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Dong He
Hong Kong Monetary Authority

Honglin Wang
Hong Kong Monetary Authority

"Dual-track Interest Rates and the Conduct of Monetary Policy in China"

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Dong He and Honglin Wang
Research Department
Hong Kong Monetary Authority

Abstract

China has a dual-track interest-rate system: bank deposit and lending rates are regulated while money and bond rates are market-determined. The central bank also imposes an indicative target, which may not be binding at all times, for 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 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 are the means 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 results are verified and supported by both linear and GARCH models using daily money and bond market data. Overall, the findings of this study help us to understand why the central bank conducts monetary policy in China the way it does, using a combination of price and quantitative instruments with differing degrees of potency in terms of their influence on the cost of credit.

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Author's email address: dhe@hkma.gov.hk; hwang@hkma.gov.hk

1. INTRODUCTION

The conduct of Chinese 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 the instruments operate to impact the target variables. It is also unclear how the price- and quantity-based instruments are chosen or combined to influence the availability and/or cost of credit.

The key to understanding China's monetary policy framework is the "dual-track" interest-rate system: on the one hand, bank deposit and lending rates are regulated by the central bank (imposition of a deposit-rate ceiling and a lending-rate floor); on the other hand, interest rates in the 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 planned to market economy and is consistent with China's 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 on the basis of controlled prices (Qian, 1999). The controlled or regulated sector shrinks over time, and the whole system gradually 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 who set the regulated prices about changes in the underlying condition of demand and supply.

The objective of this paper is to provide a framework that allows enables a better understanding of the conduct of monetary policy in China under the dual-track interest-rate system and a juxtaposition of 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 which, together with an indicative quantitative credit target in the banking system, ultimately are the means 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 transmission works under the dual-track system. Empirical models employed in those studies either assume that the transmission mechanism in China is the same as in advanced economies or simply treat it as a black box.

[1] There are still a few regulations on yields at issuance in the bond market. For example, a corporate bond cannot yield over 40% more 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 markets.

However, three recent studies do 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 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 show 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. The result may however 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 theoretical model based partly on Porter and Xu (2009) and Chen et al. (2011) and extend their earlier analyses by taking into account money flows between the banking sector and bond market. Our new model shows that monetary policy instruments work reasonably well in 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 credit target 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 a 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 issuance rate for 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 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 predictable effects on market interest rates. For the People's Bank of China (PBC), setting the benchmark deposit rate is the most powerful instrument for influencing market rates, and setting the RRR is the second in line. The relative potency of setting the benchmark deposit rate versus the RRR is not fixed over time but depends on the supply elasticity of deposits. However, setting the issuance rate for central bank bills does not have a significant impact on market rates, presumably due to the relatively small weight of such bills in the PBC balance sheet.

The rest of the paper is organized as follows. The next section briefly reviews China's monetary policy framework and 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 and provides an estimate of the equilibrium interest rate in China, which allows us to determine 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 is obliged to maintain the stability of the Chinese financial system, in connection with its role as lender of last resort. The policy implementation framework has evolved since the mid-1990s, from reliance on quantity-based instruments to a mixture of quantity- and price-based instruments. Although the PBC seems not to have an official definition of its policy framework, it can be described as follows:

- (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 frequency of policy adjustment, the reserve requirement ratio seems to be the key instrument. Adjustments in the benchmark deposit and lending rates of banks are less frequent but are perceived to be more important than RRR adjustments for signaling the strength of a policy change. Open market operations,

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

including issuance of new central bank bills and notes, and the related repos and reverse-repos, 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 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 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 the 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 have been liberalized since 1996 as well as interest rates on foreign-currency-denominated instruments. In retail lending and deposit markets, the deposit-rate floor and the lending-rate ceiling were eliminated in October 2004, except in respect of credit cooperatives[3].

On the other hand, there is still a deposit-rate ceiling and a lending-rate floor for retail banking operations, albeit these may not 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 consider whether the ceiling and floor are 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 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 wide to maintain the aggregate profitability of the banking system.

Whether the lending-rate floor is binding is a more controversial issue. The data on actual lending rates since 2004 (when the ceiling was eliminated) indicate that the percentage of loans made at the floor rate fluctuated between 16% and 32% (the floor is 90% of the benchmark lending rate), which suggests that most loans were made at above-floor rates (Column 2, Table 1). In other words, the lending-rate floor has not been acutely 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 is in practice subject to a PBC target for aggregate credit. Lardy (2008) argues that the price of capital in China

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

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 aspect of the Chinese banking sector: competition among banks. Because of the low deposit rate ceiling, competitive considerations induce banks to push out loans as long as the marginal cost of loans (deposit rate plus administrative 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 an excess of credit in the economy. To fix this distortion (excess loan demand), two additional regulations (distortions) are added to the loan market. The first is the lending-rate floor, which limits competition among banks and guarantees the profitability (stability) of the whole banking sector. The second is a quantitative target for 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 enables researchers to study the transmission of monetary policy in China from an entirely new perspective.

2.3 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 Graph 1). The interbank market was originally designed as a wholesale market solely 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; the volume of trade in the domestic money and bond market totaled 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 total interbank market trading, while non-collateralized lending and bond trading accounted for 14% and 34%, respectively (PBC, 2010)[5].

