First-order conditions with regard to L_i, D_i, E_i and B_i are given as follows:

With regards to L_i,

$$r_l = r_{nr} + C_L^{'}(D_i, L_i, E_i) \quad (4)$$

where $C_L^{'}(D_i, L_i, E_i)$ is the first derivative of the cost function with respect to L_i, i.e., the marginal management cost of loans. Thus, to maximize bank profits, the marginal benefit from making loans, r_l, has to equal the marginal costs: the sum of the (opportunity) cost of not investing in the non-regulated market r_{nr} and marginal management cost $C_L^{'}(D_i, L_i, E_i)$.

With regards to D_i,

$$\alpha \cdot r_r + (1-\alpha) r_{nr} = r_d + C_D^{'}(D_i, L_i, E_i) \quad (5)$$

Again, the left-hand side of equation (5) is the marginal benefit of deposits, which has to equal the marginal cost of the holding deposits: the sum of the interest rate paid to depositors, r_d , and the management cost of holding deposits.

With regard to E_i and B_i ,

$$r_e = r_{nr} + C_E^{'}(D_i, L_i, E_i) \quad (6)$$

$$r_{nr} = r_b \quad (7)$$

Equation (7) means that the interest rates of central bank bills need to be at least equal to the risk-free market rates (for example, the treasury-bond yield); otherwise, no bank would buy any central bank bills.

Because we need to assume the cost function $C(D_i, L_i, E_i)$ to be strictly convex and twice continuously differentiable, the following cost-function form is assigned to simplify the discussion below:

$$C(D_i, L_i, E_i) = \frac{1}{2}(\delta_D D_i^2 + \delta_L L_i^2 + \delta_E E_i^2) \quad (8)$$

where δ_D , δ_L and δ_E are positive constants representing different marginal costs. Substituting the cost function into equations (4), (5) and (6) and solving these first-order conditions result in functions for the supply of loans, the demand for deposits and the supply of excess reserves.

Loan supply function:

$$L_i^s = (r_l - r_{nr}) / \delta_L \quad (9)$$

Deposit demand function:

$$D_i^d = [\alpha(r_r - r_{nr}) + r_{nr} - r_d] / \delta_D \quad (10)$$

Excess-reserve supply function:

$$E_i^s = (r_e - r_{nr}) / \delta_E \quad (11)$$

If the lending and deposit rates were not regulated, loan interest rate r_l would be determined by equilibrium in the loan market as follows:

$$L_i^d(r_l) = L_i^s, \qquad L_i^s = (r_l - r_{nr}) / \delta_L \tag{12}$$

where $L_i^d(r_l)$ is the loan demand function, which is a function of r_l.

For the deposit market, the equilibrium deposit rate will be as follows:

$$D_i^s(r_d) = D_i^d, \qquad D_i^d = [\alpha(r_r - r_{nr}) + r_{nr} - r_d] / \delta_D \tag{13}$$

where $D_i^s(r_d)$ is the deposit supply function, which is a function of r_d. Because the interest rate of excess reserves is set by the central bank, r_e is exogenous in this model.

Now, we turn to the interest rate in the non-regulated market, r_{nr}, which is determined by the equilibrium in the money and bond market. From Equation (2), we can observe that NR_i is the net amount of funds that a bank invests or borrows from the outside, and they can take a number of forms, for example, treasury bonds, corporate bonds and commercial bills and notes. On the other hand, in the money and bond market, funds do not come only from the banking system; governments and firms also invest or borrow in the market. Therefore, to clear the non-regulated market, the following is required:

$$\sum_{i=1}^{N} NR_i + S(r_d, r_{nr}) = T(r_l, r_{nr}) \tag{14}$$

where $S(r_d, r_{nr})$ is the supply of funds by the non-bank sector in the non-regulated market, which is a function of r_d and r_{nr}. Here, we assume $\partial S(r_d, r_{nr}) / \partial r_{nr} > 0$, which means that the supply of funds by the non-bank sector increases with the market rate r_{nr}. $T(r_l, r_{nr})$ is the demand for funds by the non-bank sector in the market, which is a function of r_l and r_{nr}. Similarly, we assume $\partial T(r_l, r_{nr}) / \partial r_{nr} < 0$, which means that the demand for funds by the non-bank sector decreases if market rate r_{nr} rises. Now, we are ready to find the competitive equilibrium in the banking sector and non-regulated market.

Loan market:

$$\sum_{i=1}^{N} L_i^d(r_l) = \sum_{i=1}^{N} L_i^s = (r_l - r_{nr})/\delta_L \quad (15)$$

$$r_l^* = h(r_{nr}, \delta_L) \quad (16)$$

where r_l^* is the equilibrium lending rate, which is a function of r_{nr} and δ_L.

Deposit market:

$$\sum_{i=1}^{N} D_i^s(r_d) = \sum_{i=1}^{N} D_i^d = [\alpha(r_r - r_{nr}) + r_{nr} - r_d]/\delta_D \quad (17)$$

$$r_d^* = d(\alpha, r_r, r_{nr}, \delta_D) \quad (18)$$

Non-regulated market:

$$\sum_{i=1}^{N} NR_i + S(r_d, r_{nr}) = T(r_l, r_{nr}) \quad (19)$$

Substituting NR_i with equation (2), equation (19) can be written as follows:

$$F(\cdot) = \sum_{i=1}^{N} NR_i + S(r_d, r_{nr}) - T(r_l, r_{nr}) = \sum_{i=1}^{N} [(1-\alpha)D_i - L_i - E_i - B_i] + S(r_d, r_{nr}) - T(r_l, r_{nr}) \quad (20)$$

The equilibrium interest rate in the non-regulated market can be determined when the interest rate r_{nr} clears the market.

Case 1: r_l, r_d and r_{nr} are all market-determined

In this case, the monetary authority does not impose any regulation in the markets. Therefore, r_l clears the loan market, r_d clears the deposit market, and r_{nr} clears the non-regulated market, all by market forces.

***Result 1**: When the lending rate r_l, the deposit rate r_d and the market rate r_{nr} are all market-determined, the lending rate and deposit rate both increase with the market rate. Raising the RRR increases the* *market rate as well as the lending and deposit rates. The impact of selling central bank bills has an impact similar to that from increasing the RRR.*

The proof of Result 1 can be found in Appendix A. Without any interest-rate regulation in markets, the three markets are cleared by market forces at three equilibrium levels: r_d^* , r_l^* and r_{nr} , respectively. The equilibrium deposit rate r_d^* increases with the market rate because the higher the return in the non-regulated market, the more a bank is willing to pay depositors to attract deposits. Similarly, the equilibrium lending rate also increases with the market rate. This is because the higher are the fundraising costs the bank has to pay in the non-regulated market, the more the bank will charge its clients for loans.

The market rate increases as the PBC raises the RRR, which means the higher the RRR, the less the funding available from the banks and the higher the demand for funding in the non-regulated market, and thus, the higher the market rate. Similarly, issuing more central bank bills also reduces liquidity in the non-regulated market, causing market interest rates to rise. Thus, when there is no interest-rate regulation, the transmission of monetary policy shocks to market interest rates is not different than the situation observed in the mature market economies.

Case 2: Regulated deposit and lending interest rates

Here, we assume that the deposit-rate ceiling is binding but differentiate between the following four cases: the lending-rate floor is not binding, and there is no credit quota; the lending-rate floor is binding, and there is no credit quota; the lending-rate floor is not binding under a credit quota; the lending-rate floor is binding under a credit quota.

Case 2.1: The deposit-rate ceiling is binding, but the lending-rate floor is not binding, and there is no credit quota

When the deposit-rate ceiling is binding, $r_d^b < r_d^*$, and this implies that the deposit market is not cleared at r_d^* and that the amount of deposits is determined by the deposit supply from households. On the other hand, because the lending-rate floor is not binding and there is no credit quota ($r_l^b < r_l^*$),the lending rate is then determined by market forces and is a market equilibrium rate, which implies that changing the lending-rate floor does not matter to the lending market (here, we assume that the new floor is still below the market equilibrium rate).

Result 2.1*: When the deposit-rate ceiling is binding and the lending-rate floor is not binding (no credit quota), raising the deposit-rate ceiling increases the market interest rate in the wholesale capital market,* *and changing the lending-rate floor has no impact on the market rate. Raising the RRR and issuing more central bank bills also increases the market interest rate.*

The proof can be found in Appendix B. In this case, because the lending-rate floor is not binding, changing the floor does not affect the lending rate in the loan market and the market rate in the wholesale capital market. Still, the lending rate that clears the loan market is the equilibrium rate r_l^*, and it increases with the market rate in the wholesale capital market r_{nr}. The key difference comes from the deposit side. Because the deposit-rate ceiling is binding, the rate in the deposit market is the ceiling rate instead of the equilibrium rate r_d^*.

When the ceiling is raised by the PBC, the higher ceiling attracts funds to flow into the banking sector from the non-banking sector. Therefore, in this sense, the deposit supply increases because of a higher deposit rate in the banking sector. On the other hand, in the wholesale capital market, funds flow out of the market, and the supply of funds in the market decreases as the deposit-rate ceiling rises. The bond price drops, and bond returns (yields) increase in the wholesale capital market.

When funds flow into the banking system and become bank deposits, some of these deposits have to be submitted to the central bank as reserve requirements that are no longer available to the markets. Therefore, the total amount of funds available to the market decreases due to fund flows from the wholesale market to the banking system.

However, the increased deposits in the banking sector can be invested back into the wholesale market in this model, and the amount of funds available decreases due to the reserve requirement in the banking sector, which leads the interest rate in the wholesale market to increase compared to the level before the rise of the deposit-rate ceiling, whereby, the monetary policy shocks can be transmitted to the wholesale capital market under the dual-track interest rate system.

Case 2.2: Both the deposit-rate ceiling and the lending-rate floor are binding, and there is no credit quota

If both the deposit-rate ceiling and the lending-rate floor are binding, i.e., $r_d^b < r_d^*$ and $r_l^b > r_l^*$, neither the deposit nor lending markets are cleared at their market equilibrium rates (r_l^* and r_d^*); instead, the deposit rate in the market is bound at r_d^b, and the lending rate is bound at r_l^b. In the deposit market, the deposit is determined by the deposit supply, and lending is determined by the loan demand from firms.

***Result 2.2**: When both the deposit-rate ceiling and the lending-rate floor are binding, raising deposit-rate ceiling increases the market rate in the wholesale capital market, but changing the lending-rate floor has an indeterminate impact on the market rate. The market rate still increases as the RRR increases and the central bank issues more bills.*

The proof can be found in Appendix C. Similar to the situation in Case 2.1, the market rate in the wholesale capital market increases as the PBC increases the deposit-rate ceiling. The impact on the market rate of changing the lending-rate floor is unclear. On the one hand, the higher lending-rate floor means lower loan demand in the banking sector, i.e., $\partial L^d / \partial r_l^b < 0$. On the other hand, higher loan costs in the banking system induce firms to opt for direct financing, for example, by issuing more bonds in the wholesale capital market, which can raise the market rate in the wholesale market, i.e., $\partial T / \partial r_l^b > 0$. Therefore, it is difficult to determine whether the overall impact of changing the lending-rate floor is negative or positive.

The policy implication for this case is as follows: the lending-rate floor itself cannot be a reliable monetary policy instrument when the deposit-rate ceiling is binding. In practice, the PBC almost always changes benchmark deposit and lending rates simultaneously, and it is difficult to determine which one matters. This model suggests that what really matters for the market rates is a change to the deposit-rate ceiling under this scenario.

Case 2.3: The deposit-rate ceiling is binding, and the lending-rate floor is not binding under a credit quota

As discussed earlier, the imposition of a credit target becomes necessary when there is excess demand for credit in the economy, which in turn is the consequence of keeping the deposit rate below the equilibrium rate. Such a credit target basically shifts the loan supply curve to the left, and there are two possible results entailed by the shift in the supply curve on the lending rate. The first one is that the supply curve becomes S2 (from S1 to S2 in Figure 2), and the new equilibrium rate (E2 in Figure 2) is higher than the floor. In this case, the lending-rate floor no longer matters, and only the credit target matters.

Figure 2.

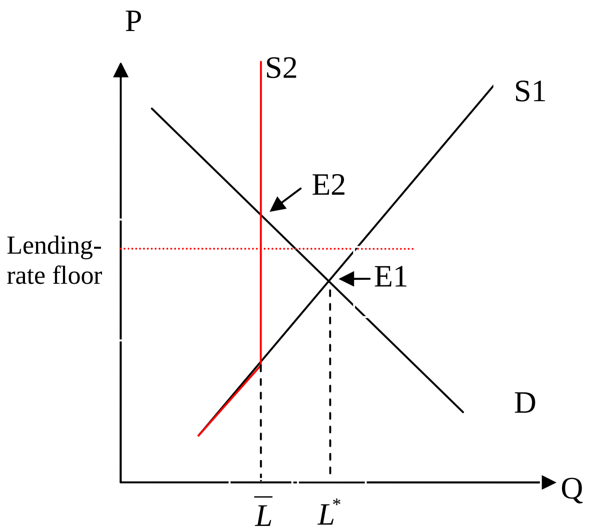
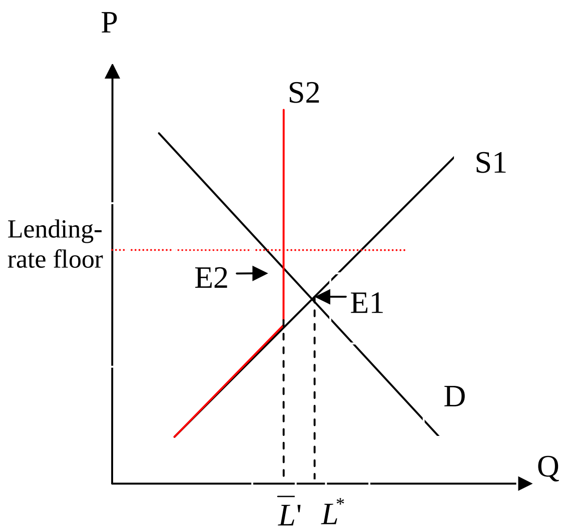


Figure 3.



