Monetary policy transmission on the yield curve in China during the financial Crisis

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Abstract

With the gradual liberalization of the Chinese financial system, the interbank bond market is playing an increasing role in macro management, fund allocation and risk management. The objective of this paper is to help understanding the mechanisms and the efficiency of monetary policy transmission in China via the management of expectations reflected in the term structure of interest rates. However, the conduct of monetary policy significantly differs from the one in developed countries, in its use of a mixture of price- and quantity-based instruments. The transmission mechanisms are quantified through an EGARCH model focusing on the recent global financial crisis. Indeed, the 2006-2011 period allows us to evaluate how changes in the monetary policy stance transmit across the yield curve according to the business cycle. Results show that bond yields are most sensitive to changes in the benchmark deposit interest rate, also respond to changes in the announced reserve requirements, but are not particularly reactive to open market operations. However, results show differences in the ability of each instrument to affect the term structure of interest rates, depending on the monetary policy stance and the macroeconomic situation in China.

Key words: Monetary Policy Transmission, People's Bank of China, Bond Market, EGARCH

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1. Introduction

With the launching of the Twelfth Five-Year Plan in 2011, the Chinese government set out new objectives to rebalance its economy, aiming at sustaining growth with more equitable wealth distribution. One of the top priorities of this new Chinese plan is also to continue, even to accelerate, the process of financial opening and reforms. China is in the process of gradual liberalization of its financial system from a planned to a market-oriented system and the interbank bond market is playing an increasing role in macro management, fund allocation and risk management. Therefore, the existence of a common benchmark yield curve grounded on a liquid governement bond market is a key element for the banking sector to reach efficient capital allocation and also for policy makers to gauge market expectations. Moreover, a large part of the literature has demonstrated the ability of the yield curve to explain future economic activity and inflation.

The term structure of interest rates, which involves a set of bonds yields of different maturities, describes the relationship among short-term, medium-term and long-term rates at a given point in time. Monetary transmission is complex, operating through many diverse channels. A large part of the literature on China has focused on the transmission to the money market rates. However, it is more appropriate to consider the impact on medium- to long-maturity yields since they are the fondamental conduits for the transmission of monetary policy. Indeed, as rightly portrayed by Svensson (2004) “monetary policy is to a large extent the management of expectations”. Along similar lines, Bernanke (2004) stresses that “monetary policy works largely through indirect channels, in particular by influencing private-sector expectations and thus long-term interest rates”. As pointed out by Kozicky and Tinsley (1998)[15], monetary policy affects the real economy since the long-maturity interest rates reflect the opportunity cost of investment and consumption. In other words, the monetary policy transmission mechanism operates through the impact of monetary instruments across the yield curve.

A large part of the literature has focused on the effects of monetary policy on the yield curve, but mostly in advanced economies. Among other works, Bernanke and Blinder (1992)[2], Estrella and Hardouvelis (1991)[6] and Mishkin (1990)[17] argue that monetary policy is a major factor in the movements of the yield curve. It is also often considered as a predictor of future real economic activity such as consumption and investment. However, few papers have dealt with the effect of monetary policy on the bond yield market in China. For instance, Fan and Johansson (2009)[8] show that monetary policy variables have a significant impact on yield changes. However, the understanding of this issue can be improved at several levels.

The objective of this paper is to evaluate how monetary policy transmits to the yield curve in China. More precisely, it aims at assessing if exogenous monetary policy shocks affect the shape of the yield curve in the same way as in OECD countries and what instruments are most efficient in this respect. In fact, to explore the effectiveness of the transmission mechanism of monetary policy in China’s case, it is crucial to well understand the specificities of the Chinese bond market and more importantly of the conduct of monetary policy. Indeed, the monetary policy led by the Central Bank of China, the People's Bank of China (PBoC), has its own characteristics and differs significantly from that of the US and Europe. As an example, while the US Federal Reserve adjusts the monetary policy through the Fed Fund rates, the PBoC uses a mixture of price- and quantity-based policy instruments. Then, a remarkable feature of the PBoC’s monetary policy is that the main monetary policy instruments have varied greatly over time. In addition, China is in a gradual process of interest rate liberalization and the national interbank bond market is not yet very developed, which could improve the efficiency of monetary policy and reduce uncertainties (Chen, Chen and Gerlach (2010)[3]).

The recent literature on China's monetary policy typically focuses on how the performance of the monetary policy transmission can be hampered by the functioning of the Chinese financial system, such as the degree of financial repression (Qin et al, 2005[23]; Fan and Zhang, 2007[9]; He and Pauwels, 2008[13]; Shu and Ng, 2010[25] etc). However, this recent literature does not yet well explain how the transmission works across the yield curve, taking into account the specificities of the Chinese financial system.

Thus, understanding the efficiciency of the monetary policy transmission through movements of the yield curve and market expectations about future economic activity are challenging tasks in China's case. This paper follows a methodology initially used in the paper of Porter and Xu (2009)[22], modified by Garcia-Herrero and Girardin (2010)[11] and recently used by He and Wang (2011)[5], extending the research on the transmission of monetary policy to the interbank bond market. Indeed, the aim of this paper is to directly assess the effect of changes of monetary instruments on the interbank bond yield curve . The empirical analysis aims at comparing the relative influence of the main policy instruments across different bond yield maturities. The analysis is also deepened considering the different phases of the business cycle, particularly focusing on the recent global financial crisis, with shifts in the monetary policy stance between "`hawkish"' and "`dovish"' periods.

Our results provide strong evidence that the monetary policy transmission channel works quite well. More precisely, we show that bond yields are most sensitive to changes in the benchmark deposit interest rates and also respond to changes in the Reserve Requirement Ratio. However, results show that the effects differ over time and also according to the phase of the business cycle.

The paper is structured as follows. Section 2 reviews the theoretical rationales for the shape of the term structure of interest rates and the different factors and mechanisms (based on portfolio allocation and macroeconomic theory) which explain the movements of the yield curve. Section 3 highlights the institutional specificities of monetary policy and the particularities of the structure of the bond market in China. Section 4 describes the data and the methodology employed. Section 5 discusses the empirical results and Section 6 draws conclusions.

2. Standard transmission mechanisms of monetary policy to the yield curve

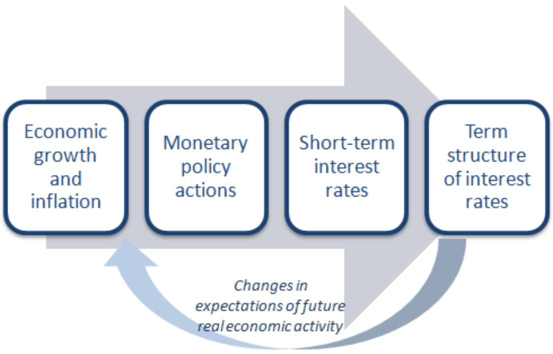
Over the last thirteen years, a significant part of the literature has been concerned about monetary policy transmission mechanisms in China. Most of them have focused on the short-term policy rate, whereas long-term bond rates are an essential transmission channel of the monetary policy (reflecting the opportunity cost of investment and consumption). Indeed, bond rates contain expectations of future policy rates, not recent monetary policy changes. Therefore, monetary policy effectiveness depends on the deformation of the yield curve which reflects new perceptions of future monetary policy.