[4] Some useful information on the repo market and non-collateralized lending can be found in Porter and Xu (2009) and Fan and Zhang (2007).
[5] Thus "interbank bond market" is now a misnomer in the sense that it is no longer bank-only market.

Table 1: Distribution of bank lending rates,%

	Share of loans priced at 10% below benchmark (the floor)	Share of loans priced at benchmark	Share of loans priced at 10% above benchmark	Share of loans priced at 10%-30% above benchmark	Share of loans priced at 30%-50% above benchmark	Share of loans priced at 50%-100% above benchmark	Share of loans priced at 100% above 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, figures in col. 4 included loans priced at 10% above benchmark. The quarterly data after 2008 are derived from monthly data using monthly loans as weights.
Source: CEIC and authors' calculations.

Interest rates (yields) in the interbank money and bond market are determined by market forces and thus serve as good indicators of the credit costs in the economy. However, because funds flow freely between the banking system and the money and bond market, the 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 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 to the above models, we introduce fund flows between the regulated banking market and the non-regulated money and bond market and illustrate the manner in which monetary policy shocks pass from one track to the other.

We assume N independent banks in the banking system and that N is sufficiently large so that no individual bank has market power in the market. Each bank takes 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 held at the central bank, according to the PBC's RRR (α), and typically some excess reserves (E_i) at the central bank. Aside from loans and reserves, each bank can buy central bank bills (B_i), on which the interest rate 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 the market is competitive, each bank is a price taker. Therefore, a bank's profit maximization function can be written as

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

where r_l is the lending rate, 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 bank's administrative cost, 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 profit maximization function for bank i can be written as

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

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

For 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 administrative cost of loans. Thus, to maximize bank profits, the marginal benefit from making loans, r_l, must equal the marginal cost: the sum of the (opportunity) cost of not investing in the non-regulated market r_{nr} and marginal administrative cost $C_L^{'}(D_i, L_i, E_i)$.

For 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 must equal the marginal cost of holding deposits: the sum of the interest rate paid to depositors, r_d, and the administrative cost of holding deposits.

For E_i and B_i,

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

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

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

Because we need 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:

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

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

Loan supply function:

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

Deposit demand function:

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

Excess-reserve supply function:

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

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

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

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 is

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

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.

We now 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 see that NR_i is the net amount of funds that a bank invests or borrows from the outside, taking various forms such as treasury bonds, corporate bonds and commercial bills and notes. On the other hand, in the money and bond market, funds do not originate solely in the banking system; governments and firms also invest or borrow in the market. Therefore, to clear the non-regulated market, the following is required:

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

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 from 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 can proceed to find the competitive equilibrium in the banking sector and non-regulated market.

Loan market:

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

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

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

Deposit market:

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

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

Non-regulated market:

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

Using the expression for NR_i in equation (2), equation (19) can be written as

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

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 regulate 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 is similar to that of 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 inclined a bank is to pay depositors to attract deposits. Similarly, the equilibrium lending rate also increases with the market rate. This is because the higher the fundraising costs to the bank 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, $r_d^b < r_d^*$, which 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 determined by market forces and is a market equilibrium rate, which implies that changing the lending-rate floor is of no consequence for 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 or the market rate in the wholesale capital market. Still, the lending rate that clears the loan market is the equilibrium rate r_l^*, which increases with the market rate in the wholesale capital market r_{nr}. The key difference is on the deposit side. Because the deposit-rate ceiling is binding, the rate in the deposit market is the ceiling rate rather than the equilibrium rate r_d^*.

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

When funds flow into the banking system as bank deposits, a part of the deposits must be held at the central bank to meet reserve requirements and 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, additional 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 an interest rate level in the wholesale market that is higher than that prior to the rise in the deposit-rate ceiling, so that 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 rate is determined by the deposit supply, and lending is determined by firms' loan demand.

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, a 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 matters most. This model suggests that in this scenario what really matters for the market rates is a change in the deposit-rate ceiling.

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, from which there are two possible results for the lending rate. One possibility is that the supply curve becomes S2 (from S1 to S2 in Figure 1), and the new equilibrium rate (E2 in Figure 1) is higher than the floor. In this case, the lending-rate floor no longer matters, and only the credit target matters.

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

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

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

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 1) and is determined by loan demand as follows:

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

Result 2.3*: With a kinked supply curve due to the imposition of a credit quota, if 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 raises the RRR and issues more bills. The impact of the credit quota on the market rate is ambiguous.*

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 clear that the floor does not matter for 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 reducing the credit quota not only induces a higher lending rate in the loan market but also increases the supply of funds 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

[6] Actually, the PBC does not have formal bank-specific credit quotas but instead has an overall credit target for the whole banking system. However, to meet the aggregate target, the PBC engages in window guidance to individual banks as necessary.

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 affects r_{nr}.

