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Abstract

Interest rates in China are composed of a mix of both market-determined interest rates (interbank rates and bond yields), and regulated interest rates (retail lending and deposit rates), reflecting China's gradual process of interest rate liberalization. This paper investigates the main drivers of China's interbank rates by developing a stylized theoretical model of China's interbank market and estimating an EGARCH model for 7-day interbank repo rates. Our empirical findings suggest that movements in administered interest rates (part of the People's Bank of China's monetary policy toolkit) are important determinants of market-determined interbank rates, in both levels and volatility. The announcement effects of reserve requirement changes also influence interbank rates, as well as liquidity injections from open market operations in recent years. Our results indicate that the regulation of key retail interest rates influences the behaviour of market-determined interbank rates, which may have limited their independence as price signals. Further deposit rate liberalization should allow short-term interbank rates to play a more effective role as the primary indirect monetary policy tool.

JEL classification: E43, E52, E58, C22
Bank classification: Financial markets; Monetary policy framework; Transmission of monetary policy; Development economics; Econometric and statistical methods

Résumé

En Chine, certains taux d'intérêt (les taux interbancaires et les rendements obligataires) sont établis par le marché, alors que d'autres (les taux des prêts aux ménages et aux entreprises et les taux de rémunération des dépôts) sont administrés. Cet état de choses traduit le processus graduel de libéralisation des taux en cours dans ce pays. Pour analyser les grands déterminants des taux interbancaires, les auteurs élaborent un modèle théorique stylisé du marché interbancaire chinois et estiment un modèle EGARCH pour les taux des pensions interbancaires à sept jours. Leurs résultats empiriques indiquent que les mouvements des taux administrés (l'un des moyens d'intervention de la Banque populaire de Chine) sont des déterminants clés du niveau et de la volatilité des taux du marché interbancaire. Les effets d'annonce des changements des exigences en matière de réserves se répercutent également sur les taux interbancaires, tout comme les injections de liquidité effectuées par le biais d'opérations d'open market ces dernières années. Les résultats montrent aussi que l'administration des principaux taux d'intérêt offerts aux ménages et aux entreprises influe sur le comportement des taux pratiqués sur le marché interbancaire, ce qui a pu limiter la capacité de ceux-ci à donner des signaux tarifaires indépendants. Une libéralisation plus poussée des taux de rémunération des dépôts devrait permettre aux taux interbancaires à court terme de jouer un rôle plus efficace en tant que premier outil d'intervention indirecte des autorités monétaires.

Classification JEL : E43, E52, E58, C22
Classification de la Banque : Marchés financiers; Cadre de la politique monétaire; Transmission de la politique monétaire; Économie du développement; Méthodes économétriques et statistiques

1 Introduction

Short-term interbank interest rates play an important role in the economy. They indicate the state of macroeconomic and liquidity conditions, and provide an important anchor for the pricing of financial assets. In many economies, but not yet in China, they are also central to the implementation of monetary policy. Consequently, large benefits are likely to follow—through the allocation of capital and risk in the economy—from ensuring that short-term funding rates provide independent market-based price signals. Recognizing this, China has been gradually liberalizing interest rates for more than a decade. However, while interbank interest rates and bond yields are now market-determined, other key interest rates continue to remain regulated. In particular, there is an administrative cap on retail deposit rates and a floor on retail lending rates.

In this paper, we ask whether short-term interbank rates can effectively reflect liquidity conditions and provide a basis for asset pricing in China. Our answer is that further reform is needed before they can fully play these roles. Although interbank rates are market-determined, these rates are not independent of the regulation of other key interest rates. Regulating the deposit rate influences the supply of funds into the financial system and, consequently, affects liquidity and the interbank rate. Similarly, regulating the lending rate affects the volume of loans demanded and so should also alter the interbank rate.

We build on the microeconomic model of the banking sector in Freixas and Rochet (2008) and develop a stylized theoretical model of China's banking sector that pins down the analytical relationship between regulated and market-determined interest rates. The model, although stylized, captures the key features of the interbank market and monetary policy in China, including the role of "informal" bank-level credit restrictions and administered interest rates in monetary policy, the regulated nature of retail interest rates, institutional demand in the interbank market, as well as a desire to hold excess reserves. To our knowledge, our paper presents one of the first theoretical models of the interbank market in China, where market-determined and regulated interest rates co-exist. Our theoretical model predicts that regulated rates influence interbank rates, and asset valuations made using interbank rates largely reflect the position of the administered rates, which are adjusted by the People's Bank of China (PBC) on an irregular basis as monetary policy tools. Similarly, interbank rates would less effectively indicate fluctuations in retail credit market conditions.

Our empirical strategy is related to several recent studies on the behaviour of interbank interest rates and the impact of monetary policy on the interbank market, see, for example, Hamilton (1996), Bartolini, Bertola, and Prati (2001), Prati, Bartolini, and Bertola (2003) and Bartolini and Prati (2006). Until now, the literature on interbank markets has largely focused on the interbank rates in G7 and euro-area economies, while little has been studied on emerging-market economies such as China. This paper aims to address this gap and provides, to our knowledge, the first comprehensive analysis on the determinants of interbank interest rates in China, taking into account the extent of interest rate liberalization and the institutional arrangements of key interest rate markets. This is particularly relevant for China and other developing countries that have experienced partial liberalization of their financial systems. Deregulating particular portions of the financial system (in this case interbank rates) does not ensure that those key interest rates can act as independent price signals.

As in the empirical studies of mature interbank markets mentioned above, an EGARCH model (Nelson, 1991) of China's 7-day repo rate is estimated using daily data from April 2003 to April 2012, which cover three distinct phases of macroeconomic environments: (i) China's pre-crisis expansion and period of growing surplus liquidity (reflecting rapid reserve accumulation); (ii) the massive post-Lehman credit expansion (2008-10); and (iii) the subsequent monetary tightening beginning in 2010. The results of the estimated empirical model (presented in Section 4) confirm the predictions from the theoretical model that China's interbank rates are not truly independent of administered interest rates. In particular, parameter estimates suggest that the interbank rate increases with administered lending rates and falls with administered deposit rates, even after controlling for systematic variations in liquidity throughout the week, during the month, or due to the timing of the Chinese New Year. Liquidity injections from reserve requirements do not have any significant influence on the level of the interbank rate, while the announcement effect does have a significant impact. Open market operations are found to be significant in driving interbank interest rates in the full sample (but not in a shorter subsample), in both levels and volatility. Finally, changes to administered interest rates also affect interbank rate volatility, as do announced changes to reserve requirements and IPO activities.

Our results indicate that the regulation of key retail interest rates influences the behaviour of market-determined interbank interest rates, and therefore limits their independence as price signals. Further interest rate liberalization should work to strengthen the information conveyed by movements in interbank rates and help to further advance the development of China's financial market. Simultaneously removing the regulatory distortions in the interbank rate and allowing retail deposit and loan markets to clear would help to reconnect wholesale and retail credit conditions. While interest rate volatility may increase after liberalization, as has happened elsewhere (Demirguc-Kunt and Detragiache, 2001), this volatility would be associated with the incorporation of macroeconomic and financial news into the pricing of risk and capital. Ultimately, this should be associated with a better allocation of scarce capital, and contribute to China's rebalancing toward greater reliance on domestic consumption and less reliance on exports and investment (see, for example, Aziz, 2007).

Our paper is structured as follows. Section 2 describes the institutional arrangements of monetary policy and key interest rate markets. Section 3 presents a stylized model of China's interbank market, reflecting the institutional features highlighted in Section 2, including the regulated nature of retail interest rates, the role of window guidance/quantitative credit controls and the desire to hold excess reserves. Section 4 estimates an EGARCH model of China's 7-day repo rate, controlling for key variables implied by the stylized model, and studies the behaviour and drivers of interbank interest rates in China. Section 5 offers some concluding remarks.

2 Monetary Policy and Interest Rates

2.1 Monetary policy

The PBC's monetary policy relies on a variety of both direct and indirect instruments.[1] While the use of indirect instruments such as open market operations has grown rapidly over time, the PBC also frequently uses reserve requirements to influence the volume of funds banks have available to lend. Moreover, "the government continues to rely on (bank-specific) quantitative limits to slow credit growth" and uses official "window guidance" to

[1] Direct instruments set prices or quantities through regulation and are aimed at the balance sheets of commercial banks, while indirect instruments operate by influencing underlying demand and supply conditions and are aimed at the balance sheet of the central bank (Alexander, Enoch, and Balio, 1995).

influence the direction of bank lending (IMF, 2010).[2] The design of reserve requirements in China is likely to increase the volatility of money markets, since they must be strictly met on a daily basis rather than over a *reserve-maintenance* period (reserve averaging), as is common in many other countries.[3] While banks may hold insufficient reserves before closing, they are penalized for not holding sufficient reserves at closing. If reserve requirements were met only over some reserve-maintenance period rather than on a daily basis, then the volatility of short-term interbank rates would likely be lower. This is seen in countries with reserve averaging, where interest rate volatility rises systematically through the reserve-maintenance period, increasing as settlement day approaches (see, for example, Hamilton, 1996; Prati, Bartolini, and Bertola, 2003). The one-year administered (benchmark) lending and deposit rates are adjusted by the PBC on an irregular basis, typically in conjunction with movements in other monetary policy indicators (i.e., administered rates of other maturities), although the slope typically changes only at the short end of the yield curve.[4] The PBC also regulates retail interest rates by setting a ceiling on the deposit rates and a floor on lending rates. Despite this array of instruments, Chinese monetary policy has relied heavily on quantity-based instruments and administrative measures (reserve requirements and window guidance/credit ceilings). Indeed Mehrotra, Koivu, and Nuutilainen (2008) argue that observed Chinese monetary growth is consistent with a McCallum monetary growth rule (see McCallum, 1988, 2003).[5]

[2] "Window guidance" is one form of the quantity-based direct monetary policy instruments used in China, which uses benevolent compulsion to persuade the banking sector and other financial intermediaries to follow official guidelines. The PBC has a major influence on the lending decisions for the four large state-owned commercial banks through the use of "window guidance" (Geiger 2006).

[3] The reserve-maintenance period refers to a time frame when banks are required to hold a certain amount of reserves on their balance sheets. The length of these periods varies from country to country: the U.S. averaging is done over a two-week period, while Japan and the euro area average over a month (see, for example, Prati, Bartolini, and Bertola, 2003).

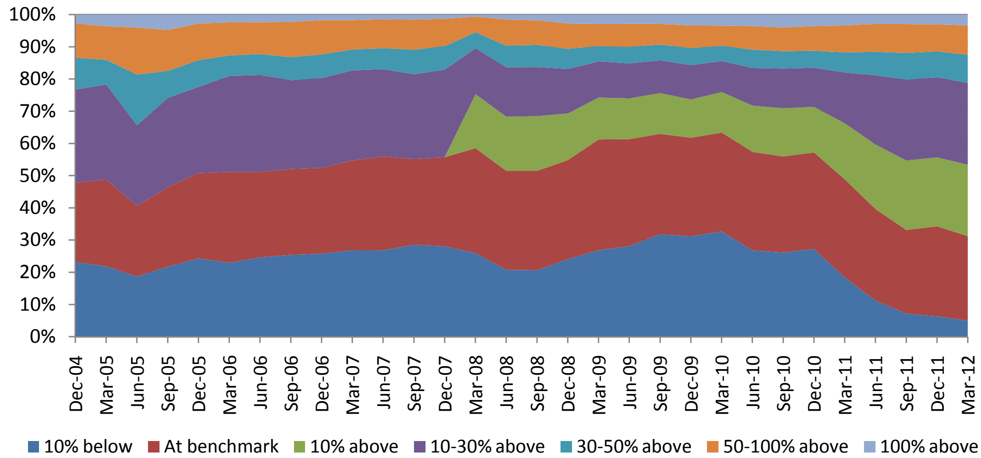
[4] The proportion of adjustment in the administered deposit and lending rates is typically greater at the front end of the yield curve than at the back end. For example, the administered deposit rates were adjusted in February 2011 from 2.25 to 2.60 (3-month), 2.50 to 2.80 (6-month), 2.75 to 3.00 (1-year), 3.55 to 3.90 (2-year), 4.15 to 4.50 (3-year) and 4.55 to 5.00 (5-year).