The nominal yield on an n-period zero-coupon bond is described as:

$$R_{n,t} = \frac{1}{n}\sum_{j=0}^{n-1} f_{t,j} = \frac{1}{n}\sum_{j=0}^{n-1}(r_{t,j} + \gamma_{t,j}) \qquad (1)$$

With $f_{t,j}$ the average of forward rates, $r_{t,j}$ the expected policy rate in the jth period and $\gamma_{t,j}$ the time-varying forward rate term premium. The nominal bond rate is the average of the expected policy rate over the lifetime of the bond plus the time-varying forward rate term premium.

Academic observers have argued that monetary policy is a major factor in the movements of the yield curve. Among other works, Bernanke and Blinder (1992), Estrella and Hardouvelis (1991) and Mishkin (1990) explore the informational content of the spread between long-term ans short-term yields (as an indicator of monetary policy) to forecast future economic activity and future inflation in the US market. They find that the slope of the term structure appears to carry information about future inflation and also provide evidence that an inverted yield curve reflects expectations of a declining rate of inflation.



Evans and Marshall (1998) have explored how exogenous impulses to monetary policy affect the yield curve for nominally risk-free bonds. They shows that a contractionary policy shock induces a pronounced positive but transitory response in short-term interest rates (with a term premium increase), with a smaller effect on medium-term rates and almost no effect on long-term rates. This finding stands in contrast to the popular opinion that changes in monetary policy systematically affect long-term bond prices (the so-called Expectation Hypothesis).

A long standing empirical literature has shown that the Expectation Hypothesis (EH) is rejected across a number of countries. Indeed, empirical studies argue that the relationship between policy actions and long-term rates appears variable. Among other works, Campbell and Shiller (1991) suggest that the empirical failure may be due to an over-reaction of long rates to the expected change in short rates. In addition, Hardouvelis believes that large measurement errors can account for the forecast in the wrong direction. Cook and Hahn (1989)[4] examine the response of short-term and long-term rates to changes in the Federal Fund rates and conclude that such changes were followed by large movements in short-term interest rates, moderate movements in intermediate-term rates and small but significant movements in long-term rates. Finally, Rudebusch (1995)[24] finds similar results, providing evidence that US monetary policy affects short-term interest rates while the long-end of the yield curve is much less affected.

Fama (1986), Cook and Hahn (1989), among others, argue that a time-varying term premium correlated with the spread can explain the empirical failure of the Expectation Hypothesis. Mankiw and Miron (1986) believe that time-varying risk premia, change in risk perception, adjustments in relative asset supplies, measurement errors and near-rational, rather than rational, expectations, can play a role in explaining the empirical rejection of EH.

A common result of the standard modelling is that the yield curve is significantly influenced by monetary policy and market expectations about future policy but their effect varies across time and across maturities. Then, the transmission of monetary policy across the yield curve can also be altered by other factors linked to the behavior of investors.

Firstly, the magnitude of the response of long-term rates to policy actions clearly depends on the expected persistence of such actions and may vary over the business cycle (Labadie, 2002). Roley and Sellon (1995) argue that the relationship between policy actions and long-term rates is likely to vary over the business cycle as financial market participants alter their views on the persistence of policy actions. Therefore, the reaction of long-term rates is likely to be much more variable than the response of short-term rates as uncertainties about future policy actions increase as maturity lengthens. For example, in the early stages of policy tightening, investors may foresee that the PBoC would renew its policy to moderate economic activity and lower future inflation. Their perceptions would imply that the change in long-term rates may fully reflect or even exceed the current change in the monetary policy instruments. At the opposite end of the cycle phase, if investors believe that inflation and economic activity have reached their target levels and that additional policy tightening is not likely to occur, while short-term rates may fully react to policy changes, long-term rates may respond very little or even decline. These examples highlight that the response of long-term rates to monetary policy depends on market perceptions of future policy actions.

Inflation expectations are generally considered as an important factor affecting long-term interest rates. More importantly, if the central bank usually does not allow inflation moving away from its target, this would keep long-term interest rates down since investors would demand only a small interest rate premium above the inflation rate. Conversely, if uncertainties about the risk of a rise of inflation increase, market participants would demand a higher interest rate as compensation of the risk they bear. Kozicki and Tinsley (2007) show that, during periods of passive policy, bond rates may exhibit stable responses to inflation if time-varying term premiums incorporate inflation-dependent risk pricing or if future policy is anticipated to be active. The key role of time-varying term premiums for capturing time variation in yields has also been pointed out in several empirical works including Shiller, Campbell and Schoenholtz (1983), Duffee (2002) and Dai and Singleton (2002).

Therefore, the perception about the persistence of monetary policy can influence the movements in the yield curve. Interestingly, in recent years, an increasing amount of attention has been paid to the qualitative impact of monetary policy changes on stock returns and interest rates. Among other works, Durhan (2005), Bernanke and Kuttner (2005), Ehrmann and Fratzscher (2004) argue that only monetary policy surprises (by the timing of the magnitude) affect the stock market. This would result on a larger response of long-term rates due to the revision of investors' expectations of future policy actions. Andersson, Dillen and Sellin (2006) find that central bank speeches are a more important determinant for the longer end of the term structure. The efficiency of monetary policy is strongly related to monetary policy signaling, i.e. the way policy makers indicate their intentions through policy reports, speeches and other communication channels.

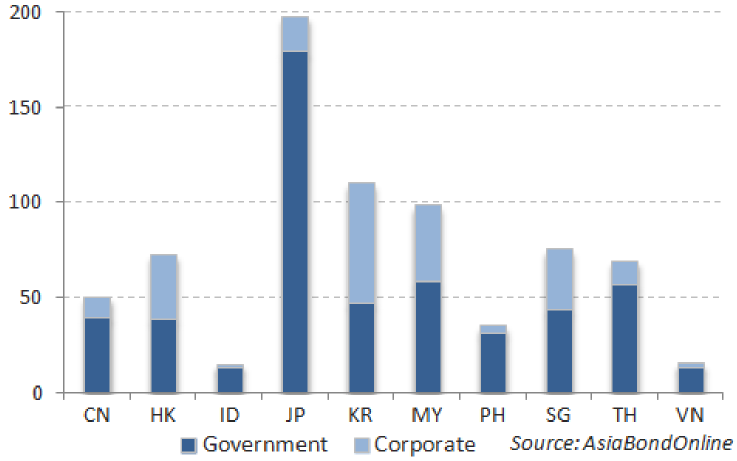
3. China-specific factors in understanding monetary policy transmission

The Chinese bond market cannot be analysed in exactly the same way as OECD bond markets for a number of reasons. The idiosyncrasy of the financial system organization as well as of the conduct of monetary policy in China may be responsible for a departure from the standard pattern in the transmission of monetary policy to the yield curve.