Under the credit target, a bank's profit-maximization function can be written as follows:

$$\Pi_i = \underset{Li,Di,Ei,Bi}{Max}\{r_l L_i + r_e E_i + r_r \alpha D_i + r_b B_i + r_{nr} NR_i - r_d D_i - C(D_i, L_i, E_i)\} \quad (21)$$

$$s.t. \qquad L_i \le \overline{L}_i$$

where $\overline{L}$ is the credit quota imposed by the PBC on bank i.[6] Because the credit quota is less than the equilibrium loan level ($\overline{L} < L^*$), the loan supply is constrained by the loan quota; the lending rate is higher than the lending-rate floor (E2 in Figure 2) and is determined by loan demand as follows:

$$L_i^d(r_l^*) = \overline{L_i} \qquad => r_l^* = f(\overline{L}) \quad (22)$$

Result 2.3*: With a kinked supply curve due to the imposition of a credit quota, provided that the equilibrium rate in the loan market is above the lending-rate floor, raising the deposit-rate ceiling increases the market rate in the wholesale capital market; changing the lending-rate floor has no impact on the market rate. The market rate increases as the PBC increases the RRR and issues more bills. The impact of the credit quota on the market rate is ambiguous.*

6 In reality, the PBC does not have a formal credit quota on a bank-by-bank basis but rather has an overall credit target for the whole banking system. However, to meet the aggregate target, the PBC practices window guidance to individual banks when and if necessary.

The proof of Result 2.3 can be found in Appendix D. In this case, because the lending-rate floor is not binding, it is easily observable that the floor does not matter to the market rate. The deposit-rate ceiling plays the same role as before. To the loan market, what really matters is the credit quota. Interestingly, the impact of the credit quota is ambiguous. Intuitively, this is because while reducing the credit quota would induce a higher lending rate in the loan market, it also increases the fund supply from the banking sector in the non-regulated market, as the net position of banks is determined by $NR_i = D_i - \overline{L}_i - E_i - \alpha D_i - B_i$.

The same logic applies to the case when the PBC loosens it policy stance, as long as the new equilibrium rate is still higher than the floor. However, if credit loosening is of such a scale as to drive the equilibrium rate below the floor, then what matters is the floor rate, and the credit quota no longer has an impact on r_{nr}.

Case 2.4: The deposit-rate ceiling is binding, and the lending-rate floor is binding under a credit quota

In Case 2.4, the new lending equilibrium rate is shifted by much less (from S1 to S2 in Figure 3), compared to Case 2.3. The equilibrium rate (E2 in Figure 3) is lower than the lending-rate floor, and the lending floor is still binding under a credit quota. In this case, the credit quota is not sufficiently tight to lift the lending rate away from the floor; therefore, what matters is still the lending-rate floor, and the credit quota has no impact on the market rate. Because the situation in Figure 3 is the same as that discussed in Case 2.2, there is no need to repeat it here.

A simple calibration

The model scenarios discussed above are summarized in Table 2.

The results in Table 2 provide signs of impacts on the market rate from different instruments. To understand the relative size of the impacts, calibrating the model based on certain assumptions of function forms becomes necessary. Because Case 2.3 is the most likely case in reality, we focus on this case for calibration.

As we have proved in Case 2.3, the partial impact of the deposit-rate ceiling, RRR and issues of CBB on the market rate are as follows:

$$\frac{\partial r_{nr}}{\partial r_d^b} = -[(1-\alpha)\frac{\partial D_s}{\partial r_d^b} + \frac{\partial S}{\partial r_d^b}]/(\frac{\partial F}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S}{\partial r_{nr}} - \frac{\partial T}{\partial r_{nr}}) \quad (23)$$

$$\frac{\partial r_{nr}}{\partial \alpha} = D^s / (\frac{\partial F}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S}{\partial r_{nr}} - \frac{\partial T}{\partial r_{nr}}) \quad (24)$$

$$\frac{\partial r_{nr}}{\partial B} = 1 / (\frac{\partial F}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S}{\partial r_{nr}} - \frac{\partial T}{\partial r_{nr}}) \quad (25)$$

Because the denominators of the three partial impacts are the same, ($\partial F / \partial r_{nr} + N / \delta_E + \partial S / \partial r_{nr} - \partial T / \partial r_{nr}$), we merely need to compare the three numerators. Moreover, because we estimate the elasticity between policy instruments and the market rate in the empirical analysis, we calculate the ratio of elasticities here to compare the relative potency of policy instruments. To do so, we only need to assume function forms for the deposit supply in the banking sector and the fund supply from the non-banking sector in the non-regulated market.

We calibrate the ratio of the elasticities of the three instruments by following the assumptions in Feyzioglu *et al.* (2009). The deposit supply function can be written as follows:

$$D^s = A^{-\varepsilon_d} (r_d^b)^{\varepsilon_d} \quad (26)$$

where ε_d is the price elasticity of the deposit supply and A is a constant term. Similarly, the supply of funds by the non-banking sector in the non-regulated market can be written as follows:

$$S(r_d^b, r_{nr}) = A^{-\varepsilon_d} (r_{nr})^{\varepsilon_d} (r_d^b)^{-\varepsilon_d} \quad (27)$$

The calibration results (details can be found in Appendix E) show that the price elasticity between the deposit rate and the market rate is approximately twice the elasticity between the RRR and the market rate during the sampling period. This implies that the impact of a 1% change in the deposit-rate ceiling on the market rate is twice as big as the impact of a 1% change in the RRR.

The ratio of the two elasticities increases with the deposit supply elasticity in the banking sector. In other words, compared to the RRR, the benchmark deposit rate as a policy instrument becomes more important if depositors are more sensitive to changes in the deposit rate.

On the other hand, the impact on market interest rates of issues of CBB is small compared to that of the benchmark deposit rate and the RRR. This is because the average size of issues of CBB is quite small compared to the size of deposits in the banking sector. As shown in Appendix E, the ratio of the two elasticities depends on the relative size of deposits and issues of CBB (see Equation E.9 in Appendix E).

4. Empirical Analysis

To test the results predicted by the theoretical model and its calibration, we construct and estimate two empirical models using daily data from both money and bond markets. We estimate how market interest rates (yields) react to policy shocks after controlling for other factors. To obtain reliable results, two empirical models are compared with each other: a linear model estimated by the Ordinary Least Square (OLS) method and a Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model estimated by Maximum Likelihood Estimation (MLE).

4.1 The Linear Model

The theoretical model predicts that the market rates in the wholesale capital market increase when the PBC increases the benchmark deposit rate, the RRR and issues more of CBB if and when the deposit-rate ceiling is binding. The lending-rate floor either has an indeterminate impact or no impact on the market rates, depending on whether the floor is binding or not. In this linear model, we test how market rates react to changes of the three policy instruments, controlling for IPOs, macroeconomic news and seasonal effects. The linear model can be written as follows:

$$\Delta Y_t = \beta_0 + \beta_1 \Delta IR_t + \beta_2 \Delta RRR_t + \beta_3 \Delta CBR_t + \beta_4 NEWS_t + \beta_5 CBI + \beta_6 IPO_t + \beta_{7,8} Dummies + u_t \quad (28)$$

where ΔY_t represents the annualized log-difference (percentage change) of interest rates (yields) in the wholesale capital markets and u_t is the idiosyncratic error term, which is assumed to be uncorrelated with explanatory variables. ΔIR_t denotes the log-difference of benchmark interest rates, ΔRRR_t denotes the log-difference of RRR,[7] and ΔCBR_t denotes the log-difference of the benchmark (one-month) central bank bill issuing rate.

To control for shocks due to macroeconomic news, we introduce $NEWS_t$ to represent surprises derived from the difference between data releases of macroeconomic variables and market consensus forecasts of such variables. Seven macroeconomic indicators are included in the model: real GDP growth rate, broad money (M2) growth rate, consumer price index (CPI), producer price index (PPI), growth of export, import, and retail sale growth.

[7] The changes of RRR are measured when the changes become effective in this study. We also attempted to measure the changes when they were announced, and it turns out that the former measurement outperforms the latter in empirical models (twelve significant cases vs. five significant cases), which suggests the market rates are more sensitive to RRR changes on effective dates.

We also introduce two variables to control for market liquidity conditions: CBI_t, net issues of central bank bills on day t, as measured by the difference between the amount of bills being issued and bills maturing on that day; and IPO_t, the amount of funds frozen due to IPOs in the stock market on day t. Seasonal dummies include one dummy for the end of the month and one dummy for the Chinese Lunar New Year.

We have several issues to discuss before we move on to the GARCH model. First, to remove possible non-stationarity in the time-series variables, all interest rate (yield) variables in the model are measured as the log-difference forms (percentage change). All variables in the log-difference form passed augmented Dickey-Fuller tests. Second, because the PBC usually changes the benchmark deposit rate and benchmark lending rate simultaneously,[8] it is difficult to identify the impact of these two variables using econometric methods.[9] Therefore, we concentrate on the benchmark deposit rate in the empirical analysis. Third, even though OLS estimation cannot capture the high volatility of interest rates (especially in the money market), the results from OLS can provide us with a reliable unbiased linear estimator.[10] More importantly, OLS results can be used as a benchmark to help us construct the GARCH model.

4.2 The GARCH Model

To capture high volatility and clustering attributes in high-frequency data such as interest rates in money markets, we construct a GARCH model to examine the impact of policy shocks on market rates under the dual-track system. Taking into account the "fat-tails" exhibited in interest rates in the Chinese money market (Porter and Xu, 2009 and Herrero and Girardin, 2010), we follow Herrero and Girardin (2010) to assume innovations in the GARCH model with a generalized-error distribution. A standard GARCH model can be written as follows:

$$\Delta Y_t = \mu_t + \varepsilon_t \tag{29}$$

where ΔY_t is the log-difference of interest rates (yields) in money and bond markets and $\mu_t = E\{\Delta Y_t \,\|\, F_{t-1}\}$ is the conditional mean of ΔY_t given information set F_{t-1}. The innovation $\varepsilon_t = z_t h_t^{1/2}$ and z_t is an iid random variable with zero mean and unit variance. This implies that

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[8] There were only two exceptions since 2004. On 28 April 2006 and 16 September 2008, the PBC changed the benchmark lending rate but kept the benchmark deposit rates unchanged.

[9] If we put both rates in the same equation simultaneously, it would cause a severe multicollinearity problem, and the estimation result would be very misleading.

[10] GARCH estimates both mean and volatility equations and provides more efficient estimators than OLS but is more sensitive to distribution assumptions and specifications in both mean and volatility equations.

$\varepsilon_t \mid F_{t-1} \sim D(0, h_t)$, where D stands for the distribution (a generalized-error distribution in this model). The conditional mean μ_t is a function of some exogenous factors:

$$\mu_t = \beta_0^{'} + \beta_1^{'}\Delta IR_t + \beta_2^{'}\Delta RRR_t + \beta_3^{'}\Delta CBR_t + \beta_4^{'}NEWS_t + \beta_5^{'}CBI_t + \beta_6^{'}IPO_t + \beta_{7,8}^{'}Dummies_t \quad (30)$$

To capture the clustering-volatility attribute of interest rates, the conditional variance can be written as follows:

$$h_t = \lambda_0 + \sum_{n=1}^{p}\gamma_n h_{t-n} + \sum_{j=1}^{q}\lambda_j \varepsilon_{t-j}^2 + \xi_i X_{it} \quad (31)$$

where the λ_j terms are ARCH effects and γ_n are GARCH terms. ξ_i measures the impact of other exogenous factors that drive volatility, and X_i are the variables that also affect volatility.

4.3 Data

As we discussed before, changing the benchmark interest rates in China means changing the one-year deposit-rate ceiling and the one-year lending-rate floor, which implies that policy shocks are transmitted from the middle of the yield curve to the two ends of the curve. Therefore, to examine the transmission mechanism, we need to consider the impact at both ends of the yield curve. On the left hand of the yield curve (money market), we choose overnight, seven-day and one-month repo rates because the repo market is the money market with the best liquidity in China.[11] On the right-hand side of the yield curve (bond markets), we use market bond yields, ranging from one-year to ten-year from the interbank bond markets: one-year, two-year, five-year and ten-year treasury-bond yields; and financial bonds and corporate bonds (LCB and MTN) of similar maturities.[12]

The sample includes daily data covering 30 October 2004 to 15 November 2010. The starting date was chosen because the deposit-rate floor and the lending-rate ceiling were removed by the PBC on 29 October 2004. In other words, the sample period is chosen such that the interest-rate regime corresponds to that described in the theoretical model: a deposit-rate ceiling and a lending-rate floor.