[5] Under the McCallum monetary growth rule, money growth is equal to target (nominal) GDP growth less the velocity growth of money, and plus half the previous deviation of nominal GDP from its target, see Mehrotra, Koivu, and Nuutilainen (2008) for details.

2.2 Regulated and market-determined interest rates

Interest rates in China reflect a mix of regulated and market-determined outcomes. Wholesale interest rates, including interbank rates and bond yields, are largely market-determined, while there remains a floor on retail lending rates and a ceiling on retail deposit rates, which in effect protect the profit margins of commercial banks, which average around 3 per cent.[6] Retail lending rates can typically be no lower than 70 per cent of the administered lending rate and retail deposit rates could rise to 110 per cent of the administered deposit rate. As can be seen in Figure 1, more than 80 per cent of loans occur at or above the administered lending rate, suggesting that this rate is not effective. The ceiling on deposit rates is generally considered binding, with deposit rates typically clustered at their benchmarks (administered deposit rates). This conclusion was reinforced by the fact that deposit rates jumped to their new ceiling following the June 2012 reform.[7] While generally positive, real deposit rates have, at times, been close to zero or negative for long

Figure 1: Retail Lending Rates Relative to Administered Lending Rates



Sources: People's Bank of China and Haver Analytics (CEIC)

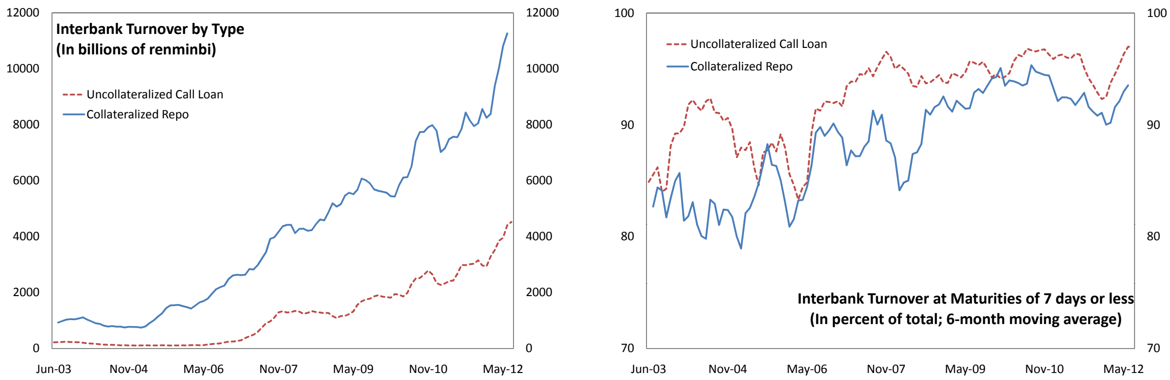
[6]See a longer working paper version of this study "What Drives China's Interbank Market?" (Porter and Xu, 2009) for a detailed history of China's interest rate liberalization.

[7]Given the binding nature of the deposit rate ceiling, six major banks in Beijing have raised their retail deposit rates (10 per cent above the administered rate for demand deposits and 7.69 per cent above the administered rate for one-year time deposits) immediately after the announcement of a higher deposit rate ceiling in June 2012.

periods.[8]

While interbank interest rates and bond yields have been liberalized since the late 1990s, funding costs continue to be subject to a number of other restrictions. For example, there have been various restrictions on the issuance of securities in the interbank and exchange markets (Cassola and Porter, 2011). Among the two types of interbank lending?uncollateralized lines of credit and collateralized repos?the latter is by far the most important, see Figure 2. Repo lending is typically short term (overnight to 7 days, with more than 60 per cent of the transactions at 7 days), although transactions with a maturity of up to one year are possible. Activity in these markets would seem somewhat segmented, with the largest banks in China principally borrowing in the (unsecured) call loan market while being net lenders in the (secured) repo market. Other, smaller, commercial banks exhibit the opposite behaviour (see Porter and Xu, 2009).

Figure 2: The Importance of the Interbank Repo Market



(a) Most interbank credit is extended through collateralized repos,...

(b) ... with activity concentrated at short maturities.

Source: CEIC, People's Bank of China and IMF staff estimates.

[8]For example, the ex post real 1-year deposit rates in our sample period (April 2003 to April 2012) were negative for three episodes: November 2003 to December 2004; February 2007 to October 2008; and February 2010 to January 2012.

3 A Stylized Model of China's Interbank Market

While interbank interest rates have been largely market-determined, we consider whether these rates can act as independent price signals, free from the impact of other retail interest rates in China that have been regulated. We discuss this question with the aid of a stylized model of China's banking sector, which we set out below. Subsequently, we examine some empirical evidence that bears on this issue.

The model, although highly stylized, captures the key features of the market highlighted in the previous section on the institutional set-up of the interbank market in China, including the regulated nature of retail interest rates, the role of window guidance/quantitative credit control and, despite the absence of reserve averaging, a desire to hold excess reserves.[9] Following Freixas and Rochet (2008), we consider a competitive model of risk-neutral commercial banks, where there are N independent price-taking banks, and they optimize over the number of deposits to take and loans to make in each period. The banks take as given the lending rate (r_L), the deposit rate (r_D), the bond yield (r_B), the reserve remuneration rate (r_R) for required reserves, the reserve remuneration rate (r_x) for excess reserves, and the interbank lending rate (r). The retail lending and deposit rates are regulated off the administered interest rates, which are set by the PBC. Banks are also assumed to face administratively set individual lending constraints on the volume of loans (represented by $\bar{L}_n$).[10] Taking into account the need to maintain some operational excess reserves, management costs, and the need to withstand deposit fluctuations, we assume that the typical bank has some liquidity preference β ($\beta > 0$), and faces real costs when their own reserve target $\bar{T}_n$, is not met (see, for example, Bartolini, Bertola, and Prati, 2001). Finally, banks face credit risk on both their retail and wholesale lending portfolios. We assume that these banks have well-diversified loan portfolios, meaning that expected loan losses are the same as actual realized losses.

[9] The stylized model focuses on the *level* of interbank rates, to study the analytical relationship between interbank rates and other interest rates. For the purposes of exposition, we model banks and the interbank market in a deterministic framework to illustrate the potential spillover from regulated interest rates to unregulated market-determined ones.

[10] We abstract from modelling the impact of window guidance on the direction of lending (for example, directed lending to industries with environmentally friendly technology or directed lending away from the real estate sector). Instead, we focus on the impact of window guidance and the quantitative credit ceiling on the total loan target (the volume of loans), to keep the model tractable.

The profit-maximization problem of bank n is given below:

$$\Pi_n = \max_{R_n^e, D_n, L_n, B_n, M_n} \left[\hat{r}_{_L} L_n + \hat{r} M_n + r_{_R} \alpha D_n + r_x R_n^e + r_{_B} B_n - r_{_D} D_n - c(D_n, L_n) - \frac{\beta}{2}(R_n^e - \bar{T}_n)^2 \right],$$
$$\text{s.t } R_n^e \geq 0, L_n \leq \bar{L}_n,$$
$$\text{where } \hat{r}_{_L} \equiv r_{_L}(1-\kappa) + \kappa\delta_L; \ \hat{r} \equiv r(1-\gamma) + \gamma\delta_M. \tag{1}$$

For simplicity, we define $\hat{r}_{_L}$ and $\hat{r}$ as the default-adjusted loan rate and the interbank interest rate, respectively. The probability κ is the default rate of bank loans, and γ is the probability of default in the interbank market. δ_L and δ_M are the recovery rates of loans (one minus the loss-given-default rate) for bank and interbank loans, respectively. We assume that $\kappa > \gamma$ and $\kappa\delta_L < \gamma\delta_M$.[11] M_n is the net position of the bank on the interbank market, D_n is the level of deposits, B_n is the security holdings of the bank (which are assumed to be supplied inelastically by the government). αD_n is the level of required reserves, and R_n^e is the level of excess reserves each bank voluntarily decides to hold. The cost of managing deposits and loans is given by $c(D_n, L_n)$, which we assume to be strictly convex, twice continuously differentiable, and separable in its arguments.

Since each bank's balance sheet requires $M_n = D_n - B_n - L_n - \alpha D_n - R_n^e$, the profit-maximization condition in (1) can be expressed as

$$\Pi_n = \max_{R_n^e, D_n, L_n, B_n} \Big[(\hat{r}_{_L} - \hat{r}) L_n + (r_{_B} - \hat{r}) B_n + (r_{_R} - \hat{r}) \alpha D_n + (r_x - \hat{r}) R_n^e + (\hat{r} - r_{_D}) D_n$$
$$- c(D_n, L_n) - \frac{\beta}{2}(R_n^e - \bar{T}_n)^2 \Big],$$
$$\text{s.t } R_n^e \geq 0, L_n \leq \bar{L}_n. \tag{2}$$

[11] This condition is not necessary for an equilibrium, but it simplifies the existence condition.

First-order conditions with regard to R_n^e, L_n, D_n and B_n are:

$$
\begin{aligned}
\frac{\partial \Pi_n}{\partial R_n^e} &= (r_x - \hat{r}) - \beta(R_n^e - \bar{T}_n) + \lambda = 0, \\
\frac{\partial \Pi_n}{\partial L_n} &= (\hat{r}_{\scriptscriptstyle L} - \hat{r}) - c_{\scriptscriptstyle L}(D_n, L_n) - \xi = 0, \\
\frac{\partial \Pi_n}{\partial D_n} &= \alpha(r_{\scriptscriptstyle R} - \hat{r}) + (\hat{r} - r_{\scriptscriptstyle D}) - c_{\scriptscriptstyle D}(D_n, L_n) = 0, \\
\frac{\partial \Pi_n}{\partial B_n} &= r_{\scriptscriptstyle B} - \hat{r} \leq 0; B_n > 0, (r_B - \hat{r})B_n = 0.
\end{aligned}
$$

The first-order conditions have intuitive interpretations. The first condition determines the overall amount of excess reserves that a bank wishes to hold, suggesting that the amount is determined by equating the opportunity cost of holding excess reserves, $(r_x - \hat{r}) + \lambda$, with the marginal cost incurred by deviating from the reserve target, $\beta(R_n^e - \bar{T}_n)$. Notice that if target reserves exceed zero, reserves will typically fall short of the bank's own target, given the cost of holding them (as typically $r_x < \hat{r}$). The second condition implies that lending continues until the lending rate (accounting for the anticipated default in the loans market) equals the cost of marginal funds (the interbank rate accounting for the possibility of default in the interbank market) and the marginal administrative costs of lending and the shadow cost of a binding credit ceiling. If the lending constraint is binding (and $\xi > 0$), then $\hat{r}_{\scriptscriptstyle L} - \hat{r} > c_{\scriptscriptstyle L}(D_n, L_n)$. Given that $c_{\scriptscriptstyle L}(D_n, L_n)$ is upward sloping in loans L_n, this condition suggests that a binding credit ceiling holds the level of loans below its equilibrium level. The third condition determines deposit holdings by equating the marginal profits from additional deposits (in terms of interbank lending), $\hat{r} - r_{\scriptscriptstyle D}$, with the marginal costs from managing deposits, $c_{\scriptscriptstyle D}(D_n, L_n)$, and the marginal cost of meeting the reserve requirement $\alpha(\hat{r} - r_{\scriptscriptstyle R})$. Finally, in this simple framework, a no-arbitrage condition requires that all liquid funds (for bonds or in the interbank market) attract the same yield, given that these rates are market-determined. The first-order conditions characterize a unique solution to each bank's profit-maximization problem. The solution to the first-order conditions implies the optimal demand for deposits, the supply of loans, demand for (excess) reserves, and the optimal demand for bonds that depend on the key interest rates and the reserve requirement (as well as parameters governing the bank's costs and liquidity preferences).[12]

We now turn to the competitive equilibrium in the interbank market. Indexing the banks by $n = 1, 2, ..., N$, they each have a *loan-supply* function $L_n(r_L, r)$ and a *deposit-demand* function $D_n(r_D, r)$. Under binding lending restrictions, the loan-supply function $L_n(r_L, r) = \bar{L}_n$ would be inelastic. Let $L^d(r_L)$ be the demand function for loans and $S(r_D)$ the supply function for deposits (savings). Typically, the loan and deposit markets would be cleared (and relevant interest rates determined) by equating the demand and supply in these markets. However, given the extent of retail interest rate regulation in China and the clustering of the deposit rate at its ceiling, it is likely that the regulated deposit rate is below its equilibrium level (savings market does not clear at r_D).[13] The lending rate, reflecting its regulated floor, is probably no longer binding on many (especially marginal) borrowers, given that more than 80 per cent of loans occur at and above the administered lending rates (Figure 1), implying that the floor on the administered lending rate is not binding. However, under the assumption of a binding credit ceiling, the level of bank loans would be lower than equilibrium, implying that the loan market does not clear at r_L. If either the borrowing or lending market does not clear, then the quantity would be determined by the short side at the regulated interest rate.