3.1. Structure of China's bond market

A key component of the Chinese financial system is the increasing role of the interbank market in relation with the substantial progress in financial market liberalization (Feyzioglu et al.(2009)[10]). Even if the bond market has been growing fast in the last few years, bond markets have generally been underdeveloped in East Asia (Figure 2).

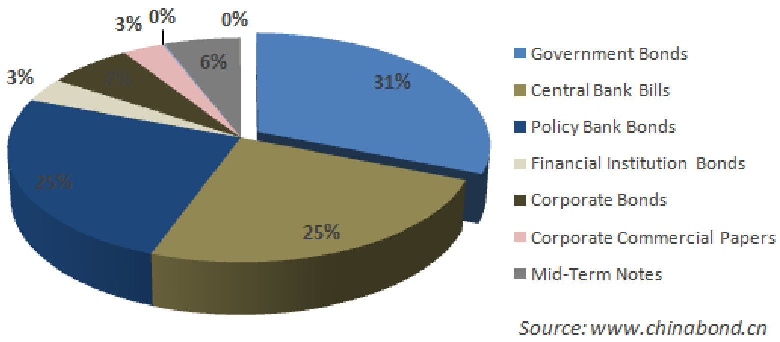
Figure 1: Size of LCY Bond Market in % GDP (Sep. 2011)



The total amount of bonds outstanding reached in May 2010 RMB 18.9 trillion (about 50% of GDP), which looks already large. However, bonds outstanding in China are much smaller than in neighboring markets such as Hong-Kong, South Korea, Malaysia and Thailand and it is one fourth of the size of the bond market in Japan. Only bond markets in Indonesia, Philippines and Vietnam appear to be less developed than the Chinese one. Nonetheless, the Chinese bond market has been growing very fast since 2004, faster than any other market in the region, with an annual growth between 15% and 45%.

China's bond market has been developing since the mid-1980s. It has developed into a multi-layered market, comprised of two segments: the national interbank market and the Exchange-traded market. The interbank market , established in 1996, is a quote-driven over-the-counter (OTC) market and is governed by the People's Bank of China (PBoC). Still modest in size, it has become the most active bond market (absorbing almost all trading in the second half of the 2000s) and plays an increasing role in macro management, fund allocation and risk management. Government bonds, central bank bills and policy bank bonds dominate in the total amound of bonds outstanding with respectively 31%, 25% and 25% of the total (Figure 3).

Figure 2: Bonds outstanding by type in May 2010



The Central bank bill is a short-term debt certificate issued to commercial banks, used very frequently to regulate the monetary base in the background of the persistent increase in China's foreign exchange reserves.

In this paper, the analysis of the transmission of monetary policy will focus on the interbank government bond market as it represents the most dynamic segment of the market in China. It is worth noting that banks remained the largest investors in this market, holding 60.4% of the total at mid-2010 and special members[2], 26.1%. Therefore, the understanding of the transmission of the monetary policy to the governement bond rates structure is examined through the strategy or the incentives of banks to invest on this market rather than lending to firms for instance.

Three recent papers have developed theoretical models based on the objective function of banks to explain the transmission mechanism of monetary policy in China to the money market, building on the model developed by Freixas and Rochet (2008): Porter and Xu (2009), Chen, Chen and Gerlach (2011), and He and Wang (2011). Each bank absorbs deposits (D_i) from households and makes loans (L_i) to firms in the loan market. The assets on the bank's balance sheet also include required reserves submitted to the central bank, according to the RRR (α) set by the PBoC, and excess reserves (E_i) deposited in the central bank. Aside from loans and reserves, each bank can buy central bank bills, and invest in bonds or other financial products in the money and bond markets. The most recent papers (Chen et al., He and Wang (2011)) analyse the transmission mechanism of monetary policy in China to the money market considering the complex financial system, and the latter especially attempt to extend the analysis to bond yields. However, these papers not explicitly integrated the Expectations Theory in the model to explain monetary policy mechanisms. Therefore, we differentiate in the formulation, the short-end (B_{ST} which include central bank bills) and the long-end (B_{LT}) of the yield curve. Because it is a competitive market, each bank is a price taker in this model.

Therefore, a bank's profit maximization function can be written as follows:

$$\pi_i = Max\{r_l L_i + r_e E_i + r_r \alpha D_i + r_{ST} B_{ST} r_{LT} B_{LT} - r_d D_i - C(D_i, L_i, E_i)\} \qquad (2)$$

where r_l is the lending rate of loans, r_d the deposit rate, r_e the rate paid on excess reserves set by the PBoC, r_r the interest rate paid on required reserves, r_{ST} the short-term bond yield and r_{LT} the long-term bond yield. $C(D_i, L_i, E_i)$ is the managing cost of the bank, which is a function of deposits, loans and excess reserves.

We argue that each component are interconnected, particularly analysing the Chinese financial system. Therefore, we will analyse step by step how exogenous changes in each main monetary policy instrument (r_l, α, r_d) can modify the strategy of Chinese banks. The rest of this section will concentrate on the link between the behavior of Chinese commercial banks, in terms of both capital allocation and the deformation of their expectations, and the different ways the PBoC conducts its monetary policy to explain the movements on the yield curve.

3.2. The conduct of monetary policy in China

According to the *Law on the People's Bank of China*, monetary policy has a dual mandate, aiming at maintaining the stability of the currency and thereby promoting economic growth. While not stated in the law, the PBoC has also the mandate to maintain the stability of the financial system. The conduct of monetary policy differs signicantly from the United States and Europe, which mostly focuses on the interbank market rate, as the PBoC relies on a mix of price- and quantity-based market instruments to control the volume and composition of credit flows. These instruments are described as follows:

[2] Special members comprise the PBOC, Ministry of Finance, policy banks, China Government Securities Depository Trust and Clearing Co., and China Securities Depository and Clearing Corporation.