Figure 1

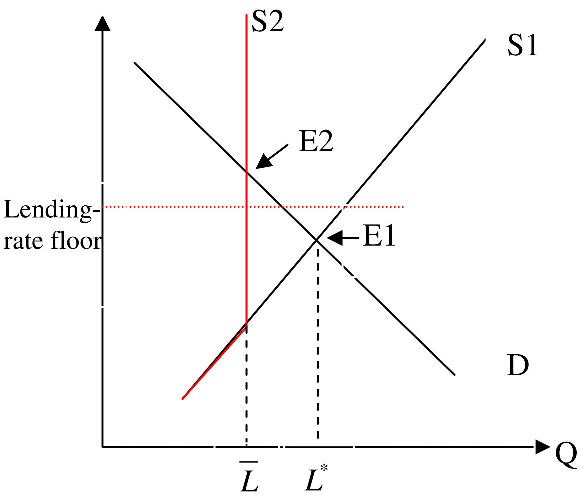
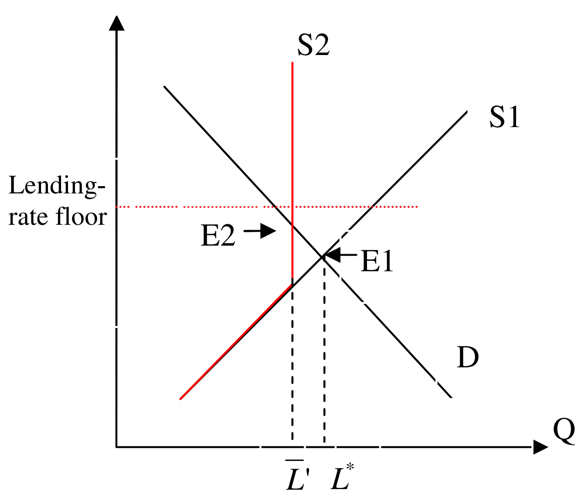


Figure 2



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 changes much less (from S1 to S2 in Figure 2), compared to Case 2.3. The equilibrium rate (E2 in Figure 2) 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 above the floor; therefore, what matters is still the lending-rate floor, and the credit quote has no impact on the market rate. Because the situation in Figure 2 is the same as that discussed in Case 2.2, we do not repeat it here.

A simple calibration

The model scenarios discussed above are summarized in Table 2.

The results in Table 2 are indicative of the impacts of different instruments on the market rate. To understand the relative sizes of the impacts, one needs to calibrate the model based on certain assumptions about of function forms. Because Case 2.3 is the most likely case in reality, we focus on this case for calibration.

Table 2: Impact of policy shocks on market rates

Policy Shocks		Deposit-rate ceiling 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 not binding (no credit quota)	lending-rate floor binding (no credit quota)	lending-rate floor not binding under credit quota (Figure 1)	lending-rate floor binding under credit quota (Figure 2)

	Market rates reaction to policy shocks				
Deposit-rate ceiling	N.A.	+	+	+	+
Lending-rate floor	N.A.	No impact	Indeterminate	No impact	Indeterminate
RRR	+	+	+	+	+
Issuance of central bank bills	+	+	+	+	+
Credit quota	N.A.	N.A.	N.A.	Indeterminate	No impact

As we have proved for Case 2.3, the partial impacts of the deposit-rate ceiling, RRR and issuance of CBB on the market rate are as follows:

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

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

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

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 need only compare the three numerators. Moreover, because we estimate the elasticities of market rate with respect to various policy instruments in the empirical analysis, we calculate the ratio of elasticities here to compare the relative potencies of policy instruments. To do so, we need only assume function forms for deposit supply in the banking sector and the supply of funds from the non-banking sector to the non-regulated market.

We calibrate the ratio of the elasticities of the three instruments under the assumptions of Feyzioglu et al. (2009). The deposit supply function can be written as

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

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 to the non-regulated market can be written as

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

The calibration results (details in Appendix E) show that the price elasticity of market rate with respect to deposit rate is approximately twice that with respect to the RRR 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 of CBB issuance on market interest rates is small compared to that of the benchmark deposit rate and the RRR. This is because the average size of an issue of CBB is quite small compared to the amount 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 issuance of CBB (see Equation E.9 in Appendix E).

4. EMPIRICAL ANALYSIS

To test the results predicted by the theoretical model and calibration, we construct and estimate two empirical models using daily data from the 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 Ordinary Least Square (OLS) method and a Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model estimated by Maximum Likelihood Estimation (MLE).

The linear model

The theoretical model predicts that market rates in the wholesale capital market increase when the PBC increases the benchmark deposit rate or the RRR or issues more 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. 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

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

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 $NEWS_t$

[7] The changes in RRR are measured when the changes become effective in this study. We also attempted to measure 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.

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), and growth of exports, imports and retail sales.

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 are included for the end of the month and 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-differences (percentage change). All variables in the log-difference form passed the 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 impacts 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 give us a reliable unbiased linear estimator[10]. More importantly, OLS results can be used as a benchmark for constructing the GARCH model.

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) in assuming innovations in a GARCH model with a generalized-error distribution. A standard GARCH model can be written as

$$\Delta Y_t = \mu_t + \varepsilon_t \qquad (29)$$

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 $\varepsilon_t \mid F_{t-1} \sim D(0, h_t)$, where D stands for the distribution (a generalized-error distribution in this model). The conditional mean $\mu_t(\Delta Y_t)$ is a

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

9 Putting both rates in the same equation simultaneously would cause a severe multicollinearity problem, and the estimation result would be very misleading.