The competitive equilibrium is then characterized by three conditions, assuming N is sufficiently large:

$$L^d(r_L) \geq \sum_{n=1}^{N} L_n(r_L, r) \text{ (Loans market)}, \tag{3}$$

$$S(r_D) \leq \sum_{n=1}^{N} D_n(r_D, r) \text{ (Savings market)}, \tag{4}$$

$$D^I(r) + \sum_{n=1}^{N} L_n(r_L, r) = (1-\alpha)S(r_D) - B - \sum_{n=1}^{N} R_n^e(r_x, r, \bar{T}_n, \beta) \text{ (Interbank market)}, \tag{5}$$

where $R_n^e(r_x, r, \bar{T}_n, \beta)$ is the level of excess reserves for bank n, B is the aggregate level of the security holdings of bank n, and $B = \sum_{n=1}^{N} B_n(r_B)$. $D^I(r)$ is the net demand for interbank funds from institutional investors, where $D^I(r)$ is decreasing in r, the interbank

[12] The second derivatives of the system ensure that the solution leads to a global maximum.

[13] Provided the following condition holds: $\bar{T}_n > (\hat{r} - r_x)/\beta$.

interest rate. Institutional investors are net borrowers in the interbank market, while domestic commercial banks are net lenders.[14]

Result 1: *There exists an equilibrium market-determined interbank rate, r^*, that solves equation (5), which is a unique function of the administratively set benchmark interest rates r_L and r_D, as well as reserve requirements and government bond issues. The same holds for the market-determined bond yields. The equilibrium interbank rate, r^*, lies between the interest rate on excess reserves, r_x, and the administered lending rate, r_L, provided certain conditions hold.*

Proof. For a given r_L, r_D, r_R, α, B and the reserve target function parameters, there exists a unique interbank rate that solves equation (5). Note that the right-hand side of equation (5) is an increasing function in the interbank rate ($\frac{\partial R_n^e(r_x,r,\bar{T}_n,\beta)}{\partial r} < 0$). For the left-hand side, we consider two different cases: in the first case, the credit cap does not bind ($\xi = 0$), and the left-hand side is downward sloping in the interbank rate ($\frac{\partial L_n(r_L,r)}{\partial r} < 0$, $\frac{\partial D^I(r)}{\partial r} < 0$). In the second case, the credit cap binds ($\xi > 0$) and $L_n(r_L, r) = \bar{L}_n$, the left-hand side of equation (5) is also downward sloping in the interbank rate ($\frac{\partial \bar{L}_n}{\partial r} = 0$, $\frac{\partial D^I(r)}{\partial r} < 0$). In both cases, the necessary condition is satisfied.

On the sufficient condition of the existence of equilibrium, note that both the left- and right-hand sides of equation (5) are monotone in r, given the reserve target function assumed.

If $r \to r_L$, then by first-order conditions and the assumptions of γ, δ_L, δ_M and κ, we must have $L_n = 0$, since $c_L(D_n, L_n) \neq (\gamma - \kappa) + (\kappa\delta_L - \gamma\delta_M)$ and $c_L(D_n, L_n) > 0$. Consequently, the right-hand side of (5) is greater than the left-hand side, provided that $B \leq (1 - \alpha)S(r_D) - \sum_{n=1}^{N} R_n^e(r_x, r, \bar{T}_n, \beta)$ (Condition A), where $R_n^e(r_x, r, \bar{T}_n, \beta) = \max[0, (\hat{r} - r_x)/\beta + \bar{T}_n]$ and $D^I(r_L) = 0$. If $r \to r_x$, then $R_n^e(r_x, r, \bar{T}_n, \beta) = (\hat{r} - r_x)/\beta + \bar{T}_n > \bar{T}_n$, so a sufficient condition for the left-hand side of (5) to be greater than or equal to the right-hand side is $B \geq (1 - \alpha)S(r_D) - D^I(r_x) - c_L^{-1}(S(r_D), \hat{r}_L - \hat{r}_x) - \sum_{n=1}^{N} \bar{T}_n$ (Condition B). The equilibrium interbank rate, r*, lies between the interest rate on excess reserves, r_x, and the administered lending rate, r_L, provided conditions A and B are met. □

[14]Foreign banks also borrow in renminbi terms in the interbank market, for their subsidiary activities in China. Given the binding capital controls in China, these subsidiaries in effect operate in a closed capital market. We model them in a similar approach as institutional investors, since the majority of foreign banks operate in China under the QFII (qualified foreign institutional investors) scheme.

The direct implication of Result 1 is that the market-determined interbank and bond rates cannot be independent of the administratively determined interest rates.[15] Some key properties of the resulting equilibrium interbank interest rate are summarized in Results 2 and 3:

Result 2: *Provided the lending rate does not exceed its equilibrium, the equilibrium interbank rate, r^*, that solves (5), is increasing or flat in the lending rate, decreasing in the deposit rate, and increasing in central bank bond issuance and the loan target under credit control. An increase in the required reserve ratio has an ambiguous impact on the interbank rate. If the lending rate exceeds its equilibrium, then the interbank rate is decreasing in the lending rate.*

Proof. We consider two different cases here:
Case 1: The lending rate does not exceed equilibrium: $r_L \leq r_L^*$, where r_L^* is the equilibrium lending rate.
Subcase 1.1: Credit control does not bind for any banks ($\xi = 0$): $L_n^* < \bar{L}_n$, $\forall n$, where L_n^* is the equilibrium level of loans determined by market forces. The following comparative statics follow from equation (5), where

$$\Delta \equiv \frac{\partial D^I(r)}{\partial r} + \sum_n \left[\frac{\partial L_n(r_{\scriptscriptstyle L}, r)}{\partial r} + \frac{\partial R_n^e(r_x, r, \bar{T}_n, \beta)}{\partial r} \right] < 0, \tag{6}$$

[15] Note that we abstract from frictions in the interbank market and assume that, at the unique interbank rate, the interbank market clears without any cost. For models that consider financial frictions faced by the banking sector, see for example, Gertler and Kiyotaki (2010) and Christiano, Motto, and Rostagno (2010).

$$
\begin{aligned}
\frac{dr}{dr_L} &= -\frac{\sum_n \frac{\partial L_n(r_L, r)}{\partial r_L}}{\Delta} = -\frac{(+)}{(-)} > 0, \\
\frac{dr}{dr_D} &= \frac{(1-\alpha)\frac{\partial S(r_D)}{\partial r_D}}{\Delta} = \frac{(+)}{(-)} < 0, \\
\frac{dr}{d\alpha} &= -\frac{S(r_D)}{\Delta} = -\frac{(+)}{(-)} > 0, \\
\frac{dr}{dB} &= -\frac{1}{\Delta} > 0.
\end{aligned}
$$

Subcase 1.2: Credit control binds for all banks ($\xi > 0$): $\bar{L}_n < L_n^*$, $\forall n$ and $L_n(r_L, r) = \bar{L}_n$. In this case,

$$
\Delta \equiv \frac{\partial D^I(r)}{\partial r} + \sum_n \left[0 + \frac{\partial R_n^e(r_x, r, \bar{T}_n, \beta)}{\partial r} \right] < 0. \tag{7}
$$

The comparative statics for $\frac{dr}{dr_D}$, $\frac{dr}{d\alpha}$ and $\frac{dr}{dB}$ hold as in subcase 1.1. We have the following new conditions

$$
\begin{aligned}
\frac{dr}{dr_L} &= -\frac{\sum_n \frac{\partial \bar{L}_n}{\partial r_L}}{\Delta} = -\frac{0}{(-)} = 0, \\
\frac{dr}{d\bar{L}_n} &= -\frac{\sum_n \frac{\partial \bar{L}_n}{\partial \bar{L}_n}}{\Delta} = -\frac{1}{(-)} > 0.
\end{aligned}
$$

Since the above conditions hold for the two extreme cases, they also hold for the intermediate case where credit control is binding for some banks but not all banks.

Case 2: The lending rate exceeds its equilibrium: $r_L > r_L^*$.

In this case, $L^d(r_L) \leq \sum_{n=1}^N L_n(r_L, r)$, and Δ is same as in subcase 1.2. Hence, we have

$$
\frac{dr}{dr_L} = -\frac{\frac{\partial L^d(r_L)}{\partial r_L}}{\Delta} = -\frac{(-)}{(-)} < 0.
$$

□

The result that a rise in the deposit rate reduces the interbank rate follows from the fact that interest rate regulation holds the deposit rates below their equilibrium level.

With rates below their equilibrium level, a rise in the deposit rate increases deposits in the system, resulting in additional liquidity in the banking system and lower overall interest rates. If, however, such regulation was not binding, then an exogenous rise in the deposit rate (due to developments in that market) would result in higher costs for the bank, thereby limiting their demand for deposits and resulting in higher interbank rates because of a reduction in the liquidity in the system. This is Result 3:

Result 3: *If the deposit (savings) market were allowed to clear*

$$S(r_D) = \sum_{n=1}^{N} D_n(r_D, r),$$

then an increase in the deposit rate would increase the interbank rate. All other comparative static results from Result 2 would continue to hold.

Proof. We present the case where credit control is not binding. In this case, equation (5) would become

$$D^I(r) + \sum_{n=1}^{N} L_n(r_L, r) = (1-\alpha)\sum_{n=1}^{N} D_n(r_D, r) - B - \sum_{n=1}^{N} R_n^e(r_x, r, \bar{T}_n, \beta),$$

and

$$\Delta \equiv \frac{\partial D^I(r)}{\partial r} + \sum_n \left[\frac{\partial L_n(r_L, r)}{\partial r} + \frac{\partial R_n^e(r_x, r, \bar{T}_n, \beta)}{\partial r} - (1-\alpha)\frac{\partial D_n(r_D, r)}{\partial r}\right] < 0,$$

where $\frac{\partial D_n(r_D, r)}{\partial r} > 0$ as the demand for deposits is upward sloping in the interbank rate. Then

$$\frac{dr}{dr_D} = \frac{(1-\alpha)\sum_n \frac{\partial D_n(r_D, r)}{\partial r_D}}{\Delta} = \frac{(-)}{(-)} > 0.$$

All other comparative static expressions remain as in the proof of Result 2. The case where the credit cap is binding can be obtained by putting $\frac{\partial L_n(r_L, r)}{\partial r} = 0$. □

The results from the stylized theoretical model have several implications: first, market-determined interbank interest rates cannot be independent of administratively determined interest rates, such as regulated deposit and lending rates. Second, the model implies that interbank interest rates are influenced by changes in the reserve requirement ratio, an important monetary policy tool employed by the PBC. The model also yields some predictions on the direction of the responses in the interbank rate. In particular, the interbank rate is increasing in the lending rate (providing the lending rate has not already exceeded its equilibrium) and decreasing in the deposit rate (as interest rate regulation holds the deposit rate below the equilibrium level).