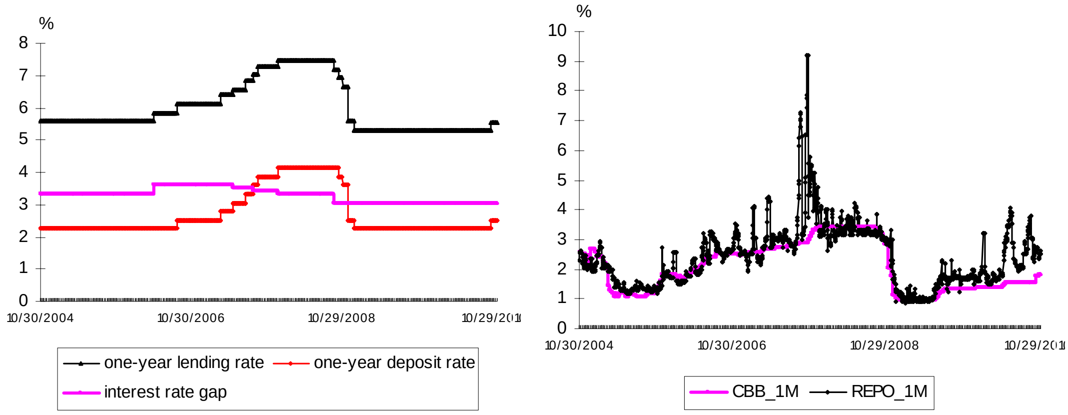
[11] The size of the repo market was three times larger than the non-collateralized lending market in 2009.

[12] The yields data are from China Central Depository & Clearing Co., Ltd.

4.4 Monetary Policy Instruments

As we discussed before, the benchmark lending rate was usually changed simultaneously with the benchmark deposit rate. The gap (mark-up) between deposit and lending rates declined slowly after 2005, but the process was suspended due to the global financial crisis (Figure 4, left). Open market operations are supposed to affect market rates in two ways: to increase or decrease liquidity from the

Figure 4. Monetary Policy Instruments

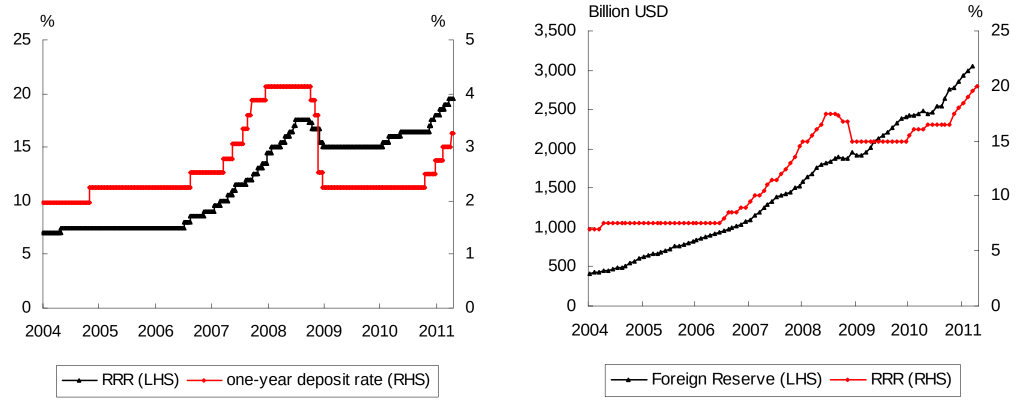


Data source: CEIC

market and to send a price signal by setting the issuing rates of CBBs. However, market rates (for example, the one-month repo rate) often deviate from CBB issuing rates, persistently staying at a higher level than the CBB issuing rates in recent periods, suggesting that the PBC might not be able to or did not aim to use the issue or redemption of CBBs to adjust market liquidity sufficiently to bring these two rates in line (Figure 4, right).

The RRR can be considered a cornerstone of implementation of the credit target, and as a quantity-based instrument, it usually moves in line with price-based instruments (ceiling or floor of interest rates). The RRR has been used more frequently and has recently reached a historically high level r (Figure 5, left). This might be due to three reasons: first, raising the reserve requirement is a relatively cheaper way (compared to issuing CBBs) for the PBC to absorb excess liquidity resulting from rapidly increasing foreign reserves (Figure 5, right). Second, changing the RRR, compared to the benchmark interest rates, is perceived as carrying less weight in signaling the strength of a policy change and, hence, can be used more flexibly. Third, the PBC is relatively independent in changing the RRR compared to changing benchmark interest rates, which typically requires approval by the State Council or the Cabinet.

Figure 5. Reserve Requirement Ratio

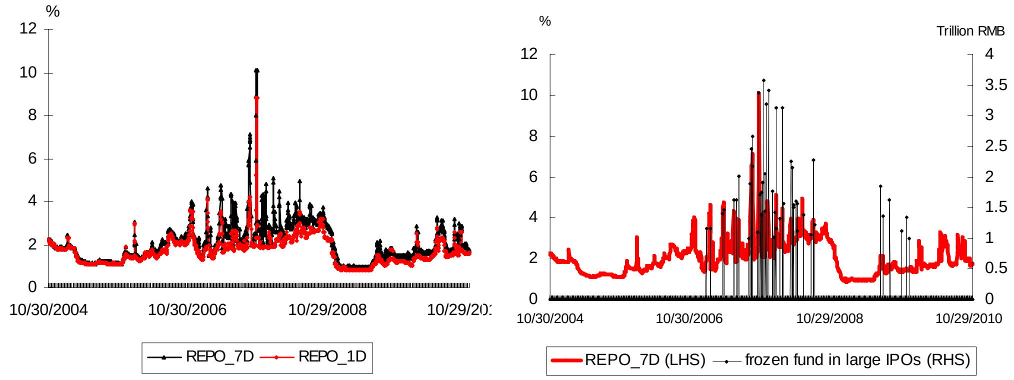


Data source: CEIC

4.5 Money Markets

In money markets, we choose overnight, seven-day and one-month repo rates. As in other money markets in the world, repo rates exhibit high volatility as well volatility clustering (Porter and Xu, 2009). Not surprisingly, we can observe that the overnight repo rate moves together with the seven-day repo rate (Figure 6, left). More interestingly, the seven-day repo rate seems more volatile than the overnight repo rate, which might be caused by high funding demand for IPOs in the stock market (Figure 6, right).[13]

Figure 6. Money Markets and IPOs



Data source: CEIC

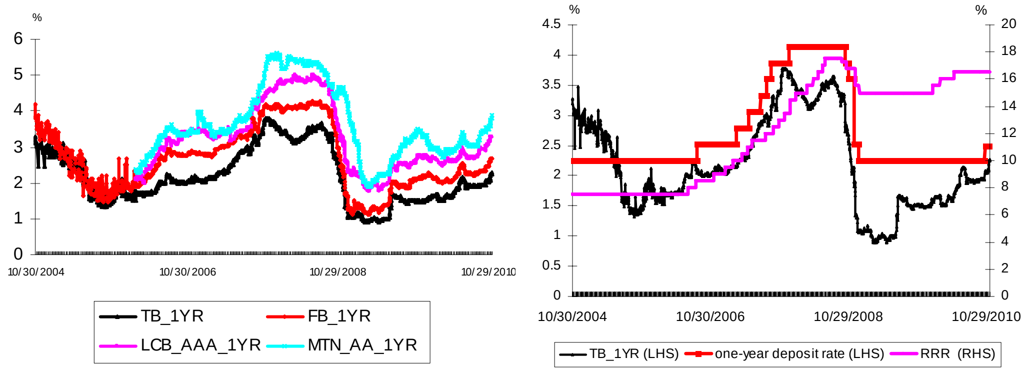
4.6 Bond Markets

In bond markets, we choose one-year, two-year, five-year and ten-year bonds to examine how policy shocks transmit along the yield curve. Not surprisingly, different bond yields generally move together, and the gap between them indicates the risk premium for different bonds (Figure 7, left). The volatility in the

[13] To make it easier to read, only large IPOs that froze funds of more than RMB 1 trillion are shown in Figure 6.

treasury bonds and financial bonds declined significantly after 2006, which suggests marked improvement in market liquidity. The one-year treasury-bond yield moves together with the benchmark deposit rate and the RRR, as the theoretical model predicts, as do other bond yields (Figure 7, right).

Figure 7. Bond Markets



Data source: CEIC

5. Empirical Results

Linear and GARCH models are estimated by OLS and MLE, respectively. For the linear models estimated by OLS, the results might not be the most efficient; however, they are quite robust. The GARCH model provides more efficient estimators if the model specifications and relevant assumptions are appropriate. However, the efficiency comes at the cost of less robustness. Therefore, both linear and GARCH models are estimated to cross-check the results. The main results are summarized as follows.

First, market rates increase with the benchmark deposit rate and the RRR in most cases, consistent with the prediction of the theoretical models. The impact of the benchmark deposit rate is larger than that of the RRR on the market rate, while issues of CBBs have no significant impact on the market rate, in line with the calibration results. The consistency between theory and the empirical study suggests that the transmission mechanism illustrated in the theoretical models is a sensible way to understand the conduct of monetary policy in China.

Second, in linear models, all market rates increase with the benchmark deposit rate significantly (the first row in both Tables 5 and 6). While not all market rates increase with RRR and CBB issuing rates significantly in linear models, all estimated coefficients point to the right direction: market rates increase with RRR and CBB issuing rates (the second and third rows in Tables 5 and 6). More importantly, the results verify the prediction from the calibration exercise: the impact of the benchmark deposit rate on market rates is larger than the RRR in most cases. As the calibration predicts, issuing CBBs itself has no significant impact on the market rate in most cases,[14] This might be due to the fact that the size of issues of CBBs is too small compared to the size of deposits in the banking sector and IPOs in the capital market.[15]

Third, in GARCH models, most market rates increase with the benchmark deposit rate significantly, and the estimated coefficients are close to those in linear models (Tables 7 and 8). Market rates increase with the RRR in more cases in GARCH models, which might be due to the efficiency improvement from MLE. Similar to the linear models, CBB issuing rates have an impact on the market rate in half of the cases, which suggests that markets care more about policy signals in the CBB issuing rate than the direct impact from a liquidity change caused by issues of CBBs.

Fourth, comparing the results from money and bond markets, the impact of changes in the deposit rate and the RRR on money market rates is larger than those on bond market rates in both linear and GARCH models: a 1% change in the benchmark deposit rate, on average, brings about a 0.61% change in money market rates, while the elasticity is only 0.19 in the bond market, on average (Table 3, row 11). Similarly, market rates react to the RRR more strongly in the money market, which makes sense because money-market rates are more sensitive to liquidity change. For the CBB issuing rate, the elasticity in both the money and bond markets is quite small, suggesting that using the CBB issuing rate as a policy instrument might not be an effective choice for the PBC.

Finally, Table 3 provides some useful information about the potency of various policy instruments. To money markets, both the benchmark deposit rate and the RRR have an economically significant impact on market rates. The benchmark deposit rate is more potent than the RRR, while the impact of changing the CBB issuing rate is economically negligible. To bond markets, the RRR becomes almost as potent as the benchmark deposit rate, implying that market liquidity plays an important role in the bond markets. The CBB issuing rate plays some marginal roles in bond markets, while the quantity of CBB issues itself is too weak to affect the market rates.

5.1 Two Caveats

Before we conclude the paper, we would like to discuss two caveats.

5.1.1 Is the Deposit-Rate Ceiling Binding?

Until now, we have assumed that the deposit-rate ceiling is binding in China in most cases. However, we have no data available to prove that the deposit-rate ceiling is indeed binding in China. Although previous

[14] The impact is still not significant after we take into account the repo and reverse-repo operations performed by the PBC.

[15] Since 2004, approximately 48 IPOs have frozen funds of more than RMB one trillion, while the largest size of CBBs issued was only RMB 210 billion.

discussions in the PBC (2009) and Feyzioglu *et al.* (2009) point to the validity of this assumption, there is little solid evidence. To address this issue, we estimate the equilibrium interest rate in China without financial repression (because the deposit-rate ceiling is a major component of the repression) and compare this estimated equilibrium interest rate with the observed real interest rate. If the estimated rate is higher than the observed one, the deposit-rate ceiling must be binding because competition among banks would induce banks to drive their deposit rates toward the equilibrium interest rate if the ceiling were removed.