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

function of other 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

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

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.

Data

As discussed above, 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 out 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 most liquid money market 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 so that the interest-rate regime corresponds to that described in the theoretical model: a deposit-rate ceiling and a lending-rate floor.

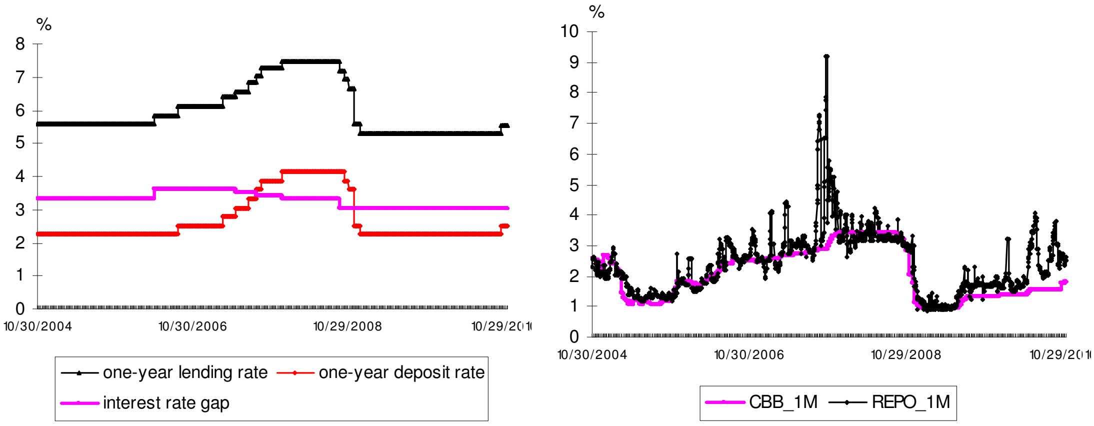
Monetary policy instruments

As discussed above, 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 (Chart 1, left). Open market operations are supposed to affect market rates in two ways: to increase or decrease liquidity from the market and to send a price signal by setting the issuing rates for 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 issuance or redemption of CBBs to adjust market liquidity sufficiently to bring the two rates into line (Chart 1, right).

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

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

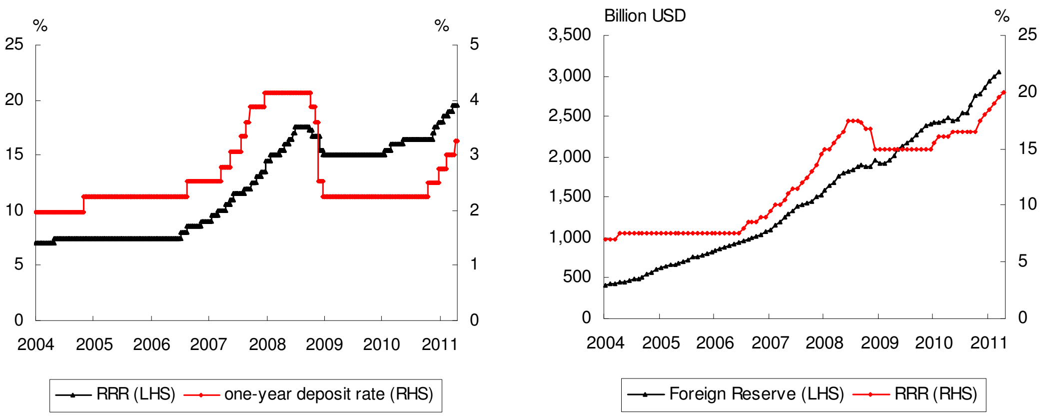
Chart 1: Monetary policy instruments



Data source: CEIC

The RRR can be considered to be the 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 (Chart 2, 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 (Chart 2, 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.

Chart 2: Reserve requirement ratio

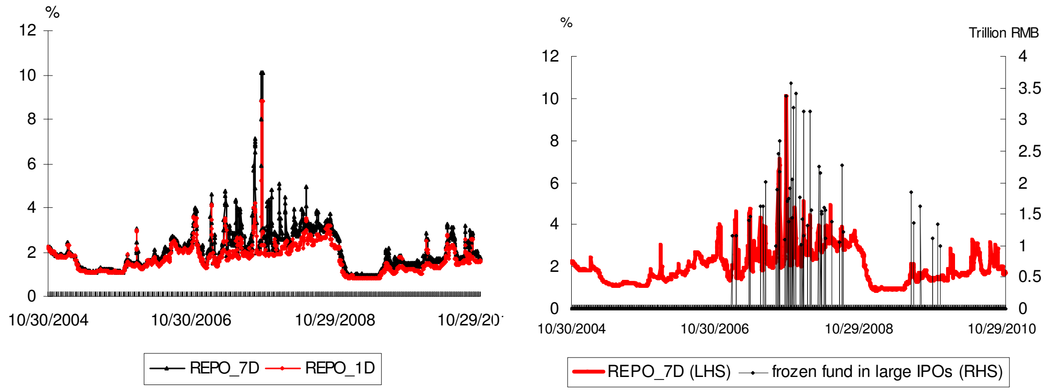


Data source: CEIC

Money markets

For the money markets, we chose the overnight, seven-day and one-month repo rates. As those in other money markets in the world, the repo rates exhibit high volatility as well as volatility clustering (Porter and Xu, 2009). Not surprisingly, we find that the overnight repo rate moves together with the seven-day repo rate (Chart 3, left). More interestingly, the seven-day repo rate seems more volatile than the overnight repo rate, which might be due to the high funding demand for IPOs in the stock market (Chart 3, right)[13].