4 Empirical Analysis

In this section, we estimate an empirical model of the interbank interest rate in China and examine the extent to which administered interest rates influence interbank rates, as predicted by the stylized theoretical model. We note that short-term exogenous factors that affect liquidity, such as open market operations (OMOs) and IPO activities, should influence interbank rates in the same way as the exogenous changes in bond holdings (as seen in the stylized model), increasing the interbank rate when liquidity falls and reducing the interbank rate when liquidity rises. As a result, we include administered interest rates, net liquidity injections from OMOs and reserve requirements, and IPO funds as exogenous (independent) factors in the empirical model of the interbank rate.[16] We also control for the predictable (seasonal) factors that tend to affect liquidity in money markets in advanced economies, such as within week, month and end-of-year effects. Finally, we undertake some robustness checks, which show that, despite changes in the extent of liquidity and policy stance over the sample, the conclusion regarding the impact of administered interest rates (and hence retail interest rate regulation) on market-determined rates holds.

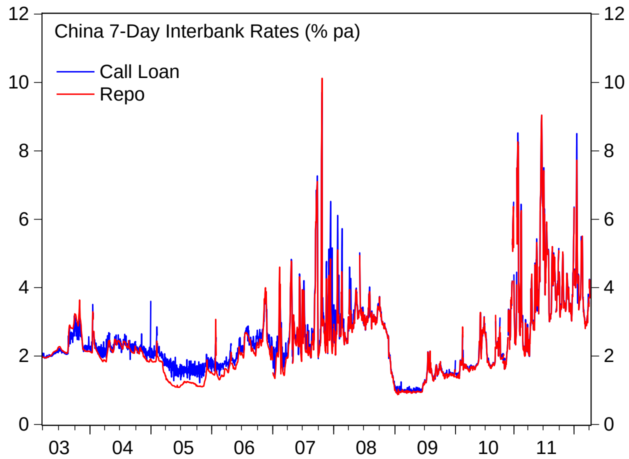
4.1 Properties of interbank interest rates in China

As can be seen from Figure 3, the two main market-determined rates for short-term interbank funds (call loan and the repo rates) have followed each other very closely over

[16]Other exogenous variables, such as exchange rate intervention, or capital inflows could also influence the interbank interest rates. However, the analysis of their impact is beyond the scope of the current version of the paper.

the past few years, with volatility having increased substantially since late 2005.[17] The rise in volatility reflects both the growing depth of these markets (see, for example, Xu, 2006), and is also coincident with the development of other parts of the financial market, especially the foreign exchange market and the equity market (as seen by IPO activity, Figure 4).

Figure 3: 7-day Interbank Rates in China



Sources: People's Bank of China and Haver Analytics (CEIC)
Observation Dates: April 2003 to April 2012

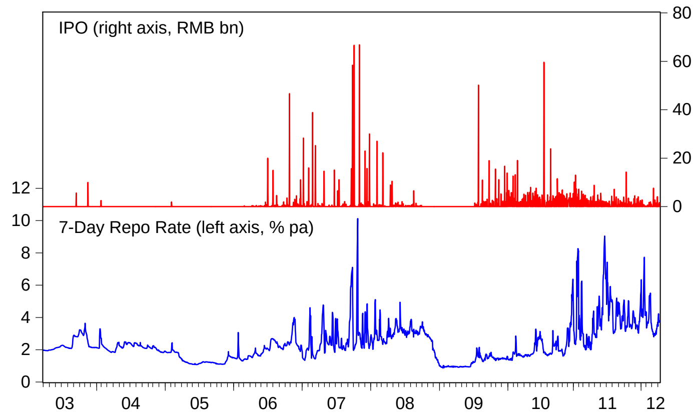
While the extent of the volatility is likely driven by several other institutional and policy factors, it is also probably affected by the institutional arrangements governing reserve requirements (for example, the period of reserve averaging). Given the greater liquidity in the repo market (with the turnover in the repo market far exceeding that in the uncollateralized call loan market), and the close relationship between the call loan and repo (see Figure 3), we focus on the 7-day repo rate as the measure of interbank interest rates in the empirical analysis that follows.[18]

Before moving on to discuss the empirical model, we consider the key empirical properties of the repo rate. As can be seen from Figure 5, the repo rate is clearly persistent, with its mean seemingly well characterized by autoregressive processes (slow decay in the

[17] In addition to the call loan (CHIBOR: China Interbank Offered Rate) and repo rates, SHIBOR (Shanghai Interbank Offered Rate) is the other key reference interest rate in the interbank market. SHIBOR is not determined in a funding market, but is set in the similar way to LIBOR, with the rate calculated as an arithmetic average of renminbi offered rates by participating banks (currently 16).

[18] The correlation between 7-day repo and call-loan rates is very high, at around 0.99.

Figure 4: 7-day Repo Rate and IPO Activities



Sources: People's Bank of China, Haver Analytics (CEIC) and Stockstar
Observation Dates: April 2003 to April 2012

autocorrelation function (ACF) and decay after more than 5-15 lags of the partial ACF (PACF)). Despite the persistence, the unit root test is clearly rejected.[19] There are also clear signs of volatility clustering, with similar indications of significant persistence in the squared repo rate.[20]

4.2 The empirical model

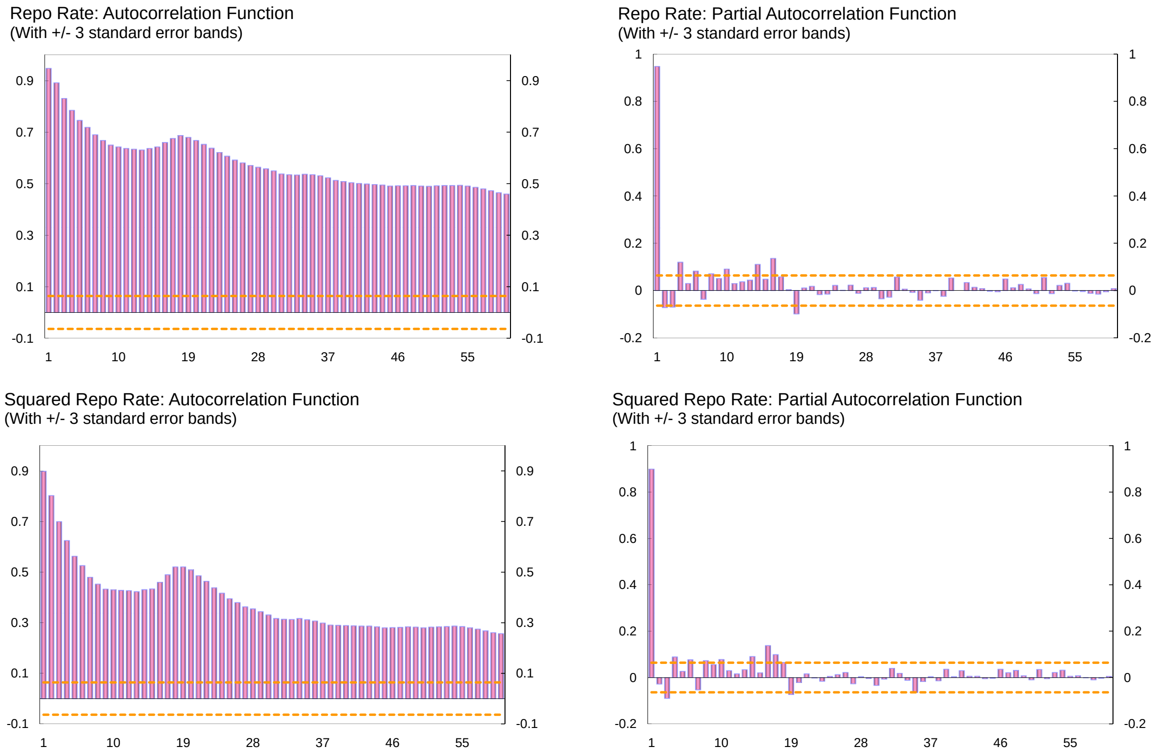
China's interbank rates, as those in advanced economies, exhibit high volatility as well as volatility clustering (Figure 5). Consequently, we model the interbank rate using an exponential GARCH (EGARCH) model (Nelson, 1991), which allows for rich specifications for both the time-varying mean as well as the time-varying volatility of the observed interest rate.[21] Given the apparent "fat tails" exhibited by the Chinese interbank data, we assume that these innovations follow Student's t-distribution, with degrees of freedom estimated to match the "fat tails" found in the data. Such a model has been applied to many advanced-country interbank markets (see, for example, Prati, Bartolini, and Bertola,

[19] The augmented Dickey-Fuller test is rejected with a p-value of 0.012, and the Phillips-Perron test is rejected with a p-value of 0.000.

[20] Volatility clustering refers to the phenomenon that large changes in the price of an asset (here we refer to interbank interest rates) tend to be followed by further large changes and, similarly, small changes in asset prices (interbank rate) tend to be followed by further small changes (see Mandelbrot, 1963).

[21] For a discussion of the properties of the EGARCH model and a comparison with standard GARCH, see, for example, Terasvirta (2009).

Figure 5: Interbank Rate Persistence



2003; Moschitz, 2004; and Quiros and Mendizabal, 2006). The focus of these studies differs from ours in that they examine the interbank markets in developed (G7) economies, where the central bank targets a short-term interbank rate for monetary policy purposes. Their primary concern is to identify the liquidity effects within the market, driven by the differences between reserve settlement and non-settlement days, as well as the impact of the parameters of the interest-rate-targeting regime on the interbank rate. We, however, are principally concerned with the impact of administered interest rates and other monetary policy instruments, such as open market operations and reserve requirements, on interbank rates in a less-developed market with partial financial liberalization.

Our basic empirical model of the interbank interest rate r_t is given by

$$r_t = \mu_t + \sqrt{h_t}\nu_t, \tag{8}$$

where ν_t is a unit variance, serially uncorrelated, zero mean, i.i.d error term, and μ_t and

h_t are the time-varying mean and variance, respectively, of the interbank interest rate. The mean μ_t is assumed to show persistence in the interbank interest rates, as well as in exogenous factors that affect the interbank interest rate, $\mathbf{X}_t^m$,

$$\mu_t = c + \sum_{i=1}^{s} \phi_i r_{t-i} + \beta_m' \mathbf{X}_t^m, \tag{9}$$

where the autoregressive coefficient, ϕ_i, is aimed to capture the possible persistence of the interbank interest rate, and $\beta_m' \mathbf{X}_t^m$ reflects the impact of exogenous factors on the average interbank rate. Consistent with the volatility clustering observed in the interbank data, the variance of the interbank rate is specified as follows:

$$ln(h_t) = \omega + \sum_{i=1}^{q} \gamma_i ln(h_{t-i}) + \sum_{j=1}^{p} \alpha_j \frac{|\nu_{t-j}|}{\sqrt{h_{t-j}}} + \sum_{k=1}^{l} \lambda_k \frac{\nu_{t-k}}{\sqrt{h_{t-k}}} + \beta_\nu' \mathbf{X}_t^\nu, \tag{10}$$

where $ln(h_t)$ is the logarithm of the conditional variance h_t, the α_j terms are the "ARCH" effects (based on innovations in the absolute standardized residual), the γ_i terms are the "GARCH" terms, and the λ_k terms capture the asymmetric impact of positive or negative innovations to the standardized residuals.[22] If $\lambda_k = 0$, then both positive and negative innovations have symmetric impacts on interest rate volatility. $\beta_\nu' \mathbf{X}_t^\nu$ measures the impact of exogenous factors that drive volatility. The EGARCH specification implies that the forecasts of conditional variance is always non-negative.