To estimate the equilibrium interest rate without distortions, we need to gauge the impact from distortions. Following Laubach and Williams (2001), the equilibrium interest rate is determined by

$$r = q(1/\sigma) + n + \theta \tag{32}$$

where r is the equilibrium interest rate, σ denotes the intertemporal elasticity of substitution in consumption, n is the rate of population growth, q is the rate of labor-augmenting technological change, and θ is the rate of time preference. The first two terms can be combined as rates of trend growth (g), and therefore, we can derive the equilibrium interest rate as a function of

$$r = f(g,\theta) \tag{33}$$

In the long run, the real interest rate without financial repression is supposed to fluctuate around the equilibrium interest rate. Therefore, we can write the observed real interest rate under financial repression as follows:

$$r = f(g,\theta,\tau) \tag{34}$$

where τ is a measure of financial repression in an economy. If we can estimate the partial impact of financial repression, we can determine the equilibrium interest rate in an economy using the above equation. To do so, the key is to find a good measure of financial repression across economies. Fortunately, Abiad *et al.* (2008) provide a good measure of such an index in 91 economies from 1973 to 2005.[16] Therefore, an empirical model can be written as follows:

$$r_i = a_0 + a_1 g_i + a_2\theta_i + a_3\tau_i + \pi_i + u_i \tag{35}$$

16 If the index is one, it means no financial repression, zero means maximum financial repression. Therefore, one minus the index can be defined as a good measure of financial repression.

where g_i is the real GDP growth rate in economy i, θ_i is represented by the saving rate in an economy to measure the time preference, τ_i is the financial repression index, using one minus the financial reform index, and π_i is the fixed effect for an economy. The dataset used in the regression includes 49 economies from 1973 to 2005.[17] The real interest-rate, real GDP and saving-rate data come from the World Bank's World Development Indicators dataset. The empirical model is estimated by both fixed- and random-effects estimation, and the regression results are as follows.

The regression results are consistent with the theory: the real interest rate is positively related to real GDP growth and negatively related to the time preference (saving rate). Financial repression has a significant negative impact on the observed real interest rate: the more financially repressed the economy, the lower the real interest rate compared to the equilibrium interest rate.

Using the regression results, we can then estimate the equilibrium interest rate by subtracting the effects of financial repression from the observed real interest rate: the equilibrium deposit rate in China was estimated at 4.7% in 2005. This estimated equilibrium deposit rate is significantly higher than the observed real deposit rate of 1.6% in 2005, which means that the deposit-rate ceiling must have been binding in China.

5.1.2 Credit Quota?

The theoretical model illustrates that a credit quota might change the loan supply curve and move the lending rate above the floor. Because sufficient data on credit quotas are not available, we are unable to include credit quotas in the empirical study. Therefore, we need to be aware that a credit quota might affect the size of the estimated coefficients due to the so-called omitted-variable problem. However, we argue that the impact of a credit quota would be limited because of the following reasons: first, a credit quota is usually set by the PBC at the beginning of a year, which is not adjusted within the year, and the one-off impact of a credit quota change can be captured by the year-end dummy. Second, from our theoretical model, we can observe that the credit quota mainly affects the lending rate, for example, by changing the loan supply curve (Figure 2), and it does not affect the deposit-rate ceiling directly. Third, we have included surprising news about M2 growth in our empirical model, which might help us partly control for shocks from a credit quota because M2 growth is highly correlated with the growth of credit quotas.

[17] Economies in Latin America, the Middle East and North Africa, and Sub-Saharan Africa are not included in the dataset because these economies had significantly higher and more volatile inflation rates during the sample period.

6. Concluding Comments

In this study, we develop and calibrate a theoretical model to illustrate how monetary policy transmission works under the dual-track interest-rate system in China. The model shows that market interest rates are most sensitive to changes in benchmark deposit interest rates, significantly responsive to changes in reserve requirements, but not particularly reactive to open market operations. These theoretical predictions are verified and supported by both linear and GARCH models using daily money and bond market data.

The results of this study help us understand why the PBC conducts monetary policy in China the way it does: a combination of price and quantitative instruments, with various degrees of potency in terms of their influence on the cost of credit. They also help us understand why the central bank needs to retain quantitative targets on credit when the observed real interest rate is below the equilibrium interest rate.

The monetary policy framework illustrated in this study might be useful for consideration of a strategy of interest-rate liberalization in China. The current strategy of interest liberalization designed by the PBC is as follows: "liberalize money and bond market first, then deposit and lending market; liberalize foreign currency rates first, then domestic currency rates; liberalize lending rate first, then the deposit rate; liberalize long-term rates first, then short-tem rates" (PBC, 2005). Some of these reforms have been implemented since 2004: money and bond markets are now mostly determined by market forces, but the strategy toward liberalizing interest rates in the deposit and lending market has been hotly debated.

For example, should we liberalize the lending-rate floor before we remove the deposit-rate ceiling? Because the lending-rate floor is not binding in most cases, if it is removed, it is not expected to be destabilizing. However, does it mean that lifting the deposit-rate ceiling will become easier after the lending-rate floor is removed? The results from this study should help us better understand this question.

Under the dual-track interest-rate system, the role of the deposit-rate ceiling is like that of an anchor, which keeps overall interest rates low in China's formal financial sector, as the banking sector still dominates the Chinese credit market. As long as the regulated deposit rate is lower than the equilibrium interest rate, a quantitative credit target is necessary to curb excess loan demand from firms. On the other hand, the lending-rate floor limits competition among banks to maintain the profitability and stability of the whole banking system.

If the central bank liberalizes the lending market first without lifting the deposit-rate ceiling and the credit target, the credit target would still likely keep the lending rate above the floor, as we illustrated in Figure 2. However, that step would not make the next step of liberalizing the deposit rate any easier because credit-target operations would be under even larger pressure.

Thus, instead of removing the lending-rate floor first, a better strategy is for the PBC to gradually increase the deposit-rate ceiling toward the equilibrium, which would help relieve pressure on the credit target. At the same time, the PBC would also increase the lending-rate floor in line with the higher deposit-rate ceilings to maintain the stability of the banking sector.[18] As a result, the subsidy from depositors to debtors is gradually reduced, and the profitability of the banking sector remains reasonable. As interest rates become higher in the banking sector, market rates in the wholesale capital markets will also increase, as the model illustrates. Therefore, the factor price of capital in the economy becomes less distorted, which increases the overall efficiency of the Chinese economy.

[18] However, this does not necessarily mean that the current interest margin of approximately 3% should be maintained. Whether this margin should be reduced is a question beyond this paper.

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Table 1. Distribution of Bank Lending Rates (In Percent)

	Share of loans priced at 10% below the benchmark (the floor)	Share of loans priced at the benchmark	Share of loans priced at 10% above the benchmark	Share of loans priced at 10%-30% above the benchmark	Share of loans priced at 30%-50% above the benchmark	Share of loans priced at 50%-100% above the benchmark	Share of loans priced at 100% above the benchmark
2004Q4	23.2	24.6		29.0	9.9	10.7	2.7
2005Q1	21.9	26.9		29.5	7.7	10.4	3.6
2005Q2	18.7	22		25.0	15.8	14.6	4.0
2005Q3	21.8	24.6		27.8	8.4	12.7	4.8
2005Q4	24.3	26.5		26.8	8.3	11.4	2.7
2006Q1	23.0	28.2		29.8	6.4	10.2	2.4
2006Q2	24.7	26.5		30.1	6.5	9.9	2.4
2006Q3	25.4	26.7		27.6	7.1	10.9	2.3
2006Q4	25.8	26.6		27.9	7.3	10.6	1.7
2007Q1	26.9	27.9		28.0	6.5	9.1	1.7
2007Q2	16.9	29.1		27.1	6.5	9.0	1.4
2007Q3	28.6	26.7		26.4	7.6	9.4	1.5
2007Q4	28.1	27.7		27.2	7.3	8.5	1.3
2008Q1	26.0	32.6	16.8	14.3	4.9	4.8	0.6
2008Q2	20.8	30.8	16.8	15.4	6.7	8.1	1.5
2008Q3	20.7	30.8	17.0	15.3	6.9	7.6	1.8
2008Q4	24.1	30.7	14.5	13.8	6.3	7.8	2.7
2009Q1	27.0	34.4	13	11.2	4.7	6.9	2.9
2009Q2	28.2	33.2	12.6	10.9	5.1	7.1	2.9
2009Q3	31.8	31.2	12.6	10.2	4.9	6.5	2.8
2009Q4	31.2	30.6	11.9	10.7	5.2	7.1	3.3
2010Q1	32.7	30.7	12.6	9.6	4.7	6.3	3.4
2010Q2	26.8	30.5	14.4	11.7	5.7	7.3	3.5
2010Q3	26.1	29.7	14.9	12.3	5.4	7.4	3.9
2010Q4	27.3	30	14.2	12.1	5.3	7.7	3.6

Note: Before 2008, the numbers in Column 4 also included loans priced at 10% above the benchmark. The quarterly data after 2008 are derived from monthly data using monthly loans as weights.
Source: CEIC and the authors' calculations.

Table 2. Impact of Policy Shocks on the Market Rates

Policy Shocks		Deposit-rate ceiling is binding			
	Case 1	Case 2.1	Case 2.2	Case 2.3	Case 2.4
	No deposit-rate ceiling nor lending-rate floor	Lending-rate floor is not binding (no credit quota)	Lending-rate floor is binding (no credit quota)	Lending-rate floor is not binding under credit quota (Figure 2)	Lending-rate floor is binding under credit quota (Figure 3)
	Market rates reaction to policy shocks				
Deposit-rate ceiling	N.A.	+	+	+	+
Lending-rate floor	N.A.	No impact	Indeterminate	No impact	Indeterminate
RRR	+	+	+	+	+
Issues of central bank bills	+	+	+	+	+
Credit quota	N.A.	N.A.	N.A.	Indeterminate	No impact

Table 3. Elasticity of Money and Bond Market Rates to Changes in Policy Instruments

	Elasticity in money market	Elasticity in bond market
Linear model		
Benchmark deposit rate	0.65	0.20
RRR	0.51	0.16
CBB issuing rate	0	0.08
GARCH model		
Benchmark deposit rate	0.58	0.17
RRR	0.33	0.15
CBB issuing rate	0.03	0.06
Average		
Benchmark deposit rate	0.61	0.19
RRR	0.42	0.15
CBB issuing rate	0.02	0.07

Table 4. Regression Results for Measuring the Impact of Financial Repression

Dependent variable : real interest rate	Fixed effect estimation		Random effect estimation	
	Coefficients	Standard errors	Coefficients	Standard errors
Real GDP growth	0.692**	0.087	0.700**	0.086
Saving rate	-0.455**	0.077	-0.411**	0.070
Financial repression index	-6.180**	1.474	-6.210**	1.416
Observations	1062		1062	
R-square	0.07		0.07	

** denotes significant at 1% level.

Table 5. Linear Models Estimated by OLS

Variables	Dependent variables						
	Repo_1d	Repo_7d	Repo_1m	TB_1YR	TB_2YR	TB_5YR	TB_10YR
Benchmark Deposit rate	0.606***	0.477**	0.853***	0.290***	0.309***	0.165***	0.190***
	(0.147)	(0.190)	(0.172)	(0.068)	(0.053)	(0.035)	(0.028)
RRR	0.511*	0.561	0.551	0.296**	0.270**	0.129*	0.059
	(0.299)	(0.387)	(0.349)	(0.138)	(0.108)	(0.071)	(0.058)
Benchmark CBB issuing rate	0.078	0.073	0.031	0.117***	0.116***	0.084***	0.039**
	(0.081)	(0.105)	(0.095)	(0.037)	(0.029)	(0.019)	(0.016)
PPI_gap	0.129**	0.065	0.102**	0.017	0.017	0.024**	0.011
	(0.048)	(0.057)	(0.052)	(0.020)	(0.016)	(0.010)	(0.009)
CPI_gap	-0.018	-0.020	0.009	0.023	0.008	0.013	0.012*
	(0.035)	(0.045)	(0.041)	(0.016)	(0.013)	(0.008)	(0.006)
Retail_gap	0.002	-0.136	-0.044	-0.030	-0.005	0.012	0.023
	(0.151)	(0.196)	(0.177)	(0.070)	(0.054)	(0.036)	(0.029)
M2_gap	-0.067	0.123	0.412	0.027	0.012	0.056	0.079**
	(0.182)	(0.236)	(0.212)	(0.084)	(0.065)	(0.043)	(0.035)
Export_gap	0.015	0.053*	0.059**	0.007	0.005	-0.003	-0.006
	(0.023)	(0.030)	(0.027)	(0.010)	(0.008)	(0.005)	(0.004)
Import_gap	0.036	-0.010	0.023	-0.004	-0.002	0.001	-0.001
	(0.022)	(0.028)	(0.026)	(0.010)	(0.008)	(0.005)	(0.004)
GDP_gap	0.459	0.889**	0.936**	-0.028	-0.005	0.004	0.034
	(0.348)	(0.451)	(0.407)	(0.161)	(0.125)	(0.080)	(0.068)
Month end dummy	-0.003	-0.009	-0.008	-0.002	-0.001	-0.001	-0.001
	(0.004)	(0.005)	(0.005)	(0.002)	(0.001)	(0.001)	(0.001)
Lunar year dummy	0.045***	0.020	0.007	0.002	-0.001	0.001	-0.001
	(0.013)	(0.017)	(0.016)	(0.006)	(0.005)	(0.003)	(0.002)
IPO	0.014***	0.004	-0.016***	0.001	0.001	0.001	-0.002
	(0.004)	(0.006)	(0.005)	(0.007)	(0.002)	(0.001)	(0.008)
IPO(1)	0.004	0.032***	0.017***	0.001	-0.001	0.001	0.004
	(0.005)	(0.006)	(0.005)	(0.002)	(0.002)	(0.001)	(0.009)
Net CBB issuing	0.045	0.097	-0.030	-0.003	0.004	-0.004	-0.008
	(0.045)	(0.059)	(0.053)	(0.021)	(0.002)	(0.019)	(0.009)
Observation	1574	1574	1574	1574	1574	1574	1574
Adjusted R^2	0.04	0.04	0.05	0.03	0.04	0.04	0.04

Note: Repo_1d denotes overnight Repo rate, Repo_7d denotes seven_day Repo rate, and Repo_1m denotes one-month Repo rate. TB_1yr, TB_2yr, TB-5yr and TB_10yr denote one-year, two-year, five-year and ten-year treasury-bond yields, respectively. Standard errors of estimated coefficients are reported in the brackets. ***, **, and * denote significance at 1%, 5% and 10%, respectively.