Chart 3: Money markets and IPOs

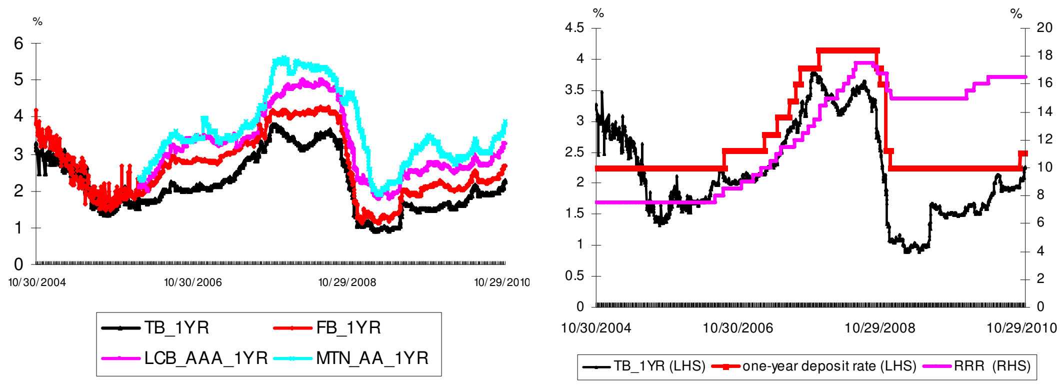


Data source: CEIC

Bond markets

For the bond markets, we chose one-year, two-year, five-year and ten-year bonds to examine how policy shocks are transmitted along the yield curve. Not surprisingly, the different bond yields generally move together, and the gaps between them indicate the risk premia for different bonds (Chart 4, left). The volatility in the treasury bonds and financial bonds declined significantly after 2006, which suggests a 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 (Chart 4, right).

Chart 4: Bond markets



Data source: CEIC

5. EMPIRICAL RESULTS

The linear and GARCH models are estimated by OLS and MLE, respectively. For the linear models estimated by OLS, the results might not be the

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[13] To make it easier to read, only large IPOs that froze funds of more than RMB 1 trillion are shown in Chart 3.

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 the theory and the empirical results suggests that the transmission mechanism illustrated in the theoretical models is a sensible way to view 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 in 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 impact of 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 amount 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 the linear models (Tables 7 and 8). Market rates increase with the RRR in more cases in the GARCH models, which might be due to the efficiency improvement from MLE. Similar to the linear models, CBB issuing rates impact the market rate in half of the cases, which suggests that markets care more about policy signals via the CBB issuing rate than the direct impact from a liquidity change caused by CBB issuance.

Fourth, comparing the results for the money and bond markets, the impacts of changes in the deposit rate and RRR on money market rates are larger than those on bond market rates in both the 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 the CBB issuing rate might not be an effective policy instrument for the PBC.

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

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

Table 3: Elasticity of money and bond market rates with respect to 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

Finally, Table 3 provides some useful information about the potency of various policy instruments. As regards money markets, both the benchmark deposit rate and the RRR have economically significant impacts 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. As regards 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 marginal roles in bond markets, while the quantity of CBB issues itself is too weak to affect the market rates.

Two caveats

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

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 this is indeed the case. Although previous discussions by 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

$$r = q(1/\sigma) + n + \theta \qquad (32)$$

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 express the equilibrium interest rate as

$$r = f(g, \theta) \qquad (33)$$

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

$$r = f(g, \theta, \tau) \qquad (34)$$

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 for 91 economies from 1973 to 2005[16]. Therefore, an empirical model can be written as

$$r_i = a_0 + a_1 g_i + a_2 \theta_i + a_3 \tau_i + \pi_i + u_i \qquad (35)$$

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 (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.

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.

[16] Index value of one means no financial repression, zero means maximum financial repression. Therefore, one minus the index can be considered a good measure of financial repression.

[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.

The regression results are consistent with the theory: the real interest rate is positively related to real GDP growth and negatively related to 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 (Table 4).

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.

Credit quota?

The theoretical model shows that a credit quota may change the loan supply curve and raise 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, for the following reasons: first, a credit quota is usually set by the PBC at the start of the year and is not adjusted during 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 see that the credit quota mainly affects the lending rate, for example, by changing the loan supply curve (Figure 1), 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.

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 aid in understanding 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 shed light on 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 considering 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 the deposit and lending market; liberalize foreign currency rates first, then domestic currency rates; liberalize the 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 largely determined by market forces, but the strategy for 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, its elimination is not expected to be destabilizing. However, does this mean that lifting the deposit-rate ceiling will become easier after the lending-rate floor is removed? The results from this study should shed some light on this issue.