Table 1: Policy instruments used by PBoC

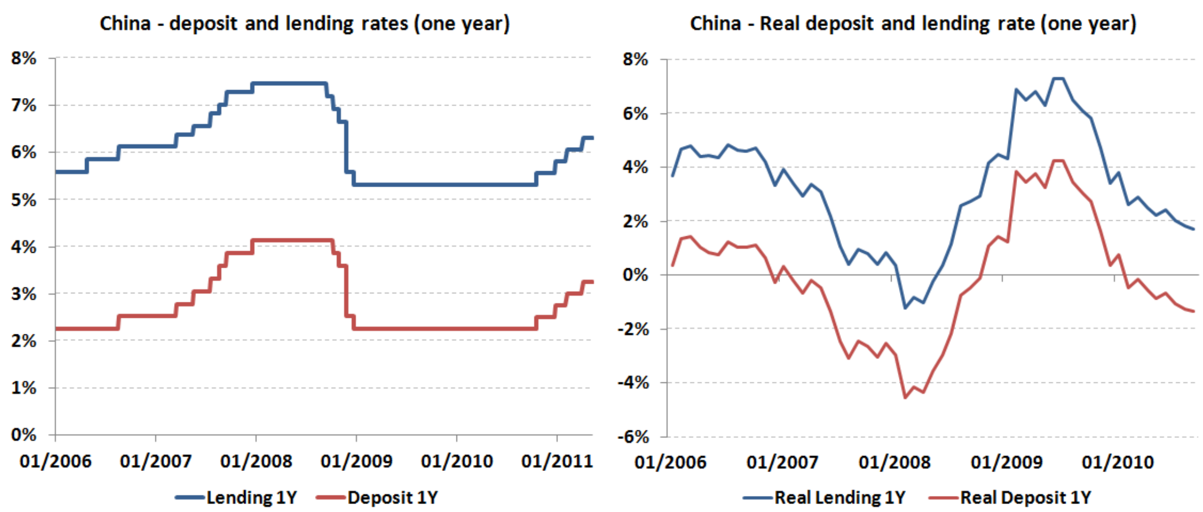
Price-based	Regulated deposit and lending rates
	Interest rates for required and excess reserves
	Rediscount rate
Quantity-based	Reserve Requirement Ratio (RRR)
	Open Market Operations (OMOs) (through central bank bill issuance)
	Credit controls

The credit supply is controlled by a system of credit quotas and "moral suasion". Other policy instruments, not easily observable, include foreign-exchange interventions, window guidance and administrative measures. Foreign-exchange interventions are used by the PBoC to influence the level of the renminbi exchange rate.

Price-based instruments (lending and deposit rates)

As a key component of the Chinese financial system, while the money and bond markets are now liberalized, deposit and lending rates remain regulated. There exists a deposit rate ceiling and a lending-rate floor in retail banking operations (even if they may not necessarily be binding in practice).

Figure 3: Regulated lending and deposit rates

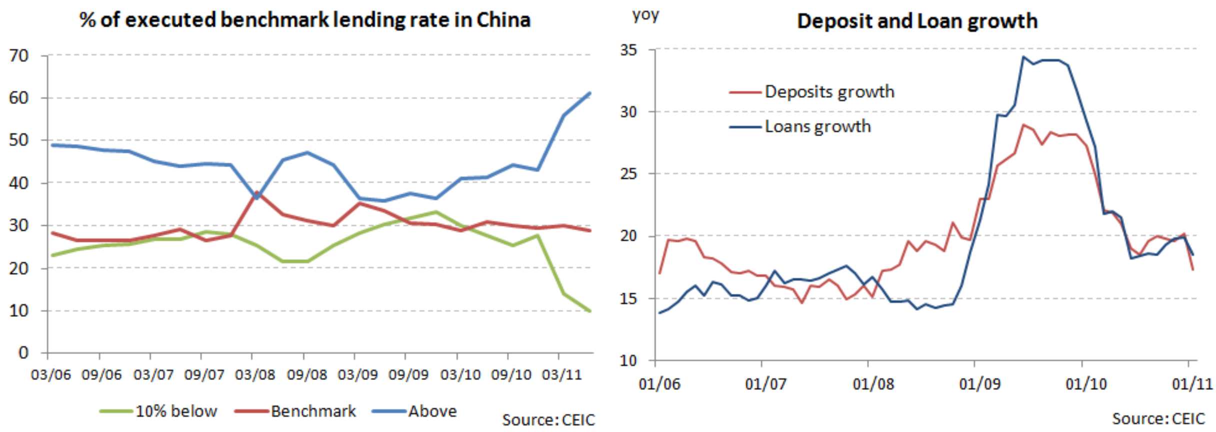


In general, adjustements on the benchmark deposit and lending rates are less frequent than changes on other instruments used by the PBoC. Over our considered sample (from 2006 to May 2011), PBoC has operated 15 changes on the benchmark deposit rate, with 7 increases before July 2008, 4 decreases from July 2008 to December 2009, no changes in 2009 and 4 changes from January 2010 to May 2011.

However, those changes are in general perceived to carry a larger weight than adjustments of the quantity-based instruments in signaling the strength of policy changes (He and Wang(2011)). In addition, the PBoC operates in general coordinated policy, shifting at the same date both benchmark lending and deposit rates in the same direction.

It is quite important to understand if both rates are binding in practice. Looking at the actual lending rates, data show that the percentage of loans made at the floor has been around 30% since 2006 whereas loans at above the floor rate concern from 40% to 60% of the total (at the beginning of 2011), which suggests that the lending-rate floor has not been particularly binding in practice (Figure 4).

Figure 4: Executed benchmark lending rate in China and evolution of the deposit and the lending growth



In parallel, the deposit-rate ceiling is generally considered binding (PBoC, 2009; Feyzioglu *et al.*, 2009; He and Wang, 2011). One consequence of imposing a deposit-rate ceiling is low and often negative real returns on household deposits, which implies an implicit tax on households.

Figure 3 shows that the increase in deposit and lending rates in 2007 was not as strong as the increase of inflation resulting in a large decrease of both real rates. Real deposit rates even became negative from January 2007 to October 2008. A second period beginning in 2010 shows a similar evolution with negative real deposit rates. Moreover, Ma, Xiandong and Xi (2011) explain that the net interest margin (which is the difference between interest income and interest expense over the earning assets) widely increased in 2007 and 2008, decreased during the financial crisis in 2009 and began to incease again in 2010. This means that, during tightening periods of monetary policy, banks have transferred a large part of their implicit tax on households.

This specific point well describes the so-called "`financial repression'" in China through interest rates control by the PBoC. Here, it is defined as the low and sometimes negative real return on deposits and loans, which directly impact households. Then, Lardy (1998) argues that the price of capital is far too low resulting in excess demand for banks loans and an increasing use of quantitative instruments to control credit growth. He and Wang (2011) find that low real deposit interest rate would shift down the level of the global term structure of interest rates under its equilibrium, an effect more pronounced when real interest rates are negative. He and Wang further show that raising the deposit-rate ceiling would lead to a rise in market rates if the deposit-rate ceiling is binding and the lending-rate floor is non-binding. We expect similar results on bond yields, meaning that an increase in the deposit-rate would lead to at least a rise in the short-end of the yield curve.