Table 6. Linear Models Estimated by OLS (Continued)

Variables	Dependent variables						
	FB_1yr	FB_2yr	FB_5yr	LCB_1yr	LCB_2yr	LCB_5yr	MTN_1yr
Benchmark Deposit rate	0.244**	0.247***	0.174***	0.162***	0.150***	0.132***	0.117***
	(0.113)	(0.086)	(0.045)	(0.026)	(0.022)	(0.019)	(0.022)
RRR	0.111	0.150	0.030	0.109**	0.071	-0.031	-0.027
	(0.231)	(0.175)	(0.092)	(0.053)	(0.044)	(0.040)	(0.044)
Benchmark CBB issuing rate	0.069	0.054	0.026	0.066***	0.051***	0.012	0.027
	(0.063)	(0.047)	(0.025)	(0.019)	(0.016)	(0.014)	(0.015)
PPI_gap	-0.015	-0.006	0.007	0.003	0.011	0.016**	0.010
	(0.034)	(0.026)	(0.013)	(0.008)	(0.007)	(0.006)	(0.007)
CPI_gap	0.037	0.024	0.019*	0.003	-0.004	-0.002	-0.011
	(0.027)	(0.020)	(0.011)	(0.007)	(0.006)	(0.005)	(0.006)
Retail_gap	0.008	0.014	-0.010	-0.025	0.006	-0.003	-0.006
	(0.116)	(0.088)	(0.046)	(0.028)	(0.024)	(0.021)	(0.024)
M2_gap	0.184	0.112	0.094	0.045	-0.006	-0.014	-0.011
	(0.140)	(0.107)	(0.056)	(0.034)	(0.029)	(0.026)	(0.029)
Export_gap	-0.002	0.005	-0.001	-0.005	0.004	0.001	-0.007*
	(0.018)	(0.013)	(0.007)	(0.004)	(0.004)	(0.003)	(0.003)
Import_gap	-0.003	-0.002	0.003	0.001	-0.001	0.001	0.001
	(0.017)	(0.013)	(0.006)	(0.004)	(0.003)	(0.003)	(0.002)
GDP_gap	-0.369	-0.160	0.094	0.010	0.096	0.076	0.056
	(0.269)	(0.204)	(0.108)	(0.071)	(0.059)	(0.053)	(0.059)
Month end dummy	0.002	0.001	-0.001	-0.001	-0.001	0.001	-0.001
	(0.003)	(0.002)	(0.004)	(0.001)	(0.001)	(0.001)	(0.001)
Lunar year dummy	0.001	-0.003	0.001	-0.004	-0.007	-0.003	-0.003
	(0.010)	(0.008)	(0.004)	(0.003)	(0.004)	(0.002)	(0.002)
IPO	0.002	-0.003	0.002	0.007	0.006	0.006	0.005
	(0.003)	(0.002)	(0.020)	(0.008)	(0.006)	(0.006)	(0.006)
IPO(1)	0.003	0.001	0.009	0.002*	0.012*	0.010**	0.019**
	(0.003)	(0.003)	(0.013)	(0.001)	(0.006)	(0.005)	(0.007)
Net CBB issuing	-0.039	-0.003	-0.025	-0.016*	-0.007	-0.008	-0.006
	(0.035)	(0.003)	(0.016)	(0.008)	(0.007)	(0.006)	0.007
Observation	1574	1574	1574	1574	1574	1574	1226
Adjusted R^2	0.01	0.01	0.05	0.03	0.07	0.05	0.05

Note: FB_1yr, FB_2yr and FB-5yr denote one-year, two-year and five-year financial-bond yields, respectively. Similarly, LCB_1yr, LCB_2yr and LCB_5yr denote one-year, two-year and five-year long-term corporate-bond yields, respectively. MTN_1yr denotes one-year medium-term note yields (longer-maturity MTN yields are not available now). Standard errors of estimated coefficients are reported in the brackets. ***, **, and * denote significance at 1%, 5% and 10%, respectively.

Table 7. GARCH Models Estimated by MLE

Variables	Dependent variables						
Mean equation	Repo_1d	Repo_7d	Repo_1m	TB_1YR	TB_2YR	TB_5YR	TB_10YR
Benchmark Deposit rate	0.431***	0.553***	0.759***	0.290	0.309***	0.165***	0.178***
	(0.045)	(0.029)	(0.094)	(0.193)	(0.106)	(0.046)	(0.014)
RRR	0.193***	0.290***	0.512***	0.296**	0.271***	0.129*	0.018
	(0.051)	(0.069)	(0.171)	(0.127)	(0.101)	(0.077)	(0.028)
Benchmark CBB issuing rate	0.022***	0.038***	0.036	0.117	0.116*	0.084***	0.055***
	(0.006)	(0.010)	(0.047)	(0.079)	(0.069)	(0.032)	(0.010)
PPI_gap	0.029***	-0.030***	0.103***	0.017	0.017	0.024	0.001
	(0.006)	(0.006)	(0.025)	(0.077)	(0.088)	(0.029)	(0.005)
CPI_gap	0.006**	-0.004	0.008	0.023	0.008	0.013	0.005***
	(0.003)	(0.004)	(0.019)	(0.044)	(0.035)	(0.029)	(0.004)
Retail_gap	0.013	0.013	-0.013	-0.031	-0.005	0.012	0.004
	(0.007)	(0.017)	(0.080)	(0.229)	(0.201)	(0.101)	(0.014)
M2_gap	-0.028**	0.019	0.357***	0.027	0.012	0.056	0.057***
	(0.014)	(0.037)	(0.095)	(0.421)	(0.296)	(0.137)	(0.014)
Export_gap	0.001	0.001	0.045***	0.007	0.006	-0.002	-0.004**
	(0.006)	(0.004)	(0.013)	(0.027)	(0.029)	(0.016)	(0.002)
Import_gap	0.002	0.008	0.015	-0.004	-0.002	0.001	-0.001
	(0.002)	(0.005)	(0.014)	(0.038)	(0.031)	(0.012)	(0.002)
GDP_gap	0.129***	0.387***	0.943***	-0.028	-0.005	0.004	0.006
	(0.045)	(0.071)	(0.174)	(0.517)	(0.537)	(0.357)	(0.049)
Month end dummy	-0.003	-0.001	0.001	-0.001	-0.001	-0.001	-0.001
	(0.004)	(0.007)	(0.003)	(0.004)	(0.003)	(0.002)	(0.001)
Lunar year dummy	0.001	0.043***	0.019	0.002	-0.001	0.001	-0.001
	(0.006)	(0.011)	(0.020)	(0.017)	(0.011)	(0.009)	(0.002)
IPO	0.002	0.001	-0.003	-0.005	-0.006	-0.002	0.003
	(0.006)	(0.003)	(0.003)	(0.010)	(0.009)	(0.005)	(0.030)
IPO(1)	0.003	0.005*	0.004	-0.005	0.007	0.002**	0.004
	(0.005)	(0.002)	(0.004)	(0.040)	(0.039)	(0.001)	(0.026)
Net CBB issuing	0.004	-0.029***	-0.005	-0.009	-0.009	0.005	-0.001
	(0.003)	(0.009)	(0.020)	(0.060)	(0.034)	(0.020)	(0.004)
Variance equation							
C	0.004***	0.003**	0.008***	0.008**	0.005**	0.009***	0.002**
	(0.001)	(0.001)	(0.001)	(0.004)	(0.002)	(0.002)	(0.001)
RESID(-1)	0.249***	0.265***	0.164***	0.100***	0.100***	0.100***	0.239***
	(0.043)	(0.045)	(0.024)	(0.018)	(0.019)	(0.013)	(0.029)
RESID(-2)	0.025	0.006***	0.032	0.033	0.033	0.033	0.050**
	(0.056)	(0.075)	(0.042)	(0.092)	(0.097)	(0.033)	(0.025)
RESID(-3)	-0.054**	-0.104***	0.015	0.033	0.033	0.033**	0.285***
	(0.025)	(0.043)	(0.027)	(0.058)	(0.061)	(0.016)	(0.058)
GARCH(-1)	0.427***	0.807***	0.426**	0.399	0.399	0.400	-0.215***
	(0.115)	(0.090)	(0.206)	(0.852)	(0.895)	(0.310)	(0.0247)
GARCH(-2)	-0.011	-0.161*	0.001	0.033	0.033	0.033	0.151***
	(0.121)	(0.084)	(0.212)	(0.847)	(0.902)	(0.254)	(0.031)
GARCH(-3)	0.079*	0.036*	-0.053	0.033	0.033	0.033	-0.001
	(0.044)	(0.020)	(0.064)	(0.305)	(0.326)	(0.080)	(0.002)
Month end dummy	0.009***	0.001	0.008***	-0.008	-0.005	-0.003	-0.007
	(0.003)	(0.001)	(0.002)	(0.009)	(0.006)	(0.002)	(0.016)
Lunar year dummy	0.008***	0.005**	0.007***	-0.014	-0.007	-0.003	0.001
	(0.003)	(0.002)	(0.002)	(0.050)	(0.020)	(0.010)	(0.002)
IPO	0.008***	0.030***	0.012***	-0.003	-0.002	-0.008***	-0.007
	(0.002)	(0.008)	(0.003)	(0.003)	(0.002)	(0.002)	(0.012)
IPO(1)	0.005***	0.005	0.004	-0.003	-0.002	-0.009***	-0.006***
	(0.002)	(0.005)	(0.003)	(0.009)	(0.007)	(0.003)	(0.012)
Observation	1574	1574	1574	1574	1574	1574	1574
Log-likelihood	3804	2998	2366	3275	3667	4203	5261

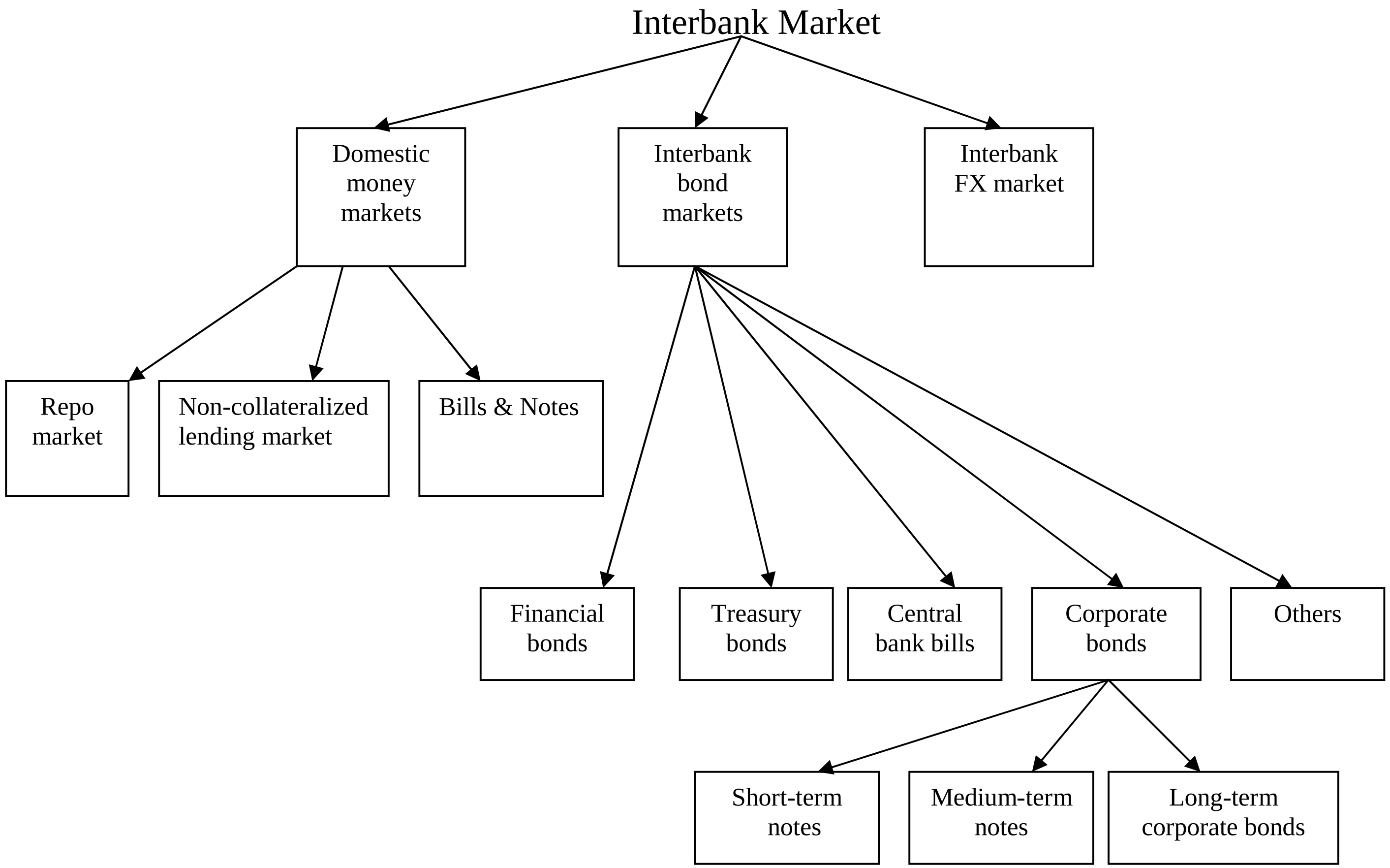
Note: Repo_1d denotes overnight Repo rate, Repo_7d denotes seven-day Repo rate, and Repo_1m denotes one-month Repo rate. TB_1yr, TB_2yr, TB-5yr and TB_10yr denote one-year, two-year, five-year and ten-year treasury-bond yields, respectively. Standard errors of estimated coefficients are reported in the brackets. ***, **, and * denote significance at 1%, 5% and 10%, respectively.