Under the dual-track interest-rate system, the role of the deposit-rate ceiling is like that of an anchor that keeps interest rates generally 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 will probably continue to keep the lending rate above the floor, as we illustrated in Figure 1. However, that step would not make the next step of liberalizing the deposit rate any easier because credit-target operations would be under even greater pressure.

Thus, instead of removing the lending-rate floor first, a better strategy is for the PBC is 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 should 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 attain higher levels in the banking sector, market rates in the wholesale capital markets will also increase, as the model shows. 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 beyond the scope of this paper.

REFERENCE

1. Abiad, Abdul, Detragiache, Enrica and Tressel, Thierry, “A New Database of Financial Reforms”, IMF Working Paper (2008) WP/08/266.

2. Chen, Hongyi, Chen, Qianying and Gelach, Stefan, “The Implementation of Monetary Policy in China”, Working Paper in the Second Annual International Conference on the Chinese Economy (2011), Hong Kong Institute of Monetary Research.

3. Dickinson, David and Liu, Jia, “The Real Effects of Monetary Policy in China: An Empirical Analysis”, China Economic Review (2007), 18, 87-111

4. Feyzioglu, Tarhan, Porter, Nathan and Takats, Elod, “Interest Rate Liberalization in China”, IMF Working Paper (2009), 09/171, Washington DC.

5. Geiger, Michael, “Monetary Policy in China (1994-2004): Targets, Instruments and Their Effectiveness”, Wurzburg Economic Papers (2006), No. 66.

6. He, Dong and Pauwels, Laurent, “What prompts the People's Bank of China to Change Its Monetary Policy Stance? Evidence from a Discrete Choice Model”, HKMA Working Papers 0806 (2008), Hong Kong Monetary Authority.

7. Fan, Longzhen and Zhang, Chu, “Beyond Segmentation: the Case of China’s Repo Markets”, Journal of Banking and Finance (2007), 31 (2007) 939-954.

8. Freixas, Xavier and Rochet, Jean-Charles, “Microeconomics of Banking”, Cambridge, Massachusetts, MIT Press (2008).

9. Gao, Jian, “Debt Capital Market in China” (Chinese version), Economic Science Press (2009).

10. Garcia-Herrero, Alicia and Girardin, Eric, “China’s Monetary Policy Communication: Money Markets Not Only Listen, They Also Understand”, Working Paper in the Second Annual International Conference on the Chinese Economy (2011).

11. Goodfriend, Marvin and Prasad , Eswar, “A Framework for Independent Monetary Policy in China”, IMF Working Papers (2006), 06/111, International Monetary Fund.

12. Lardy, Nicholas, “Financial Repression in China,” Peterson Institute for International Economics Policy Brief (2008) No. 08-8.

13. Laubach, Thomas and Williams, John, “Measuring the Equilibrium Interest Rate”, Finance and Economics Discussion Series (2001), 2001-56, Board of Governors of the Federal Reserve System (U.S.).

14. Maino, Rodolfo and Laurens, Bernard, "China: Strengthening Monetary Policy Implementation." IMF Working Paper (2007), No. 07/14.

15. Nagai, Shigeto and Wang, Hong, "Monetary Market Operations in China: Monetary Policy or FX Policy?", Bank of Japan Working Paper Series (2007) No.07-E-13.

16. PBC, "Chinese Financial Market Annual Report 2009", (Chinese). The People's Bank of China, (2010).

17. PBC, "Chinese Monetary Policy Report", (Chinese). The People's Bank of China, (2009), 2009Q2.

18. PBC, "Report on Steady Progress in Market-Based Interest Rate Reform", Supplement to the China Monetary Policy Report (2005).

19. Porter, Nathan and Xu, TengTeng, "What Drives China's Interbank Market?", IMF Working Papers (2009), WP/09/189. .

20. Qian, Yingyi, "The Institutional Foundations of China's Market Transition", in Boris Pleskovic and Joseph Stiglitz, eds., Proceedings of the World Bank's Annual Conference on Development Economics (1999). (http:/wwwecon.stanford.edu/faculty/workp/swp99011.html).

21. Qin, Duo, Quising, Pilipinas, He, Xinhua and Liu Shiguo, "Modeling Monetary Transmission and Policy in China", Journal of Policy Modelling 27(2005) 157-175.

22. Shu, Chang and Brian Ng, "Monetary Stance and Policy Objectives in China: a Narrative Approach", HKMA China Economic Issues (2010), Hong Kong Monetary Authority.

23. Wu, Xiaoling, "PBC Still Has Room to Raise Reserve Requirement Ratio This Year", Speech on the NPC press conference on March 8, 2011. http://zt.stcn.com/content/2011-03/08/content_2267482.htm

24. Zhou, Xiaochuan, "Development of China's Inter-bank Market", Speech at the opening ceremony of the Shanghai Clearing House, Shanghai, 28 November, 2009. www.bis.org/review/r100122b.pdf.