However, we can expect that an increase in deposit rate has no effect during the 'crisis period' as we observe that the loan rate widely increased during this period due the (unobservable) loosening of credit quotas.

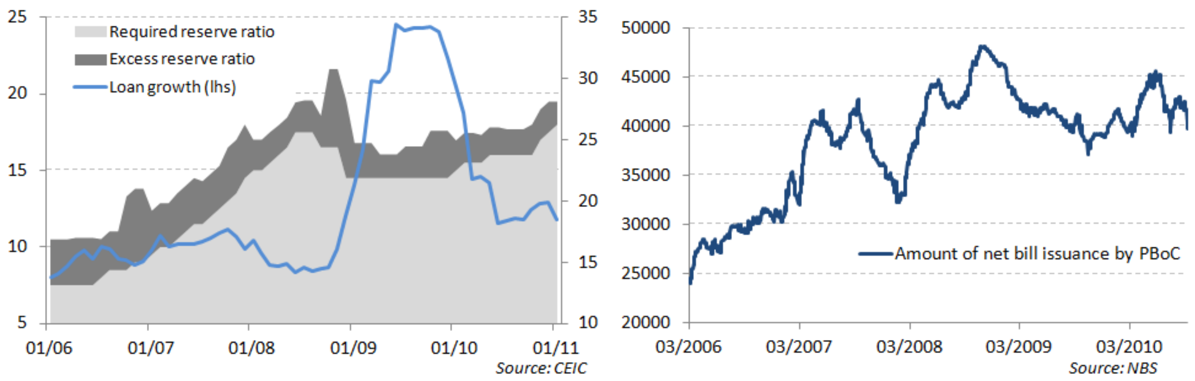
Quantity-based instruments (OMOs and RRR)

Open Market Operations (OMOs) were used very frequently over our sample in order to sterilize foreing-currency reserve inflows (the PBoc controls the amount, price and composition of central bank issuance) (Figure 5).

However, since late 2007, the central bank has increasingly used the reserve requirements to drain liquidity. Indeed, the ratio of required reservesto PBC bills outstanding stood at 6:1 in June 2011, compare to 1:1 in 2005 (Ma, Xiandong, Xi, 2011). The main reasons are related to the fact that the use of the reserve requirement ratio withdraws liquidity on a more permanent basis, is more cost efficient from the PBoC point of view and the remuneration rate on required reserves is lower than the one-year PBC bill yield.

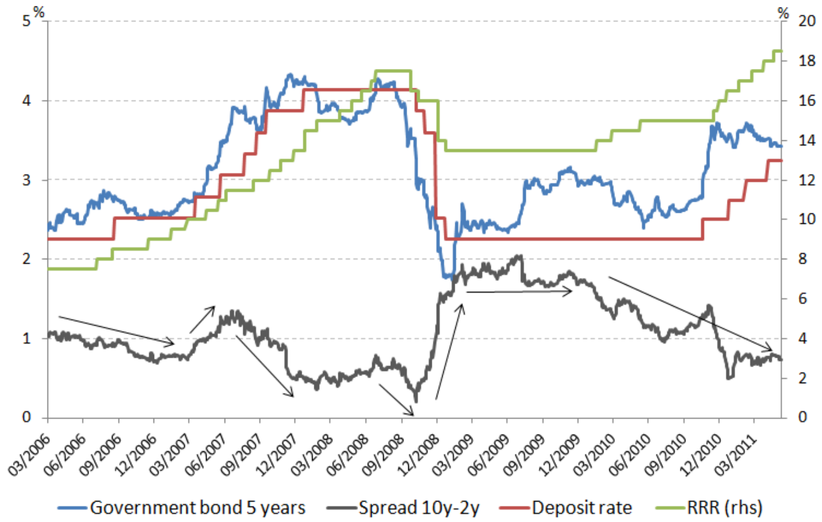
Over our sample, the RRR has been used 17 times between 2006 and July 2008, 4 times from July 2007 to end 2008, with no change in 2009 and 10 changes from January 2010 to May 2011, totalling 33 changes (twice as frequently as the benchmark deposit rate).

Figure 5: Reserve requirement ratio, excess reserves and OMOs



According to Ma, Xiandong and Xi (2011), there may be various interrelated channels for a RRR change to affect an economy's monetary conditions. A remarkable feature is that it is often difficult to isolate the effects of reserve requirements from other policy actions because, historically, we observe that both the policy rate and RRR are adjusted in the same direction (as observed in Figure 6), one after another, apparently aiming to reinforce the tightening or easing effects. This means that, first, an increase in RRR can signal a bias towards tightening and can transmit across the yield curve through corrected perceptions of future policy actions. We also document below that the annoucements of changes in RRR (in general 10 days before it becomes effective) are more significant to explain movements in the yield curve than the actual changes in RRR.

Figure 6: Evolution of main instruments and the spread of bond yields (10y-2y)



Second, if banks foresee that the PBoC will continue its tightening policy, they may adjust their portfolios in response to higher RRR resulting in more significant effects on the short-end of the yield curve. More importantly, we argue that changes in RRR have more effects on the yield curve if excess reserve levels decrease towards some minimum threshold (as in 2010 and 2011) which induce more tightened monetary conditions for banks. Accordingly banks have to modify their portfolio-allocation strategy to guarantee the holding of enough reserves to satisfy the future increase in RRR, for instance selling their short-term bonds, which flattens the yield curve by an increase in short-term yields. This is confirmed during the last two years with a decreasing spread between the long-term (10 years) and short-term (2 years) bond yields when the RRR rises.

Third, raising the RRR can limit monetary growth and squeeze excess reserves, potentially limiting banks' capacity to lend over time. This increase directly imposes a tax levy on banks, making bank credit costlier and thus tightening the monetary conditions (Borio and Disyatat, 2009). Indeed, on Figure 5, we observe that during phases with an increase in total reserves, total loan growth tends to stabilize to 10% per year, or even decrease, whereas loan growth sharply increases from September 2008 to August 2009 (the 'crisis period') with decreasing reserve requirements. It is worth noting that this period reveals the combinaison of various monetary policy instruments, decrease in regulated deposit and lending rate, reserve requirement ratio and loosening in credit quota.

A similar scenario to that of financial repression captured by the regulated interest rates can be repeated with the changes in RRR. Indeed, if banks attempt to transfer the tax levy to their customers by widening their loan-deposit rate spread (Montoro and Moreno, 2011), the effect on the yield curve will not be as significant as in the case where banks carry themselves the major part of the burden. According to the analysis made by Ma, Xiandong and Xi (2011), the China's RRR impled tax burden has evolved in recent years from 8% of GDP in 2006 to 35-37% of GDP in 2008 and 2010 (with a temporary decrease at 25% in 2009).