Table 8. GARCH Models Estimated by MLE (Continued)

Variables	**Dependent variables**						
Mean equation	FB_1yr	FB_2yr	FB_5yr	LCB_1yr	LCB_2yr	LCB_5yr	MTN_1yr
Benchmark Deposit	0.243	0.247	0.174	0.162***	0.150***	0.132***	0.120***
rate	(0.524)	(0.265)	(0.117)	(0.019)	(0.034)	(0.024)	(0.010)
RRR	0.111	0.151	0.031	0.109***	0.071	-0.031	0.004
	(0.699)	(0.481)	(0.022)	(0.037)	(0.083)	(0.054)	(0.022)
Benchmark CBB	0.069	0.054	0.026	0.066**	0.051***	0.012	0.018**
issuing rate	(0.159)	(0.081)	(0.027)	(0.026)	(0.019)	(0.023)	(0.008)
PPI_gap	-0.015	-0.006	0.007	0.003	0.011	0.017**	0.003
	(0.115)	(0.081)	(0.036)	(0.008)	(0.016)	(0.008)	(0.004)
CPI_gap	0.037	0.025	0.019	0.003	-0.003	-0.003	-0.007
	(0.065)	(0.058)	(0.027)	(0.011)	(0.017)	(0.010)	(0.004)
Retail_gap	0.008	0.015	-0.009	-0.026	0.006	-0.003	0.003
	(0.492)	(0.408)	(0.173)	(0.054)	(0.040)	(0.041)	(0.013)
M2_gap	0.184	0.112	0.094	0.044	-0.006	-0.014	0.001
	(0.584)	(0.309)	(0.143)	(0.036)	(0.045)	(0.044)	(0.016)
Export_gap	-0.002	0.005	-0.001	-0.005	0.004	0.001	-0.001
	(0.121)	(0.072)	(0.032)	(0.005)	(0.014)	(0.010)	(0.002)
Import_gap	-0.002	-0.002	0.003	0.001	-0.001	0.001	0.002
	(0.072)	(0.052)	(0.026)	(0.006)	(0.011)	(0.010)	(0.002)
GDP_gap	-0.369	-0.160	0.094	0.010	0.097	0.076	0.011
	(0.548)	(0.505)	(0.223)	(0.072)	(0.093)	(0.082)	(0.036)
Month end dummy	0.002	0.001	-0.001	0.001	-0.001	0.001	0.001
	(0.008)	(0.006)	(0.002)	(0.005)	(0.001)	(0.008)	(0.020)
Lunar year dummy	0.001	-0.003	0.001	-0.005	-0.007	-0.004	-0.003**
	(0.002)	(0.024)	(0.008)	(0.003)	(0.004)	(0.004)	(0.001)
IPO	-0.006	-0.002	0.001	0.012***	0.003	-0.004	0.001
	(0.090)	(0.005)	(0.009)	(0.004)	(0.009)	(0.003)	(0.010)
IPO(1)	0.001	0.002	0.009	0.010	0.003**	0.030**	0.003
	(0.008)	(0.008)	(0.056)	(0.013)	(0.001)	(0.009)	(0.030)
Net CBB issuing	-0.002	-0.005	-0.002	-0.012	-0.006	-0.009	-0.002
	(0.015)	(0.009)	(0.004)	(0.008)	(0.010)	(0.018)	(0.035)
Variance equation							
C	0.002**	0.002**	0.002**	0.004***	0.006***	0.005**	0.007**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.003)
RESID(-1)	0.100	0.100***	0.100***	0.101***	0.100**	0.100**	0.044***
	(0.022)	(0.020)	(0.027)	(0.018)	(0.040)	(0.038)	(0.016)
RESID(-2)	0.033	0.033	0.033	0.034	0.033	0.033	0.103**
	(0.040)	(0.077)	(0.074)	(0.024)	(0.044)	(0.048)	(0.049)
RESID(-3)	0.033	0.033	0.033	0.033	0.033	0.033**	0.015
	(0.044)	(0.047)	(0.058)	(0.024)	(0.034)	(0.052)	(0.055)
GARCH(-1)	0.399**	0.399	0.400	0.400**	0.400**	0.400	0.637
	(0.177)	(0.706)	(0.596)	(0.186)	(0.166)	(0.347)	(0.457)
GARCH(-2)	0.033	0.033	0.033	0.033	0.033	0.033	0.042
	(0.367)	(0.793)	(0.715)	(0.135)	(0.321)	(0.393)	(0.543)
GARCH(-3)	0.033	0.033	0.033	0.033	0.033	0.033	0.065
	(0.229)	(0.306)	(0.320)	(0.103)	(0.193)	(0.209)	(0.215)
Month end dummy	-0.003	-0.001	-0.003	-0.018**	-0.026**	-0.019**	-0.012***
	(0.002)	(0.001)	(0.002)	(0.004)	(0.007)	(0.008)	(0.003)
Lunar year dummy	-0.003	-0.002	-0.003	0.028	-0.004	-0.008	-0.008
	(0.010)	(0.007)	(0.010)	(0.041)	(0.040)	(0.030)	(0.006)
IPO	-0.008***	-0.005	-0.002*	-0.035	-0.040***	-0.029***	0.010
	(0.002)	(0.004)	(0.001)	(0.009)	(0.005)	(0.004)	(0.006)
IPO(1)	-0.009***	-0.005**	-0.009	0.045***	0.014*	0.001	-0.004
	(0.002)	(0.002)	(0.007)	(0.007)	(0.006)	(0.006)	(0.005)
Observation	1574	1574	1574	1574	1574	1574	1226
Log-likelihood	2571	2894	3917	3275	3982	4157	5247

Note: FB_1yr, FB_2yr and FB-5yr denote one-year, two-year and five-year financial-bond yields, respectively. LCB_1yr, LCB_2yr and LCB_5yr denote one-year, two-year and five-year long-term corporate-bond yields, respectively. MTN_1yr denotes one-year medium-term note yields (longer-maturity MTN yields are not available). Standard errors are reported in the brackets. ***, **, and * denote significance at 1%, 5% and 10%, respectively.

Figure 1. The Structure of the Chinese Interbank Market



Appendix A. Proof of the Result 1

Without any regulated interest rates in the deposit, lending and non-regulated markets, the loan lending market can be cleared at r_l^*.

$$\sum_{i=1}^{N} L_i^d(r_l) = \sum_{i=1}^{N} L_i^s = (r_l - r_{nr}) / \delta_L \tag{A.1}$$

$$r_l^* = g(r_{nr}, \delta_L) \tag{A.2}$$

We can observe that the equilibrium lending rate r_l^* is a positive function of the market rate r_{nr}, and the proof is as follows:

$$g() = (r_l - r_{nr}) / \delta_L - L^d(r_l) \tag{A.3}$$

$$\frac{\partial r_l}{\partial r_{nr}} = -\frac{\partial g / \partial r_{nr}}{\partial g / \partial r_l} = \frac{\delta_L}{(1/\delta_L - L^d{}')} > 0 \text{ because } L^d{}' < 0. \tag{A.4}$$

Similarly, the deposit market can be cleared at r_d^*:

$$\sum_{i=1}^{N} D_i^s(r_d) = \sum_{i=1}^{N} D_i^d = [\alpha(r_r - r_{nr}) + r_{nr} - r_d] / \delta_D \tag{A.5}$$

$$r_d^* = f(r_{nr}, r_r, \alpha, \delta_D) \tag{A.6}$$

The equilibrium rate r_d^* is also a positive function of r_{nr}, and it can be proved as follows:

$$f() = [\alpha(r_r - r_{nr}) + r_{nr} - r_d] / \delta_D - D^s(r_d) \tag{A.7}$$

$$\frac{\partial r_d}{\partial r_{nr}} = -\frac{\partial f / \partial r_{nr}}{\partial f / \partial r_d} = -\frac{1-\alpha}{-(1+\delta_d D^s{}')} > 0 \text{ because } D^s{}' > 0. \tag{A.8}$$

The aggregate net position in the non-regulated market is given by

$$F(\cdot) = (1-\alpha)D^s - L^d - E - B + S(r_d, r_{nr}) - T(r_l, r_{nr}) \tag{A.9}$$

Substituting $E_i^s = (r_e - r_{nr}) / \delta_E$ into equation (A.9), the $F(\cdot)$ becomes

$$F(\cdot)=(1-\alpha)D^s(r_d)-L^d(r_l)-\sum_{i=1}^{N}[(r_e-r_{nr})/\delta_E]-B+S(r_d,r_{nr})-T(r_l,r_{nr}) \quad \text{(A.9)}$$

Therefore, the partial effect of r_{nr} on the function $F(\cdot)$ is

$$\frac{\partial F}{\partial r_{nr}}=(1-\alpha)\frac{\partial[D^s(r_d)]}{\partial r_{nr}}-\frac{\partial[L^d(r_l)]}{\partial r_{nr}}+\frac{N}{\delta_E}+\frac{\partial S}{\partial r_d}\frac{\partial r_d}{\partial r_{nr}}+\frac{\partial S}{\partial r_{nr}}-\frac{\partial T}{\partial r_l}\frac{\partial r_l}{\partial r_{nr}}-\frac{\partial T}{\partial r_{nr}} \quad \text{(A.10)}$$

It is easily observed that $\frac{\partial[D^s(r_d)]}{\partial r_{nr}}=\frac{\partial D^s}{\partial r_d}\frac{\partial r_d}{\partial r_{nr}}>0$ because $\frac{\partial D^s}{\partial r_d}>0,\frac{\partial r_d}{\partial r_{nr}}>0$. (A.11)

Similarly, we can prove $\frac{\partial[L^d(r_l)]}{\partial r_{nr}}=\frac{\partial L^d}{\partial r_l}\frac{\partial r_l}{\partial r_{nr}}<0$ because $\frac{\partial L^d}{\partial r_l}<0,\frac{\partial r_l}{\partial r_{nr}}>0$. (A.12)

$\frac{\partial S}{\partial r_d}\frac{\partial r_d}{\partial r_{nr}}+\frac{\partial S}{\partial r_{nr}}$ >0, because we assume $\frac{\partial S(r_d,r_{nr})}{\partial r_{nr}}$ >0. This term includes two components: $\frac{\partial S}{\partial r_d}\frac{\partial r_d}{\partial r_{nr}}$ and $\frac{\partial S}{\partial r_{nr}}$. $\frac{\partial S}{\partial r_{nr}}$ >0, which means that the fund supply increases with market rate r_{nr}. Meanwhile, a higher r_{nr} leads to a higher deposit rate r_d because $\frac{\partial r_d}{\partial r_{nr}}$ >0. $\frac{\partial S}{\partial r_d}$ <0, which implies that a higher deposit rate might induce some of the funds to leak into banking deposits. However, it is sensible to assume that at least some funds remain in the wholesale capital market, which means $\partial S(r_d,r_{nr})/\partial r_{nr}$ >0 on the whole.

Similarly, $\frac{\partial T}{\partial r_l}\frac{\partial r_l}{\partial r_{nr}}+\frac{\partial T}{\partial r_{nr}}$ <0 because we assume that funding demand decreases with r_{nr} on the whole, despite some offsetting effects from a higher lending rate.

Combining the above discussions,

$$\frac{\partial F}{\partial r_{nr}}=\underset{+}{(1-\alpha)\frac{\partial[D^s(r_d)]}{\partial r_{nr}}}-\underset{-(-)}{\frac{\partial[L^d(r_l)]}{\partial r_{nr}}}+\underset{+}{\frac{N}{\delta_E}}+\underset{+}{\left(\frac{\partial S}{\partial r_d}\frac{\partial r_d}{\partial r_{nr}}+\frac{\partial S}{\partial r_{nr}}\right)}-\underset{-(-)}{\left(\frac{\partial T}{\partial r_l}\frac{\partial r_l}{\partial r_{nr}}+\frac{\partial T}{\partial r_{nr}}\right)} \quad \text{(A.13)}$$

Therefore, we can obtain $\partial F / \partial r_{nr}$ >0.

$$\frac{\partial r_{nr}}{\partial \alpha} = -\frac{\partial F / \partial \alpha}{\partial F / \partial r_{nr}} \Rightarrow \frac{\partial r_{nr}}{\partial \alpha}\frac{\partial F}{\partial r_{nr}} = -\frac{\partial F}{\partial \alpha} \tag{A.14}$$

$$\frac{\partial F}{\partial \alpha} = -D^{s} + (1-\alpha)(r_r - r_{nr}) + \frac{N}{\delta_E}\frac{\partial r_{nr}}{\partial \alpha} + \frac{\partial S}{\partial r_{nr}}\frac{\partial r_{nr}}{\partial \alpha} + \frac{\partial S}{\partial r_d}\frac{\partial r_d}{\partial \alpha} - \frac{\partial T}{\partial r_{nr}}\frac{\partial r_{nr}}{\partial \alpha} \tag{A.15}$$

Combining the above two equations and rearranging terms,

$$\frac{\partial r_{nr}}{\partial \alpha}\left(\frac{\partial F}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S}{\partial r_{nr}} - \frac{\partial T}{\partial r_{nr}}\right) = D^{s} - (1-\alpha)(r_r - r_{nr}) - \frac{\partial S}{\partial r_d}\frac{\partial r_d}{\partial \alpha} \tag{A.16}$$

Because $(r_r - r_{nr})$<0 , which means interest rate the for reserve requirements is usually less than the market rate. $D^{s} - (1-\alpha)(r_r - r_{nr})$ >0.