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)
Observations	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 7-day Repo rate, and Repo_1m denotes 1-month Repo rate. TB_1yr, TB_2yr, TB-5yr and TB_10yr denote 1-year, 2-year, 5-year and 10-year treasury-bond yields, respectively. Standard errors of estimated coefficients are in 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** (0.113)	0.247*** (0.086)	0.174*** (0.045)	0.162*** (0.026)	0.150*** (0.022)	0.132*** (0.019)	0.117*** (0.022)
RRR	0.111 (0.231)	0.150 (0.175)	0.030 (0.092)	0.109** (0.053)	0.071 (0.044)	-0.031 (0.040)	-0.027 (0.044)
Benchmark CBB issuing rate	0.069 (0.063)	0.054 (0.047)	0.026 (0.025)	0.066*** (0.019)	0.051*** (0.016)	0.012 (0.014)	0.027 (0.015)
PPI_gap	-0.015 (0.034)	-0.006 (0.026)	0.007 (0.013)	0.003 (0.008)	0.011 (0.007)	0.016** (0.006)	0.010 (0.007)
CPI_gap	0.037 (0.027)	0.024 (0.020)	0.019* (0.011)	0.003 (0.007)	-0.004 (0.006)	-0.002 (0.005)	-0.011 (0.006)
Retail_gap	0.008 (0.116)	0.014 (0.088)	-0.010 (0.046)	-0.025 (0.028)	0.006 (0.024)	-0.003 (0.021)	-0.006 (0.024)
M2_gap	0.184 (0.140)	0.112 (0.107)	0.094 (0.056)	0.045 (0.034)	-0.006 (0.029)	-0.014 (0.026)	-0.011 (0.029)
Export_gap	-0.002 (0.018)	0.005 (0.013)	-0.001 (0.007)	-0.005 (0.004)	0.004 (0.004)	0.001 (0.003)	-0.007* (0.003)
Import_gap	-0.003 (0.017)	-0.002 (0.013)	0.003 (0.006)	0.001 (0.004)	-0.001 (0.003)	0.001 (0.003)	0.001 (0.002)
GDP_gap	-0.369 (0.269)	-0.160 (0.204)	0.094 (0.108)	0.010 (0.071)	0.096 (0.059)	0.076 (0.053)	0.056 (0.059)
Month end dummy	0.002 (0.003)	0.001 (0.002)	-0.001 (0.004)	-0.001 (0.001)	-0.001 (0.001)	0.001 (0.001)	-0.001 (0.001)
Lunar year dummy	0.001 (0.010)	-0.003 (0.008)	0.001 (0.004)	-0.004 (0.003)	-0.007 (0.004)	-0.003 (0.002)	-0.003 (0.002)
IPO	0.002 (0.003)	-0.003 (0.002)	0.002 (0.020)	0.007 (0.008)	0.006 (0.006)	0.006 (0.006)	0.005 (0.006)
IPO(1)	0.003 (0.003)	0.001 (0.003)	0.009 (0.013)	0.002* (0.001)	0.012* (0.006)	0.010** (0.005)	0.019** (0.007)
Net CBB issuing	-0.039 (0.035)	-0.003 (0.003)	-0.025 (0.016)	-0.016* (0.008)	-0.007 (0.007)	-0.008 (0.006)	-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 1-year, 2-year and 5-year financial-bond yields, respectively. Similarly, LCB_1yr, LCB_2yr and LCB_5yr denote 1-year, 2-year and 5-year long-term corporate-bond yields, respectively. MTN_1yr denotes 1-year medium-term note yields (longer-maturity MTN yields are not available now). Standard errors of estimated coefficients are in 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	0.431***	0.553***	0.759***	0.290	0.309***	0.165***	0.178***
Deposit rate	(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	0.022***	0.038***	0.036	0.117	0.116*	0.084***	0.055***
CBB issuing rate	(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	-0.003	-0.001	0.001	-0.001	-0.001	-0.001	-0.001
dummy	(0.004)	(0.007)	(0.003)	(0.004)	(0.003)	(0.002)	(0.001)
Lunar year	0.001	0.043***	0.019	0.002	-0.001	0.001	-0.001
dummy	(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	0.004	-0.029***	-0.005	-0.009	-0.009	0.005	-0.001
issuing	(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	0.009***	0.001	0.008***	-0.008	-0.005	-0.003	-0.007
dummy	(0.003)	(0.001)	(0.002)	(0.009)	(0.006)	(0.002)	(0.016)
Lunar year	0.008***	0.005**	0.007***	-0.014	-0.007	-0.003	0.001
dummy	(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 7-day Repo rate, and Repo_1m denotes 1-month Repo rate. TB_1yr, TB_2yr, TB-5yr and TB_10yr denote 1-year, 2-year, 5-year and 10-year treasury-bond yields, respectively. Standard errors of estimated coefficients are in 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 rate	0.243	0.247	0.174	0.162***	0.150***	0.132***	0.120***
	(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 issuing rate	0.069	0.054	0.026	0.066**	0.051***	0.012	0.018**
	(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 1-year, 2-year and 5-year financial-bond yields, respectively. LCB_1yr, LCB_2yr and LCB_5yr denote 1-year, 2-year and 5-year long-term corporate-bond yields, respectively. MTN_1yr denotes 1-year medium-term note yields (longer-maturity MTN yields are not available). Standard errors are in brackets. ***, **, and * denote significance at 1%, 5% and 10%, respectively.