To conclude this section, we have seen that the strategy of banks maximizing profit from an arbitrage between reserves, loans gains, investment in the bond market and deposit costs cannot be interpreted independently. Moreover, the complex financial system can explain that there is no simple response of the term structure of interest rates to monetary policy changes, as the former depends on the instruments used by the PBoC (or their combinaison). In general, we argue that the response and also the magnitude on each segment (short-, medium- and long-term) could vary over time. Generally speaking, we expect that a policy action would have a more significant impact on the short-end of the yield curve, which is in contrast with the EH.

4. Empirical analysis

This section assesses for China the potential of each main monetary policy instruments to explain movements in the interbank bond yields at different maturities (2, 5, 7 and 10 years) selected to represent the short-, medium- and long-end of the yield curve. One important question is to evaluate if monetary policy shocks affect the different segments of the yield curve in the same way.

4.1. Model

One appropriate and frequently used model to estimate the impact of policy shocks on China's interbank bond rates is the exponential GARCH model (EGARCH) which allows asymmetric specification of conditional volatility. Indeed, volatility caused by negative shocks is usually higher than when shocks are positive . This model allows for rich specifications for both the time varying mean and volatility of the bond rates. We follow the methodology initially used by Porter and Xu (2009)[22] for interest rates in level and modified by Garcia-Herrero and Girardin (2010)[11] for the first difference of interest rates. For instance, as Chinese bond rates exhibit "fat-tails", we assume innovations in the EGARCH model with a generalized-error distribution (GED) suggested by Nelson (1991)[18]. The mean equation in the EGARCH model can be written as follows:

$$\Delta Y_t = \mu_t + (h_t)^{1/2} v_t \quad (3)$$

Where ΔY_t is the changes in government bond rates (which removes possible non-stationarity issues, a point missed by Porter and Xu, 2009) and $\mu_t = E\Delta Y_t | F_{t-1}$ is the conditional mean of ΔY_t given the information set F_{t-1}. h_t is the time-varying variance of the bond yield; v_t is an i.i.d. random variable with zero mean and unit variance. In this equation, μ_t is a function of the changes in the deposit rate (ΔDR), the reserve requirement ratio (ΔRRR), the announcement of changes in the RRR (ΔARRR) and the amount of net bill issuance by the PBoC (BILL). We omit in this estimation other instruments which are rarely used by the PBoC (such as interest rate on excess reserves) or not observable (such as credit quotas). Additional variables (Dummies) are included to take into account seasonalities: the Lunar-New-Year, the National-Day (on October 1, followed by around 5-days holidays) and May-Day vacations.

$$\mu_t = \beta_0 + \beta_1 \Delta DR_t + \beta_2 \Delta RRR_t + \beta_3 \Delta ARRR_t + \beta_4 BILL_t + \beta_5 Dummies_t \quad (4)$$

As described in the previous section, we would expect that bond yields would increase when the PBoC increases the benchmark deposit rate, the RRR and issues central bank bills (particularly when the deposit-rate ceiling is binding).

Then, the conditional volatility equation can be written as follows:

$$\ln(h_t) = a_0 + \sum_{n=1}^{p} \gamma_n \ln(h_{t-n}) + \alpha \left| v_{t-1}/h_{t-1}^{1/2} \right| + \lambda \left[v_{t-1}/h_{t-1}^{1/2} \right] + a_i X_{it} \quad (5)$$

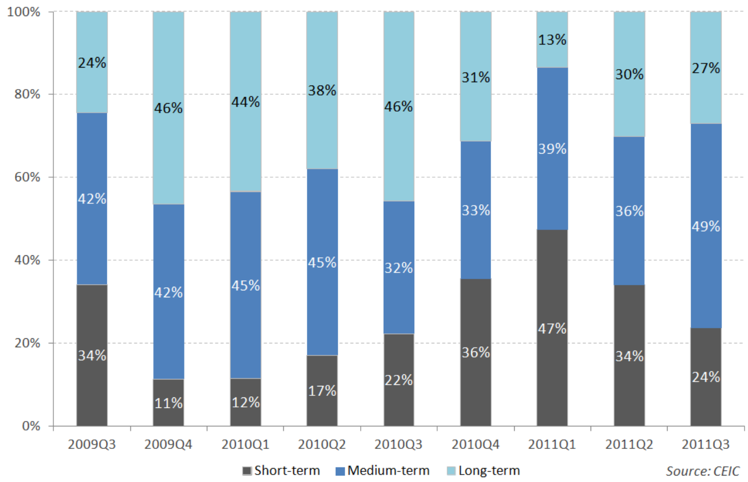
where the α terms is for the ARCH effect, the γ for GARCH term and the λ term indicates the presence of an asymmetry in the impact of either positive or negative innovations to the standardized residuals. Then, X includes all the exogenous variables of the mean equation but in absolute value.

4.2. Data

In this paper, we focus on major policy instruments used frequently by the PBoC: the RRR (observed and announced), the benchmark one-year deposit rate and central bank bill issuance, extracted from CEIC, using daily data from March 2006 to May 2011.

Then, we use daily data on “yield curve of Interbank Fixed rate Tbond”, considered as the bond yield benchmark in China, extracted from Wind over the same period (1250 observations) with maturities ranging from 1 to 10 years. Observations of longer-maturity bond yields are not introduced in our empirical analysis due to the lack of liquidity of such segments. Indeed, looking at Figure 7, the treasury bond interbank market is most active over the short- and medium-segments even if the breakdown varies over the time. For this reason, we select bond yields until the 10 year maturity.

Figure 7: Treasury bond turnover volume on interbank bond market by maturity

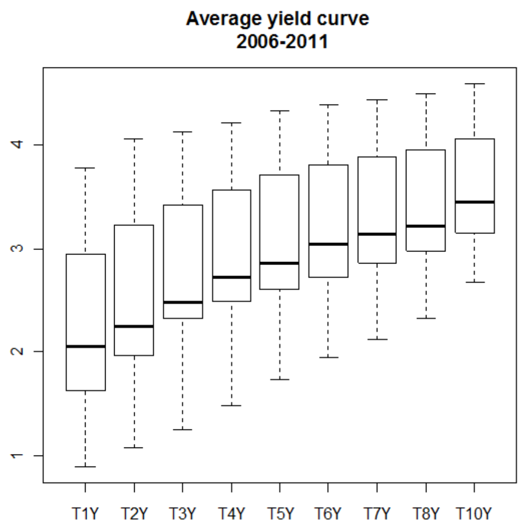


Bond yields series have standard statistical properties, that is non-stationarity, non-normality and strong correlation between maturities (over 80%) (see details in Appendix). Basic descriptive statistics also show that the median Chinese interbank bond yield curve is upward sloping and yield dynamics are highly persistent (Table 2). Then, we observe that the short-end of the yield curve is more volatile than the long-end (Figure 8).