$\frac{\partial S}{\partial r_d}\frac{\partial r_d}{\partial \alpha}$ <0 because $\frac{\partial S}{\partial r_d}$ <0 and $\frac{\partial r_d}{\partial \alpha}$ >0.

Therefore,

$$\frac{\partial r_{nr}}{\partial \alpha}\left(\frac{\partial F}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S}{\partial r_{nr}} - \frac{\partial T}{\partial r_{nr}}\right) > 0 . \tag{A.17}$$

It is easily observed that $\left(\frac{\partial F}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S}{\partial r_{nr}} - \frac{\partial T}{\partial r_{nr}}\right)$ >0 because $\frac{\partial F}{\partial r_{nr}}$ >0, $\frac{\partial S}{\partial r_{nr}}$ >0 and $\frac{\partial T}{\partial r_{nr}}$ <0.

Therefore, we can obtain $\partial r_{nr} / \partial \alpha > 0$.

Similarly, $\frac{\partial r_{nr}}{\partial B} = -\frac{\partial F / \partial B}{\partial F / \partial r_{nr}} > 0$, where $\frac{\partial F}{\partial B} = -1 + \frac{N}{\delta_E}\frac{\partial r_{nr}}{\partial B} + \frac{\partial S}{\partial r_{nr}}\frac{\partial r_{nr}}{\partial B} - \frac{\partial T}{\partial r_{nr}}\frac{\partial r_{nr}}{\partial B}$.

Combining the above two equations and rearranging terms,

$$\frac{\partial r_{nr}}{\partial B}\left(\frac{\partial F}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S}{\partial r_{nr}} - \frac{\partial T}{\partial r_{nr}}\right) = 1 \tag{A.18}$$

Therefore, $\partial r_{nr} / \partial B > 0$ Q.E.D.

Appendix B. Proof of the Result 2.1

Given that the deposit is binding and that the lending rate is not binding (no credit quota in this case), the aggregate net position in the wholesale capital market can be written as follows:

$$F(\cdot) = (1-\alpha)D^s(r_d^b) - L^d(r_l\ ) - E\ - B\ + S(r_d^b, r_{nr}) - T(r_l, r_{nr}) \quad \text{(B.1)}$$

Note here that the deposit function is only determined by the saving supply, and therefore, D^s is only the function of r_d^b. In the capital wholesale market, the supply function $S(r_d^b, r_{nr})$ is also a function of r_d^b, where r_d^b is exogenous and determined by the central bank.

The partial effect of r_{nr} on the function $F(\cdot)$ becomes

$$\frac{\partial F}{\partial r_{nr}} = (1-\alpha)\frac{\partial[D^s(r_d^b)]}{\partial r_{nr}} - \frac{\partial[L^d(r_l\ )]}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S(r_d^b, r_{nr})}{\partial r_{nr}} - \frac{\partial T(r_l, r_{nr})}{\partial r_{nr}} \quad \text{(B.2)}$$

Then, we discuss each part of equation (B.2) as follows:

$$\frac{\partial[D^s(r_d^b)]}{\partial r_{nr}} = \frac{\partial D^s}{\partial r_d^b}\frac{\partial r_d^b}{\partial r_{nr}} = 0 \quad \text{(B.3)}$$

where $\partial r_d^b / \partial r_{nr}$ =0 because r_d^b is exogenous.

As we discussed in Appendix A, $\frac{\partial[L^d(r_l\ )]}{\partial r_{nr}}$<0, $\frac{N}{\delta_E}$>0, $\frac{\partial T(r_l, r_{nr})}{\partial r_{nr}}$<0.

$$\frac{\partial S(r_d^b, r_{nr})}{\partial r_{nr}} = \frac{\partial S}{\partial r_d^b}\frac{\partial r_d^b}{\partial r_{nr}} + \frac{\partial S}{\partial r_{nr}} = 0 + \frac{\partial S}{\partial r_{nr}} > 0 \quad \text{(B.4)}$$

Therefore, $\partial F / \partial r_{nr} > 0$.

Because the lending rate is not binding, $\partial r_{nr} / \partial r_l^b = 0$.

$$\frac{\partial r_{nr}}{\partial r_d^b} = -\frac{\partial F / \partial r_d^b}{\partial F / \partial r_{nr}} \tag{B.5}$$

$$\frac{\partial F}{\partial r_d^b} = (1-\alpha)\frac{\partial D_s}{\partial r_d^b} + \frac{N}{\delta_E}\frac{\partial r_{nr}}{\partial r_d^b} + \frac{\partial S}{\partial r_d^b} + \frac{\partial S}{\partial r_{nr}}\frac{\partial r_{nr}}{\partial r_d^b} - \frac{\partial T}{\partial r_{nr}}\frac{\partial r_{nr}}{\partial r_d^b} \tag{B.6}$$

Combining the above two equations, we can obtain the following:

$$\frac{\partial r_{nr}}{\partial r_d^b}\left(\frac{\partial F}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S}{\partial r_{nr}} - \frac{\partial T}{\partial r_{nr}}\right) = -[(1-\alpha)\frac{\partial D_s}{\partial r_d^b} + \frac{\partial S}{\partial r_d^b}] \tag{B.7}$$

Because $\frac{\partial F}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S}{\partial r_{nr}} - \frac{\partial T}{\partial r_{nr}}$ >0, we only need to discuss the right-hand side of the above equation. When the ceiling is raised by the central bank, the higher ceiling will attract funds to flow into the saving system from other markets, such as from the wholesale capital market into bank savings. Therefore, in this sense, $\partial D^s / \partial r_d^b$ >0 because the deposit supply does increase because of the higher deposit-rate ceiling.[19] On the other hand, in the wholesale capital market, $\partial S / \partial r_d^b < 0$ because funds flow out of the market, and the supply of funds in the wholesale market decreases as the deposit-rate ceiling rises. Thus, $\partial D^s / \partial r_d^b > 0, \partial S / \partial r_d^b < 0$.

What, then, is the relative size of the two opposite flows? When funds flow into the banking system and become bank deposits, some of those deposits have to be reserved at the PBC as part of the reserve requirement, which is why $(1-\alpha)$ is in front of $\partial D^s / \partial r_d^b$. On the other hand, the supply of funds in the wholesale market decreases more than the deposits increase in savings. Therefore, funds as a whole decrease due to fund flows from the wholesale market to the banking sector. Therefore, the total aggregate net position decreases, which means that $(1-\alpha)\partial D^s / \partial r_d^b + \partial S / \partial r_d^b < 0$.

Therefore,

$$\frac{\partial r_{nr}}{\partial r_d^b} = -[(1-\alpha)\frac{\partial D_s}{\partial r_d^b} + \frac{\partial S}{\partial r_d^b}] / \left(\frac{\partial F}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S}{\partial r_{nr}} - \frac{\partial T}{\partial r_{nr}}\right) > 0 \tag{B.8}$$

[19] Because we focus on interactions between the banking sector and the money & bond market in the short run, total saving in the economy is assumed to be constant in the short run.

which means that the market rate in the wholesale capital market increases with the deposit-rate ceiling when the ceiling is binding.

$$\frac{\partial r_{nr}}{\partial \alpha} = -\frac{\partial F / \partial \alpha}{\partial F / \partial r_{nr}} \tag{B.9}$$

$$\frac{\partial F}{\partial \alpha} = -D^s + \frac{N}{\delta_E}\frac{\partial r_{nr}}{\partial \alpha} + \frac{\partial S}{\partial r_{nr}}\frac{\partial r_{nr}}{\partial \alpha} - \frac{\partial T}{\partial r_{nr}}\frac{\partial r_{nr}}{\partial \alpha} \tag{B.10}$$

given $\partial r_d^b / \partial \alpha$ =0.

Therefore,

$$\frac{\partial r_{nr}}{\partial \alpha}\left(\frac{\partial F}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S}{\partial r_{nr}} - \frac{\partial T}{\partial r_{nr}}\right) = D^s \tag{B.11}$$

Then, we can obtain $\partial r_{nr} / \partial \alpha$ >0.

As we proved in Appendix A, we can prove that $\partial r_{nr} / \partial B > 0$.

Q.E.D.

Appendix C. Proof of the Result 2.2

Given that both the deposit-rate ceiling and the lending-rate floor are binding, the market rate in the deposit market is the ceiling r_d^b, and the market rate in the lending market is the floor r_l^b. Therefore, the aggregate net position in the wholesale capital market can be written as follows:

$$F(\cdot) = (1-\alpha)D^s(r_d^b) - L^d(r_l^b) - E - B + S(r_d^b, r_{nr}) - T(r_l^b, r_{nr}) \tag{C.1}$$

Note here that the deposit function is only determined by the saving supply, and therefore D^s is only the function of r_d^b. Similarly, lending is determined only by loan demand, which is a function only of r_l^b. In the capital wholesale market, both the supply and demand functions $S(r_d^b, r_{nr})$ and $T(r_l^b, r_{nr})$ are functions of the deposit-rate ceiling and lending-rate floor because both r_d^b and r_l^b are exogenous and are determined by the central bank.

The partial effect of r_{nr} on the function $F(\cdot)$ becomes

$$\frac{\partial F}{\partial r_{nr}} = (1-\alpha)\frac{\partial[D^s(r_d^b)]}{\partial r_{nr}} - \frac{\partial[L^d(r_l^b)]}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S(r_d^b, r_{nr})}{\partial r_{nr}} - \frac{\partial T(r_l^b, r_{nr})}{\partial r_{nr}} \tag{C.2}$$

Now, we are ready to discuss each part of the above equation as follows:

$$\frac{\partial[D^s(r_d^b)]}{\partial r_{nr}} = \frac{\partial D^s}{\partial r_d^b}\frac{\partial r_d^b}{\partial r_{nr}} = 0 \tag{C.3}$$

$\partial r_d^b / \partial r_{nr}$ =0 because r_d^b is exogenous.

Similarly, $\partial[L^d(r_l^b)]/\partial r_{nr} = 0$.

As we discussed in Appendix A, $N/\delta_E > 0$ and

$$\frac{\partial S(r_d^b, r_{nr})}{\partial r_{nr}} = \frac{\partial S}{\partial r_d^b}\frac{\partial r_d^b}{\partial r_{nr}} + \frac{\partial S}{\partial r_{nr}} = 0 + \frac{\partial S}{\partial r_{nr}} > 0 \tag{C.4}$$

Here is the new part:

$$\frac{\partial T(r_l^b, r_{nr})}{\partial r_{nr}} = \frac{\partial T}{\partial r_l^b}\frac{\partial r_l^b}{\partial r_{nr}} + \frac{\partial T}{\partial r_{nr}} \tag{C.5}$$

where $\partial T / \partial r_{nr} < 0$ because the funding demand decreases as the funding cost increases.

$\frac{\partial T}{\partial r_l^b}\frac{\partial r_l^b}{\partial r_{nr}} = 0$ and $\frac{\partial r_l^b}{\partial r_{nr}}$=0 because r_l^b is exogenous and is set by the PBC.

Therefore,

$$\frac{\partial T(r_l^b, r_{nr})}{\partial r_{nr}} = \frac{\partial T}{\partial r_l^b}\frac{\partial r_l^b}{\partial r_{nr}} + \frac{\partial T}{\partial r_{nr}} = 0 + \frac{\partial T}{\partial r_{nr}} < 0 \tag{C.6}$$

Therefore, $\partial F / \partial r_{nr} > 0$.