4.3 Model specification

Based on our stylized model of China's banking sector, the interbank rate should reflect the administered deposit and lending rates, and the extent of liquidity in the interbank system. We use the 1-year administered deposit and lending rates to capture the impact of interest rate regulation on the mean of the interbank rates. To capture the impact of monetary policy changes on liquidity in the banking system, we use measures of open market operations and reserve requirements. Specifically, the open market operations variable is defined as the level of net liquidity injection from the expiration of repos and

[22]In the empirical analysis in the model, the lag orders p, l and q are set at 1, 1 and 1, respectively, to capture the volatility clustering as observed in the 7-day repo rate.

PBC central bank bills (expiration less issuance), and the issuance of reverse repos. For reserve requirements, the measure reflects the liquidity injected from a fall in required reserves. The change in the liquidity condition is constructed as the change in the reserve requirement ratio times the deposit base. Given that changes in reserve requirements are usually announced one or two weeks before the effective date, we also construct a dummy variable to capture the announcement effect of reserve requirement changes, where the dummy is equal to the change in the reserve requirement ratio on the date of the announcement. IPOs are also posited as an important contributor to short-term fluctuations in the interest rate, as they lock up significant funds in the banking system for around one or two weeks ahead of the IPO, and so these are included as exogenous explanatory variables. Data on IPOs cover the total amount of funds raised (in billions of renminbi) on a particular day.[23] Finally, we allow for interbank liquidity to vary systematically through the year, as it does in other interbank markets (Prati, Bartolini, and Bertola, 2003 and Moschitz, 2004). In particular, we allow for liquidity effects resulting from the day of the week, the proximity to the end of the month, and the timing of the Chinese New Year to possibly influence the average interbank rate, as well as its volatility (see Table 1).

Table 1: Variables Included in the GARCH Model

Variables	*Level equation*	*Variance (volatility) equation*
Endogenous	7-day repo rate	7-day repo rate
Exogenous	1-year administered deposit rate	*Changes* in 1-year administered deposit rate
	1-year administered lending rate	*Changes* in 1-year administered lending rate
	Net liquidity injection from OMO	Net liquidity injection from OMO
	Net liquidity injection from RR	Net liquidity injection from RR
	Announcement effect of changes in RR ratio	Announcement effect of changes in RR ratio
	IPO volume	IPO volume (inc. leads)
	Systemic liquidity dummies	Systemic liquidity dummies

A similar set of variables is hypothesized to influence the variance of the interbank rate, particularly policies such as changes in the administered lending rates and changes in liquidity. In the former case, a sudden increase in the incentive to lend is likely to cause a short-term rush for interbank funds (until, say, the level of deposits can increase) and temporarily increases volatility. In the latter case, policy-induced changes in liquidity

[23]The data sources for all series were the People's Bank of China, Haver Analytics (CEIC) and Stockstar. See Data Appendix for more details.

(through open market operations and reserve requirement changes) are likely to drive changes in volatility in the short run, as are exogenous changes in liquidity that may occur through the week, around the end of a month, or at the Chinese New Year. The main difference in the variance equation is that we control the absolute change in administered interest rates, rather than their levels (see Table 1). This difference reflects the fact that *changes* in administered rates are likely the drivers of (short-term) volatility, and any impact is more likely to be symmetric to both increases and reductions. With IPOs resulting in a significant amount of funds being locked up in the banking system (for about a week or so), we included leads of 5 and 10 days to capture the impact of this "lock up" ahead of the IPO in the variance equation.[24]

Given the persistence in the 7-day repo rate, we consider a lag order of five (approximately one week) in the mean equation. All (exogenous) explanatory variables are restricted to have the same lag order, except for the IPO in the variance equation, where leads were included to capture the lock-up effect of funds. The final equation specification is obtained using the general-to-specific approach and captures the key relationships in the interbank market in a parsimonious manner.

4.4 Empirical results

We now turn to the empirical results on the drivers of China's interbank rate, both in levels and variance. The estimation sample spans from April 2003 to April 2012 at a daily frequency. We start from April 2003, since daily data on open market operations in China only became available at that time. The sample period covers three distinct phases of macroeconomic environments: the pre-crisis liquidity surplus, the post-crisis credit expansion and the subsequent monetary tightening. The detailed estimation results and relevant tests are presented in Tables 2 to 5.

4.4.1 Mean interest rates

Persistence. China's interbank rate, like those in G7 and euro-area countries, is extremely persistent. There is a more-than-proportionate response to a change in the repo rate on the previous day, which is then unwound in the following days (Table 2).

[24]The "locked-up" funds are subsequently released from the banking sector on the date of the IPO.

Administered interest rates. Changes to administered (benchmark) lending and deposit rates clearly have a significant impact on the interbank rate.[25] Increases in the administered lending rate lead to higher average interbank rates, since the higher lending rates translate into pressure for interbank funds. The impact of a 100-basis-point rise in the 1-year lending rate is to increase the interbank rate by 1.6 basis points. A rise in the 1-year deposit rate has the opposite effect, reducing the interbank rate, possibly reflecting a likely supply response on the part of depositors, given the low level of the regulated deposit rate as suggested by our stylized model. The impact of a 100-basis-point rise in the deposit rate is a 2.1-basis-point fall in the mean interbank rate (Table 2). This empirical finding is consistent with the prediction from the stylized theoretical model that the interbank rate is increasing in the lending rate and decreasing in the deposit rate.

Open market operations and reserve requirements. Conditional on the level of administered interest rates, liquidity changes from reserve requirements do not have any significant impact on the mean interbank rate. The announcement effect of reserve requirements, however, does have a positive impact on the mean interbank rate. The impact of a 50-basis-point rise in the reserve requirement ratio (a typical move) is a 3.5-basis-point rise in the mean interbank rate (Table 2). Liquidity changes from open market operations have a significant impact on the level of interbank interest rates.

IPOs. IPOs have apparently no significant impact on the mean interest rate. While this is surprising, given the volume of funds tied up during the IPO, the result could reflect offsetting policy actions (for example, a reduction in sterilization operations during IPOs) or the guiding role played by administered (benchmark) interest rates in driving the interbank interest rates (Table 2).

Liquidity effects. Of the three variables measuring liquidity effects, the timing of the Chinese New Year has the largest impact on average interest rates, owing to the strong tendency of households to withdraw deposits ahead of the New Year. Average interbank rates are higher during the week before the New Year, and then fall significantly below average on the day of the New Year, with the New Year effect gradually declining over the subsequent week. There are also liquidity effects associated with the end of the month, with the average interest rate notably higher before the end of the month. Finally, the

[25] At a daily frequency, the null hypotheses that the administered deposit and lending rates do not Granger-cause the 7-day repo rate can be rejected, with p values of 6e-07 and 5e-06, respectively.

within-week liquidity effects do not seem to be significant for the mean interbank rates; however, jointly, they are significantly negative (Tables 3 and 4).

4.4.2 Interest rate volatility

Volatility clustering in the 7-day repo rate is confirmed with the significant GARCH effects found in our estimation (Table 2). The variance is relatively persistent and is driven by similar factors as the average interest rates. The first-order ARCH effect is marginally significant, as is the asymmetric term. Consequently, "negative innovations" (a reduction in interbank rates) have a smaller impact on interest rate volatility than news that increases the interest rate. Policy variables, IPOs and liquidity effects affect interbank volatility as follows:

Administered interest rates. Changes in administered interest rates have a significant impact on the variance of the interbank rate (Table 2). Changes in the lending rate tend to increase volatility, as the incentive to raise funds for lending changes with the lending rate. Changes in the deposit rate tend to reduce volatility, which is somewhat surprising, but may be an artifact of the structural liquidity surplus during the sample period.

Open market operations and reserve requirements. Policy changes, at least those through reserve requirements, seem to have a more significant impact on interest rate volatility than on the mean of the interbank rate. However, the impact of changing reserve requirements tends to anticipate the actual change in policy, commencing with a jump in volatility when the change is announced (Table 2).[26] The strength of this anticipatory effect probably reflects the daily nature of reserve requirements and the importance of reserve requirements as a monetary policy tool in China (see discussions in Section 2.1). An increase in net liquidity injections through open market operations has a small significant impact on volatility, as would be expected if open market operations act as a sterilization tool to adjust liquidity in the system and to stabilize interest rates in the interbank market.

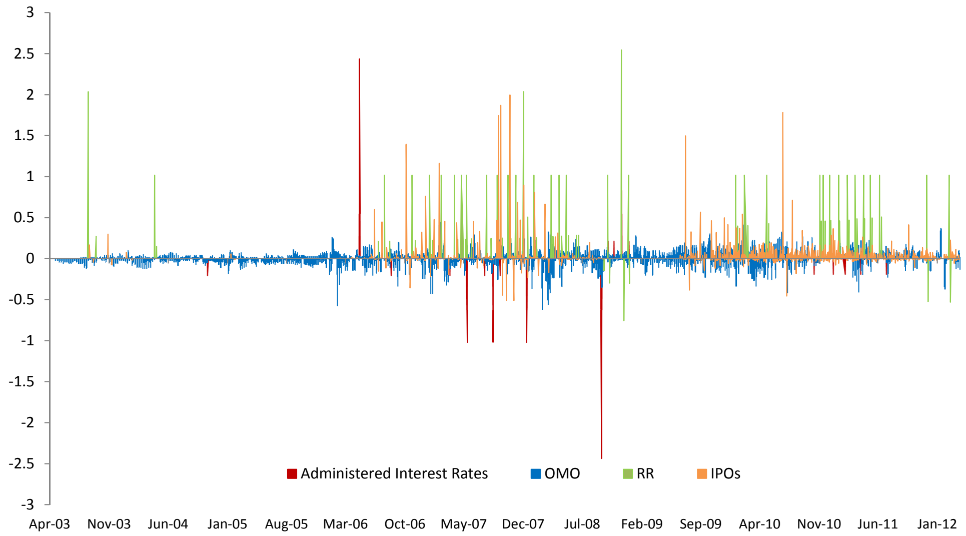
IPOs. While IPO activity did not change the behaviour of average interbank rates, they seem to increase the volatility of interbank rates marginally when they occur (Table

[26] Changes in reserve requirements are usually announced one to two weeks ahead of the execution dates. For example, the PBC announced on 18 March 2011 its decision to raise the RMB reserve requirement ratio for depository financial institutions by 0.5 percentage points, effective from 25 March 2011, see PBC website for details.

2), which is consistent with the observation in Figure 4. In particular, volatility increases significantly ahead of the IPO (when funds are locked up), but there is little sign of above-average volatility after that (including when surplus funds are released).

Liquidity effects. As with the level, the liquidity effect of the Chinese New Year is the largest (Tables 3 and 4). Volatility is typically above average one week before the New Year, as households withdraw deposits ahead of the New Year, and then it declines gradually in the trading week after the holiday. Volatility is significantly lower at the beginning of the week (Monday and Wednesday) and increases gradually toward the end of the week. There are also significant liquidity effects on interbank volatility through each month, with volatility typically higher than average as the end of the month approaches, and then declining during the first week of the month.

Figure 6: Contributions to Interbank Volatility



Note: Contribution to the log of variance, which excludes constant, liquidity, ARCH, Asymmetric and GARCH effects. RR includes the both liquidity and annoucement effects.

As can be seen in Figure 6, IPO activities, reserve requirements (including the announcement effect) and administered interest rates contribute most to the volatility of interbank interest rates, if we extract from liquidity, GARCH and ARCH effects. Monetary policy variables such as open market operations, also contribute to interbank volatility, although their impact is smaller in comparison.