Table 2: Descriptive Statistics on Chinese bond yields

Maturity (years)	Mean	Std. Dev.	$\rho(1)$
1	2.24	0.79	0.99
2	2.50	0.79	0.99
3	2.74	0.71	0.99
4	2.93	0.66	0.99
5	3.08	0.62	0.99
6	3.21	0.60	0.99
7	3.32	0.57	0.99
8	3.42	0.55	0.99
10	3.58	0.52	0.99

Figure 8: Average yield curve



At this stage, the objective of the paper is not to investigate the ability of yield curve movements to anticipate future macroeconomic developments but rather to dissect the monetary policy transmission to the yield curve under different circumstances, particularly during the recent global financial crisis. In this way, we break-down the March 2006 through May 2011 into three periods:

From March 2006 to July 2008 ('pre-crisis'): this period is characterized by continuing robust economic growth under a tightening monetary policy environment, particularly from mid-2007 to mid-2008. The slope of the term structure of interest rates is highly positive over this period and as is apparent in the Figure 8, characterized by a positive and parallel shift of the yield curve.

From July 2008 to March 2009 ('crisis period'): this period corresponds to substantial monetary easing against the background of the global financial crisis. Indeed, even if China was moderately impacted by the global crisis, the PBoC undertook a very strong (and unprecedented) cut in its main monetary policy instrument (as observed in Figure 3) to fight against the decline in real GDP growth and inflation. This accomodative policy stance led to a flattening of the yield curve and a strong decline in the level of yields followed by an increase in the slope directly explained by very low short-term interest rates.

From January 2010 to May 2011 ('post-crisis period'): the 'post-crisis' period denotes a progressive shift in monetary policy objectives, allowing weaker economic growth and a more important focus on the rise in inflation. This is revealed by the shape of the yield curve (Figure 9, third panel), with expectations of higher future short-term interest rates (an increase in interbank bond rates, particularly over the short-end of the yield curve which results in a flatter yield curve).

Figure 9: Box plots representing bond yield curves by sub-periods

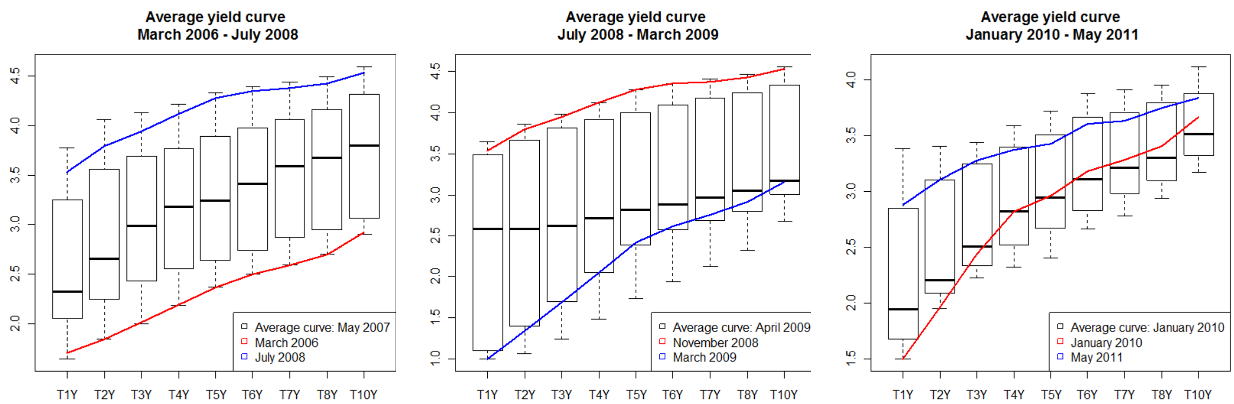
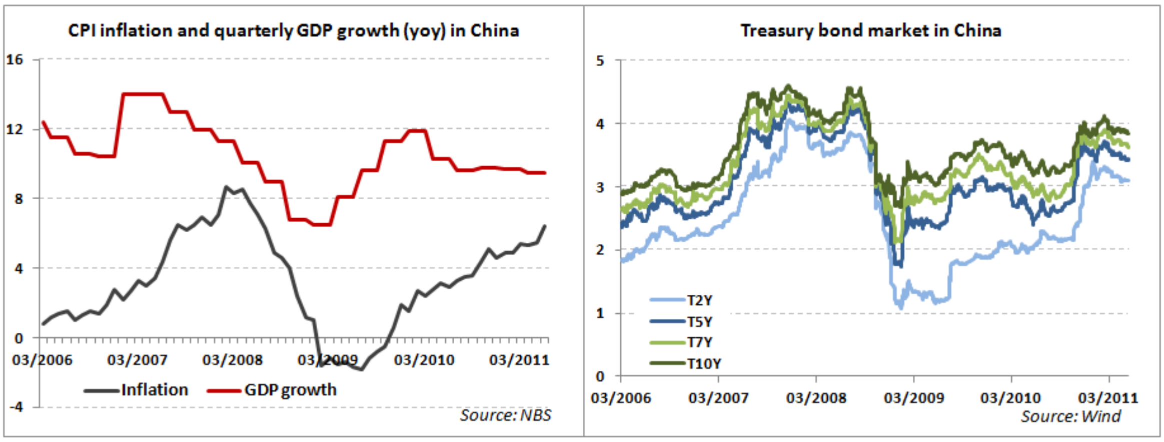


Figure 10 shows the pattern of movements in both bond yields and macroeconomic data in China. They emphasize a rather high correlation between treasury bond yields and macroeconomic variables.

Figure 10: Relation between bond yields and macroeconomic data in China



5. Empirical results

This section presents the results from our EGARCH estimates in order to understand how monetary policy changes transmit to the yield curve in China and if the impact is significant and similar across maturities. The model is applied to 'representative' Chinese bond yields: 2 years for short-term yields, 5 and 7 years for medium-term yields and 10 years for long-term yields. The analysis of the ACF-PACF of the government bond yields allows us to select 12 lags in the EGARCH model.

First, models show that the one-year deposit rate and RRR play a significant role in the movements of bond yields whereas preliminary analysis showed that the effect of net Central Bank bill issuance is insignificant (Table 3). As a consequence, net Central Bank bill issuance does not appear in the following results.

Over the whole sample (2006-2011), the magnitude of changes in interbank bond yields is larger when the benchmark deposit rate increases than with a rise in the RRR, which is consistent with previous research (for instance He and Wang(2011)). Then, our results show that the impact of deposit rate changes decreases across the term structure of interest rates. Indeed, the long-end of the yield curve is less sensitive to monetary policy changes than the short-end of the curve.