Appendix A: Proof of Result 1

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

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

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

That the equilibrium lending rate r_l^* is a positive function of the market rate r_{nr}, is proved as follows:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

It is clear 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, $\frac{\partial[L^d(r_l)]}{\partial r_{nr}} = \frac{\partial L^d}{\partial r_l}\frac{\partial r_l}{\partial r_{nr}} < 0$ 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 supply of funds increases with market rate r_{nr}. 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 could cause some leakage of the funds into banking deposits. However, it is reasonable 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 results,

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

+ -(-) + + -(-)

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

$$\frac{\partial r_{nr}}{\partial \alpha} = -\frac{\partial F / \partial \alpha}{\partial F / \partial r_{nr}} \Rightarrow \frac{\partial r_{nr}}{\partial \alpha}\frac{\partial F}{\partial r_{nr}} = -\frac{\partial F}{\partial \alpha} \quad \text{(A.14)}$$

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

Combining the above two equations and rearranging terms yields

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

Because $(r_r - r_{nr})$<0 , which means interest rate on required reserves 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,

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

It is clear that $(\frac{\partial F}{\partial r_{nr}} + \frac{N}{\delta_E} + \frac{\partial S}{\partial r_{nr}} - \frac{\partial T}{\partial r_{nr}})$ >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 yields

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

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

Appendix B: Proof of 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

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

Note that here the deposit function is determined solely by the supply of savings, and therefore, D^s is a function solely 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 is determined by the central bank.

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

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

We cover the different parts 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 noted 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, $\partial r_{nr}/\partial r_l^b=0$.

$$\frac{\partial r_{nr}}{\partial r_d^b}=-\frac{\partial F/\partial r_d^b}{\partial F/\partial r_{nr}} \quad \text{(B.5)}$$

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

Combining the above two equations, we can obtain

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

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 need only examine the right-hand side of the above equation. When the ceiling is raised by the central bank, the higher ceiling will attract funds from other markets, such as the wholesale capital market, into bank savings. Therefore, $\partial D^s/\partial r_d^b$>0 because the deposit supply increases in response to the higher deposit-rate ceiling[19]. On the other hand, in the wholesale capital market,

[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.

$\partial S / \partial r_d^b < 0$ because of an outflow of funds, 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 as bank deposits, some of the deposits have to be held as reserves at the PBC due to 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 as a result of 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,

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

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

$$\frac{\partial r_{nr}}{\partial \alpha} = -\frac{\partial F / \partial \alpha}{\partial F / \partial r_{nr}} \qquad \text{(B.9)}$$

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

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

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

Thus $\partial r_{nr} / \partial \alpha > 0$.
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

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

Note here that the deposit function is determined solely by the supply of savings, and therefore, D^s is a function solely of r_d^b. Similarly, lending is determined solely 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

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

Now we turn to the different parts of the above equation:

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

$\partial r_d^b / \partial r_{nr}$=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

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

Here is the new part:

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

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,

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

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

Next we consider $\frac{\partial r_{nr}}{\partial r_d^b}$ and $\frac{\partial r_{nr}}{\partial r_l^b}$.

$$\frac{\partial r_{nr}}{\partial r_d^b} = -\frac{\partial F / \partial r_d^b}{\partial F / \partial r_{nr}} \qquad \text{(C.7)}$$

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

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

$$\frac{\partial r_{nr}}{\partial r_l^b} = -\frac{\partial F / \partial r_l^b}{\partial F / \partial r_{nr}} \qquad \text{(C.9)}$$

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

Combining the above two equations we obtain

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

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 rises 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 proved in Appendix B, $\frac{\partial r_{nr}}{\partial \alpha} > 0$.

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

Q.E.D.

Appendix D: Proof of 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

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

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

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

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

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

Note that here 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

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

As we noted in Appendix C,

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

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 proved above.

The new term is

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

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 yields $\frac{\partial F}{\partial r_{nr}} > 0$.

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 for the market rate when there is a credit quota, as long as r_l is above the floor.

Now we examine how a credit quota affects the market rate.

$$\frac{\partial r_{nr}}{\partial \overline{L}} = -\frac{\partial F / \partial \overline{L}}{\partial F / \partial r_{nr}} \qquad \text{(D.7)}$$

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

Combining the above two equations,

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

$\frac{\partial T}{\partial r_l}\frac{\partial r_l}{\partial \overline{L}}$<0 because $\frac{\partial T}{\partial r_l}$>0 and $\frac{\partial r_l}{\partial \overline{L}}$<0 (see Figure 1), and therefore, the sign of $\frac{\partial F}{\partial \overline{L}}$ can 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, $\frac{\partial r_{nr}}{\partial \alpha} = -\frac{\partial F / \partial \alpha}{\partial F / \partial r_{nr}} > 0$.

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 1 of Case 2.3, which is the most realistic scenario, as noted 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:

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

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

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

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 need only compare the three numerators. To do so, we must 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

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

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

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

Now we compare the relative sizes of impact of 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:

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

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

where e_{r_{nr}, r_d^b} is the price elasticity between r_{nr} and r_d^b, used to measure the ratio of percent change in r_d^b to 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 (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 as follows:

Table 9: 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

Graph 1: Structure of Chinese Interbank Market