The resulting estimates also confirm the extent of extreme movements in China's interbank rate. The estimated degrees of freedom for the error term are only marginally above the lower limit of two (Table 2), and far smaller than those estimated in models of other interbank markets. For example, Prati, Bartolini, and Bertola (2003) present degrees-of-freedom estimates between 2.23 and 3.95 for shortterm G7 and euro-area interbank rates. With such a low estimate for the degrees of freedom of the error terms, estimated innovation (news events) is far more fat-tailed than implied by a normal distribution.

The model equation has well-behaved residuals, with no signs of volatility clustering in the standardized residuals. There are also no signs of persistence in either the standardized residuals or squared standardized residuals, suggesting that there are no residual autocorrelation or ARCH effects (see Table 5 and Figure 7).

4.5 Robustness check

We undertake three types of robustness checks and re-estimate our empirical model separately: (i) over the first half of the sample (effectively, most of the period of structural surplus liquidity, but before China's large post-crisis monetary expansion); (ii) with different measures of liquidity injections; and (iii) using different specifications of administered interest rates. Our main results continue to hold, particularly regarding the importance of administered interest rates as drivers of interbank rates.

4.5.1 Subsample: April 2003 to October 2007

To study the evolution of the main drivers of interbank interest rates in China, we examine a shorter subsample to October 2007 (first half of the sample). We find that, with the shorter sample, administered lending and deposit rates remain important drivers of China's interbank interest rates, in both levels and variances, although the importance of these interest rates have declined over time (as seen from the regression coefficients). While liquidity injection from open market operations is found to be significant in the full sample to April 2012, it is not significant in the subsample to October 2007, neither in levels nor in variances (Tables 6 and 7). This finding suggests that the importance of open market operations in influencing interbank interest rates has increased over time, and interbank rates are starting to reflect changes in liquidity conditions, owing to open market operations in recent years.

4.5.2 Liquidity injection

In order to check the robustness of our results to different GARCH specifications, we carry out several further experiments. First, we consider a specification where changes in liquidity from open market operations, reserve requirements and IPOs are introduced in real terms, by accounting for inflation in the economy. The results are found to be robust, particularly in both the impact coefficients and the significance of key variables of interest–namely, administered lending and deposit rates, liquidity injections from open market operations, reserve requirements, and IPOs (Tables 8 and 9).

In a second experiment, we sum up open market operations and reserve requirements (real terms) into one quantitative monetary policy variable. We postulate that the earlier baseline result that open market operations and changes in reserve requirements have a limited impact on the interbank rate in levels may be a result of the shift in monetary policy instruments in China (Qin, Quising, He, and Liu 2005). Reserve requirements played a prominent role between 2006 and 2008, and then between 2010 and 2011 as part of monetary policy tools. As expected, the combined monetary policy variable is significant in influencing the level of the interbank interest rates. The impact of a 100-basis-point rise in liquidity conditions (injection due to open market operations and reserve requirements) is a 0.4-basis-point rise in the mean interbank rate. However, the variable does not seem to be significant in explaining the volatility of interbank interest rates, which was driven mainly by changes in administered interest rates, the announcement effect from changes in reserve requirements and IPOs (Tables 8 and 9).

4.5.3 Interest rate variables

In the baseline specification, both administered lending rates and deposit rates are introduced to capture the impact of policy changes in administered interest rates. The 1-year administered lending rates typically move at the same time as the 1-year deposit rates, although there are several episodes of exception in our sample period.[27] To check the robustness of our results to different specifications of administered interest rates, we carry

[27]In September 2008, the 1-year administered lending rate was reduced by 27 basis points, while the 1-year administered deposit rate remained unchanged. The magnitude of changes in the administered lending rate was sometimes smaller than that in the administered deposit rate. For example, the 1-year administered lending rate was increased by 18 basis points in May and December 2007, while the 1-year administered deposit rate was raised by 27 basis points.

out two further experiments. First, only one administered interest rate is introduced to the regression at a time. The results are robust in that the 7-day repo rate is persistent, and open market operations and the announcement effect of reserve requirements have a significant impact on the level of interbank interest rates. The administered deposit rate also has a negative and significant impact on the interbank interest rate; however, the impact from the administered lending rate does not appear to be significant. This result is consistent with our view that the deposit rate ceiling is binding and the administered deposit rate is expected to be important in influencing the level of interbank interest rates. While changes in administered interest rates jointly influence the volatility of interbank interest rates, individually, their impact does not appear to be as significant as open market operations, the announcement effect of reserve requirements and the lock-up effect from IPOs (Tables 10 and 11).

Finally, we consider a specification in which the spread between administered lending and deposit rates is introduced in the regression. The spread is found to be significant in explaining both the level and volatility of interbank interest rates. The impact of a 100-basis-point rise in the spread between 1-year administered lending and deposit rates is a 0.7-basis-point rise in the mean interbank rate, while a change in the interest rate spread (100-basis-point rise) could increase interbank volatility by 6.8 basis points. The magnitude and significance of the responses in other key variables such as open market operations, reserve requirements and IPOs are very similar to those in the baseline specification (Tables 10 and 11).

5 Conclusion

This paper investigates the main drivers of China's interbank rates by developing a stylized theoretical model of China's interbank market, and estimating an EGARCH model for the 7-day interbank repo rate from April 2003 to April 2012, controlling for administered interest rates, monetary policy variables, IPO volumes and liquidity effects. The stylized theoretical model pins down the analytical relationship between regulated and market-determined interest rates and predicts that administratively determined deposit rates and lending rates are likely to influence the movements of interbank rates. In particular, the interbank rate is increasing in the lending rate (provided the lending rate has not already exceeded its equilibrium) and decreasing in the deposit rate (as interest rate regulation holds the deposit rate below the equilibrium level).

Our empirical results confirm the predictions from the theoretical model that China's interbank rates are not truly independent. Administered interest rates are found to be important determinants of the interbank rates, in both levels and volatility. Interbank rates are also influenced by the announcement effects of changes in reserve requirements, together with liquidity injections from open market operations in recent years. IPO activities affect interbank volatility, as well as systemic variations in liquidity throughout the week, during the month and due to the timing of the Chinese New Year. Our results suggest that the regulation of key retail interest rates influences the behaviour of market-determined interbank rates, which may have limited their ability to act as independent price signals.

These conclusions raise a number of interesting issues on the liberalization of financial prices in emerging markets. First, the theoretical and empirical results suggest that partial liberalizations may have limited effectiveness. That is, market-determined rates, even longer-term bond yields, can reflect interest rate regulation in other parts of the market. The "policy spillover" thus affects private decisions that are directly determined by unregulated prices. This would include firms that seek to fund projects through bonds, and banks participating in the interbank market, as well as those seeking to protect themselves through derivatives transactions (since derivatives prices depend on interbank rates). Moreover, if the interest rate regulation is binding, the allocation of credit across potential projects is left to the banking sector, rather than independent financial markets. Although it may be imprudent to read these considerations as suggesting a "big-bang" approach to liberalization, or considering financial market liberalization as a general precondition for assistance, they nevertheless suggest moving through the liberalization of domestic yields and asset prices somewhat quickly.[28]

Regarding the conduct of monetary policy in the process of financial and economic development, our results highlight the risks from excessive regulation on monetary policy implementation. The link between market and regulated interest rates suggests limits to the effectiveness of indirect monetary policy instruments. This can be seen in China's

[28]The general precondition for assistance should be "macro-critical," and liberalization may not meet the "macro-critical" criterion in all countries.

experience. Despite a desire to move toward indirect monetary policy instruments, the interest rate channel is still weak in China (see, for example, Maino and Laurens, 2007, and Cassola and Porter, 2011), although this would apply equally to other emerging and developing markets with partial financial liberalization. For short-term interest rates to become an effective operational target (influencing inflation and economic activity), the PBC has to be able to influence this rate effectively through open market operations. In addition, the impact of uneven financial developments and interest rate regulation is likely to erode the effectiveness of direct monetary policy tools. In particular, the incentive for disintermediation resulting from regulation (out of the banking sector and into trust companies as part of "shadow banking") is likely to affect movements in the velocity of money and the money multiplier. Maino and Laurens (2007) find that, while the PBC is able to meet its base money target, it is less effective at achieving its broad money targets and influencing economic growth.

Further interest rate liberalization should allow the interbank rate (and other interest rates) to provide better essential price signals, to better allocate capital, and to strengthen the tools for macroeconomic management. In particular, further deposit rate liberalization would allow banks to charge higher retail deposit rates to attract additional deposits, and potentially lead to a rise in retail loan rates for banks to maintain their profit margins and to meet capital requirements. This should then increase the cost of capital and thereby help to discourage marginal investment and improve the allocation of capital and the effectiveness of intermediation (Feyzioglu, Porter, and Takats, 2009). The liberalization of the deposit rate would also remove an important distortion in the interbank rate, which would allow short- term interbank rates to play a more effective role as the primary indirect monetary policy tool.

China and other emerging-market economies may face two important challenges in the process of further interest rate liberalization and financial development. First, the volatility of interest rates may increase, depending on the post-liberalization conduct of monetary policy.[29] Even if volatility does increase, as has been the experience in other money markets (Demirguc-Kunt and Detragiache, 2001), this higher volatility will result from market-determined rates being more responsive to fundamental changes in liquidity in emerging-market economies and risk characteristics rather than changes in regulated

[29] If the short-term interbank rate becomes a target for monetary policy, then volatility may decline.

interest rates. This is part of strengthening the price signals conveyed by interest rates. In any case, the volatility of Chinese money market rates could be reduced through a change in the structure of reserve requirements from daily reserve requirements to reserve averaging, irrespective of the extent of liberalization. Second, by creating new channels for banks to attract deposits and compete, liberalization could also lead to excessive lending (if banks choose to increase the quantity of loans instead of retail loan rates in response to liberalization) and place pressure on credit quality and the profitability of banks. If, however, liberalization is accompanied by heightened supervision and strengthened monetary policy, further liberalization could improve the effectiveness of intermediation and monetary transmission with enhanced financial stability.

Table 2: Estimated GARCH Parameters (Full Sample: April 2003 to April 2012)

	Coefficient	**Std. Error**	**z-Statistic**	**p-value**
Mean equation				
C	-0.038*	0.014	-2.768	0.006
Repo (-1)	1.169*	0.009	130.181	0.000
Repo (-2)	-0.076*	0.019	-3.934	0.000
Repo (-3)	-0.121*	0.024	-5.019	0.000
Repo (-4)	0.053*	0.022	2.406	0.016
Repo (-5)	-0.028*	0.014	-2.014	0.044
Administered lending rate	0.016*	0.004	3.929	0.000
Administered deposit rate	-0.021*	4.4E-03	-4.671	0.000
OMO	3.5E-05*	1.7E-05	2.037	0.042
RR	1.7E-05	0.000	0.453	0.651
RR announcement	0.069*	2.4E-02	2.929	0.003
IPO	6.4E-04	4.0E-04	1.604	0.109
Liquidity effects (see Table 3)				
Variance equation				
C	-0.100	0.095	-1.051	0.293
ARCH effect (-1)	1.735†	0.932	1.862	0.063
Asymmetric effect(-1)	0.439†	0.250	1.758	0.079
GARCH effect (-1)	0.969*	0.004	242.210	0.000
Δ in Administered lending rate	9.025*	2.854	3.162	0.002
Δ in Administered deposit rate	-9.794*	2.853	-3.433	0.001
OMO	0.002*	6.9E-04	2.918	0.004
RR	-0.001†	6.7E-04	-1.896	0.058
RR announcement	2.036†	0.378	5.381	0.000
IPO	-0.008	0.008	-1.012	0.311
IPO(+5)	2.6E-04	0.007	0.036	0.971
IPO(+10)	0.030*	0.007	4.504	0.000
Liquidity effects (see Table 3)				
T-DIST. DOF	2.03*	0.0294	68.884	0.000

R-squared	0.897	Adjusted R-squared	0.895
S.E. of regression	0.372	Sum squared residual	298.359
Log likelihood	2609.018		
Akaike info criterion	-2.112	Schwarz criterion	-2.112
Hannan-Quinn criterion	-2.236	Durbin-Watson statistics	2.208

Note: Dependent variable: Repo (7-day repo rate); sample period: 01 April 2003 to 12 April 2012. Included observations: 2197 after adjustments. Method: ML - ARCH (Marquardt) - Student's t-distribution. '*' indicates significance at 5% level, and '†' indicates significance at 10% level.