Now, we turn to $\frac{\partial r_{nr}}{\partial r_d^b}$ and $\frac{\partial r_{nr}}{\partial r_l^b}$.

$$\frac{\partial r_{nr}}{\partial r_d^b} = -\frac{\partial F / \partial r_d^b}{\partial F / \partial r_{nr}} \tag{C.7}$$

$$\frac{\partial F}{\partial r_d^b} = (1-\alpha)\frac{\partial D_s}{\partial r_d^b} + \frac{N}{\delta_E}\frac{\partial r_{nr}}{\partial r_b} + \frac{\partial S}{\partial r_d^b} + \frac{\partial S}{\partial r_{nr}}\frac{\partial r_{nr}}{\partial r_b} - \frac{\partial T}{\partial r_{nr}}\frac{\partial r_{nr}}{\partial r_b} \tag{C.8}$$

As we proved in Appendix B, $\frac{\partial r_{nr}}{\partial r_d^b} > 0$.

$$\frac{\partial r_{nr}}{\partial r_l^b} = -\frac{\partial F / \partial r_l^b}{\partial F / \partial r_{nr}} \tag{C.9}$$

$$\frac{\partial F}{\partial r_l^b} = -\frac{\partial L_d}{\partial r_l^b} + \frac{N}{\delta_E}\frac{\partial r_{nr}}{\partial r_l^b} + \frac{\partial S}{\partial r_{nr}}\frac{\partial r_{nr}}{\partial r_l^b} - \frac{\partial T}{\partial r_l^b} - \frac{\partial T}{\partial r_{nr}}\frac{\partial r_{nr}}{\partial r_l^b} \tag{C.10}$$

Combining the above two equations:

$$\frac{\partial r_{nr}}{\partial r_l^b} = (\frac{\partial L_d}{\partial r_l^b} + \frac{\partial T}{\partial r_l^b}) / (\frac{\partial F}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S}{\partial r_{nr}} - \frac{\partial T}{\partial r_{nr}}) \quad \text{(C. 11)}$$

because $\partial L^d / \partial r_l^b < 0$, which means that loan demand decreases with the lending-rate floor. $\partial T / \partial r_l^b > 0$ because there is more funding demand in the wholesale capital market when capital becomes more expensive in the loan market. In other words, when the interest rate for loans hikes in the banking sector, firms have an incentive to issue more bonds to obtain capital.

Therefore, it is difficult to determine the sign of $\partial F / \partial r_l^b$ if $\partial L^d / \partial r_l^b < 0$ and $\partial T / \partial r_l^b > 0$.

Therefore, the sign of $\frac{\partial r_{nr}}{\partial r_l^b}$ is indeterminate.

As we proved in Appendix B, $\frac{\partial r_{nr}}{\partial \alpha} > 0$ in this case as well.

Similarly, we can prove that $\frac{\partial r_{nr}}{\partial B} > 0$.

Q.E.D.

Appendix D. Proof of the Result 2.3

Given that the loan supply is constrained by the loan quota and that the lending rate is higher than the lending-rate floor, the lending rate in the loan market can be written as follows:

$$L_i^d(r_l^*) = \overline{L_i} \qquad => r_l^* = f(\overline{L}) \tag{D.1}$$

In the deposit market, the deposit-rate ceiling is still binding. In a non-regulated market, r_{nr} clears the market according to

$$\sum_{i=1}^{N} NR_i + S(r_d^b, r_{nr}) = T[r_l(\overline{L}), r_{nr}] \tag{D.2}$$

where $NR_i = D_i - \overline{L}_i - E_i - \alpha D_i - B_i$.

Then, the aggregate net position in the wholesale capital market can be written as follows:

$$F(\cdot) = (1-\alpha)D^s(r_d^b) - \overline{L} - E \ - B \ + S(r_d^b, r_{nr}) - T[r_l(\overline{L}), r_{nr}] \tag{D.3}$$

Note here that the loan demand is determined by loan quota $\overline{L}$ and that the lending rate in the loan market is also a function of the loan quota.

The partial effect of r_{nr} on the function $F(\cdot)$ becomes

$$\frac{\partial F}{\partial r_{nr}} = (1-\alpha)\frac{\partial[D^s(r_d^b)]}{\partial r_{nr}} - \frac{\partial \overline{L}}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S(r_d^b, r_{nr})}{\partial r_{nr}} - \frac{\partial T[r_l(\overline{L}), r_{nr}]}{\partial r_{nr}} \tag{D.4}$$

As we discussed in Appendix C,

$$\frac{\partial[D^s(r_d^b)]}{\partial r_{nr}} = \frac{\partial D^s}{\partial r_d^b}\frac{\partial r_d^b}{\partial r_{nr}} = 0 \tag{D.5}$$

Similarly, $\frac{\partial \overline{L}}{\partial r_{nr}}$ =0 because $\overline{L}$ is exogenous.

$\frac{N}{\delta_E}$ >0 and $\frac{\partial S(r_d^b, r_{nr})}{\partial r_{nr}}$ >0, as we proved before.

The new term is

$$\frac{\partial T[r_l(\overline{L}), r_{nr}]}{\partial r_{nr}} = \frac{\partial T}{\partial r_l}\frac{\partial r_l}{\partial \overline{\overline{L}}}\frac{\partial \overline{L}}{\partial r_{nr}} + \frac{\partial T}{\partial r_{nr}} \tag{D.6}$$

where $\frac{\partial \overline{L}}{\partial r_{nr}}$ =0 and $\frac{\partial T}{\partial r_{nr}}$ <0; therefore, $\frac{\partial T[r_l(\overline{L}), r_{nr}]}{\partial r_{nr}}$ <0.

Combining all of the above together, $\frac{\partial F}{\partial r_{nr}} > 0$.

Therefore, it is easy to prove that $\partial r_{nr} / \partial r_d^b > 0$, similar to what was formulated in Appendix B.

The lending-rate floor does not appear in $F(\cdot)$, which verifies that the lending-rate floor does not matter to the market rate when there is a credit quota, as long as r_l is above the floor.

Now, we discuss how a credit quota affects the market rate.

$$\frac{\partial r_{nr}}{\partial \overline{\overline{L}}} = -\frac{\partial F / \partial \overline{L}}{\partial F / \partial r_{nr}} \tag{D.7}$$

$$\frac{\partial F}{\partial \overline{\overline{L}}} = -1 + \frac{N}{\delta_E}\frac{\partial r_{nr}}{\partial \overline{\overline{L}}} + \frac{\partial S}{\partial r_{nr}}\frac{\partial r_{nr}}{\partial \overline{\overline{L}}} - \frac{\partial T}{\partial r_l}\frac{\partial r_l}{\partial \overline{\overline{L}}} - \frac{\partial T}{\partial r_{nr}}\frac{\partial r_{nr}}{\partial \overline{\overline{L}}} \tag{D.8}$$

Combining the above two equations,

$$\frac{\partial r_{nr}}{\partial \overline{\overline{L}}}\left(\frac{\partial F}{\partial \overline{\overline{L}}} + \frac{N}{\delta_E} + \frac{\partial S}{\partial r_{nr}} - \frac{\partial T}{\partial r_{nr}}\right) = 1 + \frac{\partial T}{\partial r_l}\frac{\partial r_l}{\partial \overline{\overline{L}}} \tag{D.9}$$

$\frac{\partial T}{\partial r_l}\frac{\partial r_l}{\partial \overline{\overline{L}}}$ <0 because $\frac{\partial T}{\partial r_l}$ >0 and $\frac{\partial r_l}{\partial \overline{\overline{L}}}$ <0 (see Figure 2), and therefore, the sign of $\frac{\partial F}{\partial \overline{\overline{L}}}$ might be negative or positive.

Therefore, $\partial r_{nr} / \partial \overline{L}$ might be negative or positive, which suggests that the impact of a credit quota on the market rate is ambiguous. The intuition behind this is that increasing the credit quota would induce a lower lending rate in the loan market, but it would also reduce the capital supply from the banking system in a non-regulated market because the net position of banks is determined by $NR_i = D_i - \overline{L}_i - E_i - \alpha D_i - B_i$.

As we proved in Appendix C, $\frac{\partial r_{nr}}{\partial \alpha} = -\frac{\partial F / \partial \alpha}{\partial F / \partial r_{nr}} > 0$ in this case as well.

Similarly, we can prove that $\frac{\partial r_{nr}}{\partial B} = -\frac{\partial F / \partial B}{\partial F / \partial r_{nr}} > 0$.

Q.E.D.

Appendix E. A Simple Calibration

In this simple calibration, we focus on the scenario in Figure 2 of Case 2.3, which is the closest scenario to reality, as we discussed in Appendix D.

From Appendices A and C, the partial impact of the deposit-rate ceiling, RRR and issues of CBB on the market rate are as follows:

$$\frac{\partial r_{nr}}{\partial r_d^b} = -[(1-\alpha)\frac{\partial D_s}{\partial r_d^b} + \frac{\partial S}{\partial r_d^b}]/(\frac{\partial F}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S}{\partial r_{nr}} - \frac{\partial T}{\partial r_{nr}}) \tag{E.1}$$

$$\frac{\partial r_{nr}}{\partial \alpha} = D^s /(\frac{\partial F}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S}{\partial r_{nr}} - \frac{\partial T}{\partial r_{nr}}) \tag{E.2}$$

$$\frac{\partial r_{nr}}{\partial B} = 1/(\frac{\partial F}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S}{\partial r_{nr}} - \frac{\partial T}{\partial r_{nr}}) \tag{E.3}$$

Because the denominators of $\frac{\partial r_{nr}}{\partial r_d^b}$, $\frac{\partial r_{nr}}{\partial \alpha}$ and $\frac{\partial r_{nr}}{\partial B}$ are the same, ($\partial F / \partial r_{nr} + N / \delta_E + \partial S / \partial r_{nr} - \partial T / \partial r_{nr}$), and we only need to compare the three numerators. To do so, we need to assume function forms for the deposit supply in the banking sector and the fund supply from the non-banking sector in a non-regulated market. Following Feyzioglu *et al.* (2009), the deposit supply function can be written as follows:

$$D^s = A^{-\varepsilon_d}(r_d^b)^{\varepsilon_d} \tag{E.4}$$

where ε_d is the price elasticity of the deposit supply and A is a constant term. Similarly, the fund supply in the non-banking sector can be written as follows:

$$S(r_d^b, r_{nr}) = A^{-\varepsilon_d}(r_{nr})^{\varepsilon_d}(r_d^b)^{-\varepsilon_d} \tag{E.5}$$

Now, we are ready to compare the relative sizes of impact from the three instruments. The nominator of $\partial r_{nr} / \partial r_d^b$ is

$$-[(1-\alpha)\frac{\partial D_s}{\partial r_d^b}+\frac{\partial S}{\partial r_d^b}]=-(1-\alpha)(\ \varepsilon_d)\ A_d^{-\varepsilon_d}(r_d^b)^{\varepsilon_d-1}+A_d^{-\varepsilon_d}(\ r_{nr}^{\varepsilon_d})(\varepsilon_d)(r_d^b)^{-\varepsilon_d-1} \quad \text{(E.6)}$$

The nominator of $\partial r_{nr}/\partial\alpha$ is: $D^s = A^{-\varepsilon_d}(r_d^b)^{\varepsilon_d}$ (E.7)

The nominator of $\partial r_{nr}/\partial B$ is 1.

Because we estimate elasticities between policy instruments and the market rate in the empirical analysis, we estimate the ratio of elasticities here to compare the relative importance of policy instruments, as follows:

$$\frac{e_{r_{nr},r_d^b}}{e_{r_{nr},\alpha}}=\frac{\dfrac{\partial r_{nr}/r_{nr}}{\partial r_d^b/r_d^b}}{\dfrac{\partial r_{nr}/r_{nr}}{\partial\alpha/\alpha}}=\frac{\dfrac{\partial r_{nr}}{\partial r_d^b}}{\dfrac{\partial r_{nr}}{\partial\alpha}}*\frac{r_d^b}{\alpha} \quad \text{(E.8)}$$

$$\frac{e_{r_{nr},\alpha}}{e_{r_{nr},B}}=\frac{\dfrac{\partial r_{nr}/r_{nr}}{\partial\alpha/\alpha}}{\dfrac{\partial r_{nr}/r_{nr}}{\partial B/B}}=\frac{\dfrac{\partial r_{nr}}{\partial\alpha}}{\dfrac{\partial r_{nr}}{\partial B}}*\frac{\alpha}{B}=\frac{\alpha D^s}{B} \quad \text{(E.9)}$$

where e_{r_{nr},r_d^b} is the price elasticity between r_{nr} and r_d^b, to measure the ratio of the percent change in r_d^b to the percent change in r_{nr}. Similarly, $e_{r_{nr},\alpha}$ is the elasticity between r_{nr} and α, and $e_{r_{nr},B}$ is the elasticity between r_{nr} and B.

Following Feyzioglu *et al.* (2009), we assume ε_d=0.2 in the benchmark scenario. During the sampling period (from October 30, 2004 to November 15, 2010), the mean of RRR is 12%, the mean of the deposit-rate ceiling is 2.7% and the average yield for a one-year treasury bond is 2.74%. Therefore, α=12%, r_d^b=2.71% and r_{nr}=2.74%. The average size of deposits is about 42 trillion RMB during the sample period, and the average size of the central bank issuance is about 43 billion RMB.
The calibrated results are shown in Table E.1.

Table E.1 Calibration Results

	Ratio of elasticities ($\frac{e_{r_{nr},r_d^b}}{e_{r_{nr},\alpha}}$)	Ratio of elasticities ($\frac{e_{r_{nr},\alpha}}{e_{r_{nr},B}}$)
Scenario 1	α =12%, r_d^b =2.71%, r_{nr} =2.74%, ε_d =0.1 0.46	α =20%, D_s =42 trillion RMB B=43 billion RMB 195
Scenario 2 (Benchmark)	**α =12%, r_d^b =2.71%, r_{nr} =2.74%, ε_d =0.2** **1.97**	**α =12%, D_s =42 trillion RMB** **B=43 billion RMB** **117**
Scenario 3	α =12%, r_d^b =2.71%, r_{nr} =2.74%, ε_d =0.3 5.20	α =20%, D_s =70 trillion RMB B=100 billion RMB 140