Table 3: Estimated Liquidity Effects (Full Sample: April 2003 to April 2012)

Lag	Mean equation		Variance equation	
	Coefficient	p-value	Coefficient	p-value
Day of week				
Monday	-4.5E-04	0.561	-0.693*	0.000
Wednesday	-2.4E-05	0.974	-0.435*	0.018
Friday	3.7E-04	0.684	0.072	0.660
End of month				
5	6.8E-04	0.581	0.004	0.986
4	-7.9E-04	0.512	-0.427†	0.070
3	0.001	0.470	-0.511*	0.031
2	-2.2E-05	0.991	0.162	0.485
1	0.001	0.434	-0.563*	0.011
0	-0.003	0.192	-0.252	0.305
-1	0.005*	0.013	-0.196	0.473
-2	0.002	0.439	0.556*	0.036
-3	0.004*	0.017	-0.204	0.432
-4	0.002	0.197	-0.099	0.704
-5	0.003*	0.019	-0.059	0.782
Chinese New Year				
5	-0.016*	0.026	-1.147†	0.094
4	-2.6E-05	0.998	0.977	0.394
3	0.003	0.792	-0.014	0.991
2	0.037*	0.004	-2.155*	0.036
1	0.062†	0.070	0.258	0.792
0	-0.477*	0.000	-0.194	0.815
-1	0.005	0.952	0.074	0.928
-2	0.341*	0.000	0.465	0.520
-3	0.089	0.240	2.689*	0.000
-4	0.060*	0.000	-0.953	0.184
-5	0.004	0.423	0.003	0.996

Note: Dependent variable: Repo (7-day repo rate); sample period: 01 April 2003 to 12 April 2012. Included observations: 2197 after adjustments. Method: ML - ARCH (Marquardt) - Student's t-distribution. '*' indicates significance at 5% level, and '†' indicates significance at 10% level.

Table 4: Joint Significance Tests (Full Sample)

	Total impact	LR statistic	p value
Mean equation			
Before and at end of month	0.013	33.70	7.7E-06
After end of month	0.002	12.49	3.4E-12
Before Chinese New Year	0.499	45.46	1.2E-08
At and after Chinese New Year	-0.392	65.14	4.0E-12
Weekdays (Monday, Wednesday, Friday)	-1.0E-04	135.73	3.1E-29
Variance equation			
Before and at end of month	-0.255	35.462	3.5E-06
After end of month	-1.336	45.814	9.9E-09
Before Chinese New Year	2.277	47.22	5.1E-09
At and after Chinese New Year	-2.275	61.258	2.5E-11
Weekdays (Monday, Wednesday, Friday)	-1.056	35.486	9.6E-08

Note: Dependent variable: Repo (7-day repo rate); sample period: 01 April 2003 to 12 April 2012. Included observations: 2197 after adjustments. Method: ML - ARCH (Marquardt) - Student's t-distribution. Null hypothesis: the coefficients of the selected subsets of variables are jointly zero.

Table 5: Standardized Residuals: ARCH Tests (Full Sample)

	F-Test	LM-Test
Lag	(p-value)	(p-value)
1	0.752	0.752
5	0.962	0.961
10	0.992	0.992
15	0.995	0.995
20	0.999	0.999
25	0.987	0.986
30	0.998	0.998
35	1.000	0.999
40	1.000	1.000
45	1.000	1.000
50	1.000	1.000

Note: Null hypothesis: there is no ARCH effect up to order q in the residuals. The F-statistic is an omitted variable test for the joint significance of all lagged squared residuals. The LM test statistics are computed as the number of observations times the R-squared from the test regression.

Figure 7: Standardized Residuals (Full Sample)

Table 6: Estimated GARCH Parameters (Subsample: April 2003 to October 2007)

	Coefficient	**Std. error**	**z-statistic**	**p-value**
Mean equation				
C	-0.130*	0.026	-5.014	0.000
Repo (-1)	1.344*	0.022	62.484	0.000
Repo (-2)	-0.160*	0.038	-4.288	0.000
Repo (-3)	-0.315*	0.038	-8.304	0.000
Repo (-4)	0.165*	0.033	5.057	0.000
Repo (-5)	-0.040*	0.018	-2.143	0.032
Administered lending rate	0.050*	0.010	5.202	0.000
Administered deposit rate	-0.063*	0.013	-5.023	0.000
OMO	2.5E-05	1.8E-05	1.402	0.161
RR	2.0E-04*	9.5E-05	2.068	0.039
RR announcement	0.056	0.039	1.428	0.153
IPO	2.1E-04	5.5E-04	0.388	0.698
Liquidity effects (see Table 7)				
Variance equation				
C	-0.621*	0.166	-3.734	0.000
ARCH effect (-1)	1.578†	0.882	1.789	0.074
Asymmetric effect(-1)	0.223	0.164	1.357	0.175
GARCH effect (-1)	0.922*	0.010	92.007	0.000
Δ in Administered lending rate	18.876*	4.707	4.010	0.000
Δ in Administered deposit rate	-17.889*	4.479	-3.994	0.000
OMO	0.002	0.002	1.401	0.161
RR	-0.009*	0.003	-3.215	0.001
RR announcement	3.423*	0.773	4.428	0.000
IPO	0.002	0.015	0.156	0.876
IPO(+5)	0.009	0.014	0.677	0.498
IPO(+10)	0.038*	0.012	3.110	0.002
Liquidity effects (see Table 7)				
T-DIST. DOF	2.06*	0.072	28.728	0.000

R-squared	0.930	Adjusted R-squared	0.928
S.E. of regression	0.193	Sum-squared residual	40.000
Log likelihood	2222.893		
Akaike info criterion	-3.856	Schwarz criterion	-3.518
Hannan-Quinn criterion	-3.729	Durbin-Watson statistics	2.128

Note: Dependent variable: Repo (7-day repo rate); sample period: 01 April 2003 to 12 October 2007. Included observations: 1114 after adjustments. Method: ML - ARCH (Marquardt) - Student's t-distribution. '*' indicates significance at 5% level, and '†' indicates significance at 10% level.

Table 7: Estimated Liquidity Effects (Subsample: April 2003 to October 2007)

Lag	Mean equation		Variance equation	
	Coefficient	p-value	Coefficient	p-value
Day of week				
Monday	-1.1E-05	0.990	-0.896*	0.000
Wednesday	1.0E-04	0.905	-0.132	0.621
Friday	2.4E-04	0.835	0.616*	0.010
End of month				
5	8.8E-04	0.504	-0.045	0.879
4	8.2E-05	0.948	-0.401	0.236
3	8.0E-04	0.581	-0.448	0.185
2	0.001	0.556	0.062	0.866
1	0.003	0.023	-0.316	0.366
0	-0.003	0.149	-0.702*	0.031
-1	0.004†	0.051	0.084	0.820
-2	0.003	0.130	0.341	0.359
-3	0.004*	0.041	0.132	0.729
-4	0.001	0.423	-0.123	0.748
-5	0.005*	0.000	-0.408	0.221
Chinese New Year				
5	-0.013	0.136	-2.571*	0.029
4	0.002	0.936	0.611	0.724
3	-0.003	0.916	0.458	0.786
2	0.083*	0.028	-0.813	0.685
1	0.153*	0.000	1.750	0.473
0	-0.511*	0.000	-1.906	0.378
-1	-0.061	0.882	1.367	0.497
-2	0.320	0.207	-0.132	0.930
-3	0.081	0.465	4.130*	0.012
-4	0.062*	0.000	2.143	0.110
-5	0.003*	0.001	-3.914*	0.008

Note: Dependent variable: Repo (7-day repo rate); sample period: 01 April 2003 to 12 October 2007. Included observations: 1114 after adjustments. Method: ML - ARCH (Marquardt) - Student's t-distribution. '*' indicates significance at 5% level, and '†' indicates significance at 10% level.

Table 8: Estimated GARCH Parameters: Robustness–Liquidity Injection

	Real liquidity injection	Combined monetary policy variable
Mean equation		
C	-0.040*	-0.033*
Repo (-1)	1.151*	1.141*
Repo (-2)	-0.065*	-0.060*
Repo (-3)	-0.143*	-0.142*
Repo (-4)	0.081*	0.072*
Repo (-5)	-0.027†	-0.015
Administered lending rate	0.015*	0.012*
Administered deposit rate	-0.019*	-0.014*
Real OMO	0.004*	
Real RR	0.002	
Real OMO+RR		0.004*
RR announcement	0.065*	0.061*
Real IPO	0.047	0.037
Liquidity effects (see Table 9)		
Variance equation		
C	-0.093	-0.177†
ARCH effect (-1)	1.569†	1.296*
Asymmetric effect(-1)	0.386†	0.347†
GARCH effect (-1)	0.969*	0.969*
Δ in Administered lending rate	7.910*	6.962*
Δ in Administered deposit rate	-8.597*	-7.481*
Real OMO	0.208*	
Real RR	-0.121†	
Real OMO+RR		0.049
RR announcement	2.110*	2.066*
IPO	-0.773	-0.725
IPO(+5)	-0.082	0.114
IPO(+10)	3.256*	3.406*
Liquidity effects (see Table 9)		

Note: Dependent variable: Repo (7-day repo rate); sample period: 01 April 2003 to 12 April 2012. Included observations: 2197 after adjustments. Method: ML - ARCH (Marquardt) - Student's t-distribution. '*' indicates significance at 5% level, and '†' indicates significance at 10% level.

Table 9: Estimated Liquidity Effects: Robustness–Liquidity Injection

Lag	Mean equation		Variance equation	
	Real liquidity injection	Combined monetary policy variable	Real liquidity injection	Combined monetary policy variable
Day of week	*Coefficient*			
Monday	-7.4E-04	-8.3E-04	-0.734*	-0.667*
Wednesday	-2.8E-04	-2.9E-04	-0.484*	-0.396*
Friday	1.7E-04	1.6E-04	0.073	0.221
End of month	*Coefficient*			
5	3.2E-04	1.1E-05	0.002	0.039
4	-6.4E-04	-0.001	-0.418†	-0.362
3	9.0E-04	7.1E-04	-0.545*	-0.595*
2	-2.0E-04	-5.5E-04	0.161	0.147
1	0.001	0.001	-0.545*	-0.547*
0	-0.003	-0.003	-0.255	-0.283
-1	0.005*	0.005*	-0.188	-0.170
-2	0.002	0.002	0.564*	0.568*
-3	0.004*	0.004*	-0.251	-0.251
-4	0.001	0.002	-0.107	-0.024
-5	0.003*	0.003*	-0.074	-0.120
Chinese New Year	*Coefficient*			
5	-0.015	-0.016	-1.097	-1.053
4	-0.005	-0.011	1.197	1.321
3	0.005	0.006	-0.141	-0.275
2	0.036*	0.038*	-2.029*	-2.113*
1	0.065*	0.064	-0.113	-0.143
0	-0.470*	-0.463*	0.022	0.067
-1	0.015	0.019	-0.002	0.033
-2	0.343*	0.345*	0.920	0.955
-3	0.090*	0.091*	2.566*	2.741*
-4	0.061*	0.061*	-1.273†	-1.116†
-5	0.004	0.003	-0.110	-0.112

Note: Dependent variable: Repo (7-day repo rate); sample period: 01 April 2003 to 12 April 2012. Included observations: 2197 after adjustments. Method: ML - ARCH (Marquardt) - Student's t-distribution. '*' indicates significance at 5% level, and '†' indicates significance at 10% level.

Table 10: Estimated GARCH Parameters: Robustness–Interest Rates

	Lending rate	**Deposit ate**	**Spread**
Mean equation	Coefficient		
C	-0.004	0.010*	-0.022†
Repo (-1)	1.149*	1.168*	1.162*
Repo (-2)	-0.065*	-0.078*	-0.075*
Repo (-3)	-0.096*	-0.126*	-0.115*
Repo (-4)	0.046*	0.069*	0.056*
Repo (-5)	-0.036*	-0.034*	-0.030*
Administered lending rate	0.001		
Administered deposit rate		-0.004†	
Interest rate spread			0.007†
OMO	3.5E-05*	3.2E-05†	3.7E-05*
RR	4.1E-05	3.2E-05	3.6E-05
RR announcement	0.065*	0.067*	0.066*
IPO	5.0E-04	5.3E-04	4.9E-04
Liquidity effects (see Table 11)			
Variance equation	Coefficient		
C	-0.077*	-0.103	-0.062*
ARCH effect (-1)	1.602†	1.389†	1.632†
Asymmetric effect(-1)	0.444†	0.388†	0.427†
GARCH effect (-1)	0.972*	0.970*	0.971*
Δ in Administered lending rate	-0.860		
Δ in Administered deposit rate		-0.888	
Interest rate spread			6.786*
OMO	0.002*	0.002*	0.002*
RR	-0.001*	-0.001	-0.001
RR announcement	1.953*	1.969*	2.141*
IPO	-0.009	-0.008	-0.010
IPO(+5)	-3.4E-04	-3.6E-04	-1.0E-04
IPO(+10)	0.029*	0.030*	0.029*
Liquidity effects (see Table 11)			

Note: Dependent variable: Repo (7-day repo rate); sample period: 01 April 2003 to 12 April 2012. Included observations: 2197 after adjustments. Method: ML - ARCH (Marquardt) - Student's t-distribution. '*' indicates significance at 5% level, and '†' indicates significance at 10% level.

Table 11: Estimated Liquidity Effects: Robustness–Interest Rates

Lag	Mean equation			Variance equation		
	Lending rate	Deposit rate	Spread	Lending rate	Deposit rate	Spread
Day of week	*Coefficient*					
Monday	-5.7E-04	-3.9E-04	-6.9E-04	-0.687*	-0.680*	-0.745*
Wednesday	-1.7E-04	-1.4E-04	-2.1E-04	-0.409*	-0.423*	-0.481*
Friday	1.5E-06	2.6E-04	1.3E-04	0.050	0.058	0.037
End of month	*Coefficient*					
5	3.8E-04	4.5E-04	2.6E-04	0.005	-0.008	0.017
4	-8.6E-04	-8.9E-04	-9.8E-04	-0.382	-0.370	-0.408†
3	6.3E-04	7.0E-04	8.3E-04	-0.499*	-0.503*	-0.511*
2	-5.4E-04	-2.7E-04	-4.7E-04	0.111	0.103	0.105
1	6.3E-04	0.001	7.6E-04	-0.510*	-0.501*	-0.501*
0	-0.003	-0.003	-0.003	-0.220	-0.244	-0.260
-1	0.004*	0.004*	0.004*	-0.227	-0.189	-0.222
-2	0.001	0.002	0.002	0.542*	0.559*	0.556*
-3	0.004*	0.004*	0.003*	-0.200	-0.220	-0.218
-4	0.002	0.002	0.001	-0.129	-0.130	-0.104
-5	0.003*	0.003*	0.003	-0.005	-0.012	-0.051
Chinese New Year	*Coefficient*					
5	-0.018*	-0.016*	-0.017*	-1.390*	-1.250†	-1.218†
4	0.003	0.002	-7.9E-05	1.218	1.062	1.081
3	-9.1E-04	-2.5E-04	0.003	-0.328	-0.073	0.051
2	0.026	0.033*	0.032*	-1.993†	-2.031*	-2.295*
1	0.046	0.063†	0.058	0.251	0.035	0.121
0	-0.476*	-0.475*	-0.476*	-0.187	-0.033	-0.072
-1	0.011	0.007	0.008	0.173	0.223	0.179
-2	0.343*	0.342*	0.342*	0.060	0.238	0.383
-3	0.089	0.089	0.089†	2.669*	2.724*	2.735*
-4	0.060*	0.060*	0.060*	-0.584	-0.899	-0.983
-5	0.004	0.004	0.004	0.214	0.053	0.098

Note: Dependent variable: Repo (7-day repo rate); sample period: 01 April 2003 to 12 April 2012. Included observations: 2197 after adjustments. Method: ML - ARCH (Marquardt) - Student's t-distribution. '*' indicates significance at 5% level, and '†' indicates significance at 10% level.

A Data Appendix: Data Source

1. China interbank interest rates:
   The 7-day call-loan and repo (Interbank repurchase bond) series are drawn from Haver Analytics and the CEIC Premium China Database. The ticker identifier for these three interbank interest rates are CDOBC, CDODM and CDODA, respectively. The three series are nominal and are measured in per cent per annum.

2. 1-year administered (benchmark) deposit and lending rates:
   The 1-year administered deposit (CDDAD) and lending rates (CDLBA) are taken from Haver Analytics and the CEIC Premium China Database. The administered interest rates are nominal and are measured in per cent per annum.

3. Measure of open market operations:
   The measure of open market operations captures the level of net liquidity injection from the expiration of repos and PBC central bank bills (expiration less issuance), and the issuance of reverse repos. The data series on open market operations and reserve requirements are taken from Haver Analytics and the CEIC Premium China Database. Repos are issued at 7-day (CDOHBE), 14-day (CDOHBF), 21-day (CDOHBG), 28-day (CDOHBH), 84-day (CDOHBI), 91-day (CDOHBJ) and 182-day (CDOHBK) maturities. Reverse repos are issued at 14-day (CDOHBT) and 21-day (CDOHBU) maturities. The issuance of PBC central bank bills is typically at 3-month (CDOHAA), 6-month (CDOHAB), 1-year (CDOHAC) and 3-year (CDOHAD) maturities. The data series are measured in millions of RMB.

4. Measure of reserve requirements:
   The variable reserve requirement measures the liquidity injected from a fall in required reserves. We construct the variable using data on the required reserve ratio (CMAAAA) and deposits in financial institutions (local and foreign currency) (CKAHNC). The required reserve ratio is measured in per cent per annum and the deposit data are measured in billions of RMB. The change in the liquidity condition is then constructed as the change in the reserve requirement ratio times the deposit base. Given that changes in reserve requirements are usually announced one or two weeks before the effective date, we also construct a dummy to capture the announcement effect of reserve requirement changes, where the dummy is equal to the change in the reserve requirement ratio on the date of the announcement.

5. IPOs:
   The data source on IPO volumes in China is the website Stockstar (http://resource.stockstar.com/DataCenter/StockData/IPODataList.aspx, in Chinese, last accessed 8 May 2012). We construct two IPO series: for the first series (funds raised), we aggregate the total amount of funds raised from IPO activities on a particular listing day to construct a daily time series for IPO volume; for the

second series (funds frozen), we aggregate the total amount of funds frozen on the application date, ahead of the IPO date. Note that the application date for an IPO is typically one or two weeks ahead of the actual IPO date. Large amounts of funds are frozen one day after the application date and the portion of funds that are unsuccessful in bidding are released four days after the application date. (See http://www1.cfi.cn/bcA0A1A8A194A1792.html for details on IPO issuance in China, in Chinese).

References

ALEXANDER, W. E., C. ENOCH, AND T. J. T. BALIO (1995): "The Adoption of Indirect Instruments of Monetary Policy," IMF Occasional Papers 126, International Monetary Fund.

AZIZ, J. (2007): "Rebalancing China's Economy: What Does Growth Theory Tell Us?," IMF Working Papers 06/291, International Monetary Fund.

BARTOLINI, L., G. BERTOLA, AND A. PRATI (2001): "Banks' reserve management, transaction costs, and the timing of Federal Reserve intervention," *Journal of Banking & Finance*, 25(7), 1287–1317.

BARTOLINI, L., AND A. PRATI (2006): "Cross-country differences in monetary policy execution and money market rates' volatility," *European Economic Review*, 50(2), 349–376.

CASSOLA, N., AND N. J. PORTER (2011): "Understanding Chinese Bond Yields and their Role in Monetary Policy," IMF Working Papers 11/225, International Monetary Fund.

CHRISTIANO, L., R. MOTTO, AND M. ROSTAGNO (2010): "Financial factors in economic fluctuations," ECB Working Papers 1192, European Central Bank.

DEMIRGUC-KUNT, A., AND E. DETRAGIACHE (2001): "Financial Liberalization and Financial Fragility," in *Financial Liberalization*, ed. by P. H. Gerard Caprio, and J. E. Stiglitz.

FEYZIOGLU, T., N. J. PORTER, AND E. TAKATS (2009): "Interest Rate Liberalization in China," IMF Working Papers 09/171, International Monetary Fund.

FREIXAS, X., AND J.-C. ROCHET (2008): *Microeconomics of Banking, 2nd Edition*. The MIT Press.

GEIGER, M. (2006): "Monetary Policy in China (1994-2004): Targets, Instruments and Their Effectiveness," Wuerzburg Economic Working Paper 68, University of Wurzburg.

GERTLER, M., AND N. KIYOTAKI (2010): "Financial Intermediation and Credit Policy in Business Cycle Analysis," in *Handbook of Monetary Economics*, ed. by B. M. Friedman, and M. Woodford. Elsevier.

HAMILTON, J. D. (1996): "The Daily Market for Federal Funds," *Journal of Political Economy*, 104(1), 26–56.

IMF (2010): "People's Republic of China: 2010 Article IV Consultation-Staff Report," IMF Country Report 10/238, International Monetary Fund.

Maino, R., and B. Laurens (2007): "China: Strengthening Monetary Policy Implementation," IMF Working Papers 07/14, International Monetary Fund.

Mandelbrot, B. (1963): "The Variation of Certain Speculative Prices," *Journal of Business*, 36, 394.

McCallum, B. T. (1988): "Robustness properties of a rule for monetary policy," *Carnegie-Rochester Conference Series on Public Policy*, 29(1), 173–203.

McCallum, B. T. (2003): "Japanese monetary policy, 1991-2001," *Economic Quarterly*, (Win), 1–31.

Mehrotra, A., T. Koivu, and R. Nuutilainen (2008): "McCallum rule and Chinese monetary policy," BOFIT Discussion Papers 15/2008, Bank of Finland, Institute for Economies in Transition.

Moschitz, J. (2004): "The determinants of the overnight interest rate in the euro area," ECB Working Papers 393, European Central Bank.

Nelson, D. B. (1991): "Conditional Heteroskedasticity in Asset Returns: A New Approach," *Econometrica*, 59(2), 347–70.

Porter, N. J., and T. Xu (2009): "What Drives China's Interbank Market?," IMF Working Papers 09/189, International Monetary Fund.

Prati, A., L. Bartolini, and G. Bertola (2003): "The overnight interbank market: Evidence from the G-7 and the euro zone," *Journal of Banking & Finance*, 27(10), 2045–2083.

Qin, D., P. Quising, X. He, and S. Liu (2005): "Modeling monetary transmission and policy in China," *Journal of Policy Modeling*, 27(2), 157–175.

Quiros, G. P., and H. R. Mendizabal (2006): "The Daily Market for Funds in Europe: What Has Changed with the EMU?," *Journal of Money, Credit and Banking*, 38(1), 91–118.

Terasvirta, T. (2009): "An introduction to univariate GARCH models," in *Handbook of Finanical Time Series*, ed. by T. G. Andersen, R. A. Davis, J.-P. Kreip, and T. Mikosch.

Xu, Z. (2006): "China's Money Markets: Policies and the Banks," in *China's Financial Markets: An Insider's Guide to How the Markets Work*, ed. by S. N. Neftci, and M. Y. Menager-Xu. New York: Academic Press.