Secondly, the elasticity of bond yields to each monetary instrument varies over time and its magnitude also differs. For instance, we identify differencies in the ability of each instrument to affect the term structure of interest rates, related to the monetary policy stance. Indeed, results show that interbank bond rates are most sensitive to changes in the benchmark deposit rate during hawkish monetary policy periods (first and third subperiods) whereas RRR seems to significantly affect the bond yield curve during the dovish period ('the crisis-period'). The latter results is not surprising as loosening credit quotas combined with cuts in RRR have surely mostly impacted the bond yields over this period.

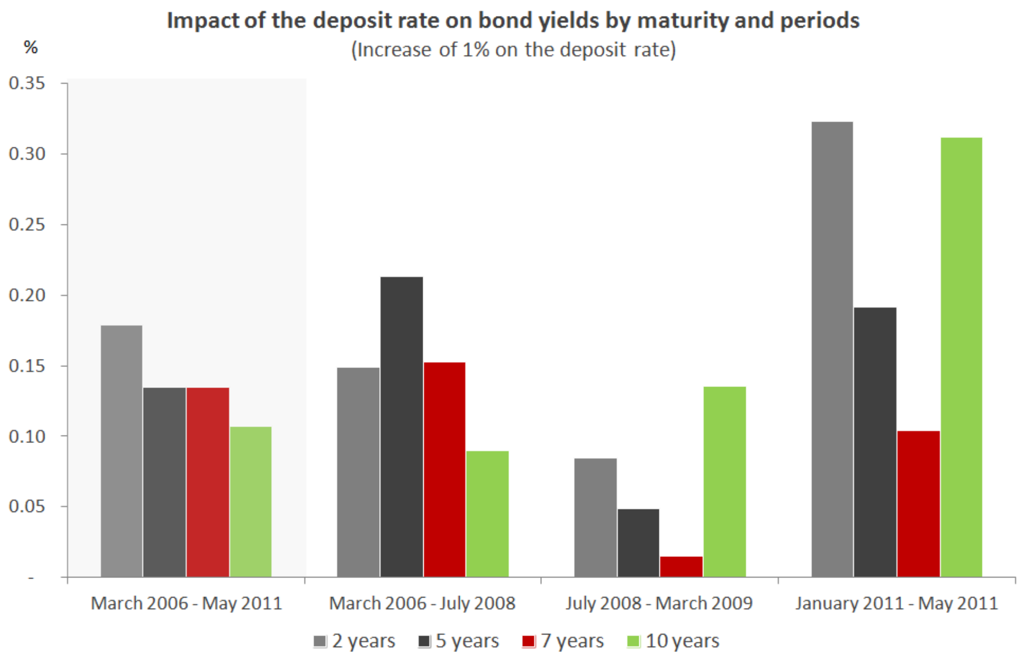
Comparing the hawkish periods, the recent episode highlights different results from those observed before the crisis. Indeed, our results clearly show a distortion in the shape of the yield curve with the short- and the long-ends of the curve strongly affected.

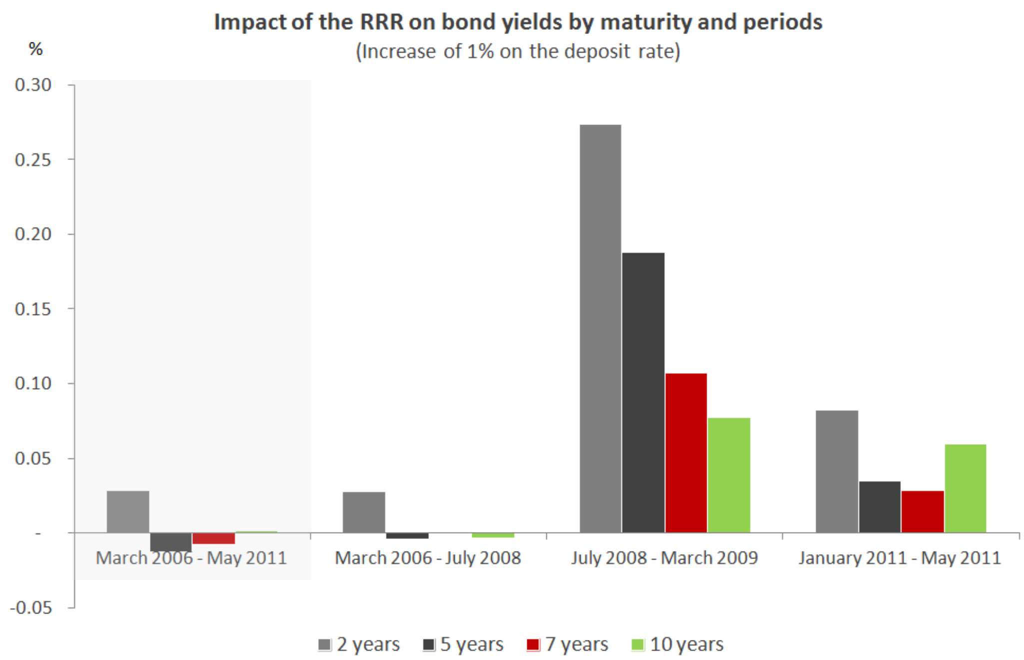
Looking at the 'post crisis' period, a 1% change in the deposit rate generates between 0.1% and 0.3% changes in bond rates, whereas a 1% change in the RRR translates into 0.03-0.08 changes in bond rates, which results in a ratio of elasticities of deposit to RRR between 3 and 6 over this period. Considering that the average change of RRR is often twice as large as the average change in the deposit rate (0.5 bp for RRR and 0.27 bp for deposit rate), this results in a ratio between 1.5 and 3.

Table 3: Impact of policy shocks on government bond yields (EGARCH estimation)

Mean equation		March 2006-May 2011	March 2006-July 2008	July 2008-March 2009	January 2011-May 2011
	$\Sigma\, AR(p)$	0.06	-0.00	0.08	0.06
2 years	$\Sigma\, \Delta deposit$	0.18	0.15	0.08	0.35
	$\Sigma\, \Delta RRR$	0.03	0.03	0.27	0.08
Ratio deposit to RRR		6.3	5.4	0.3	3.9
	$\Sigma\, AR(p)$	0.09	0.06	-0.11	0.30
5 years	$\Sigma\, \Delta deposit$	0.13	0.21	0.05	0.19
	$\Sigma\, \Delta RRR$	-0.01	-0.00	0.19	0.03
Ratio deposit to RRR		-10.8	-47.5	0.3	5.6
	$\Sigma\, AR(p)$	0.12	0.07	0.01	0.41
7 years	$\Sigma\, \Delta deposit$	0.13	0.15	0.02	0.10
	$\Sigma\, \Delta RRR$	-0.01	0.00	0.11	0.03
Ratio deposit to RRR		-17.5	205.7	0.1	3.7
	$\Sigma\, AR(p)$	0.10	0.00	0.28	0.34
10 years	$\Sigma\, \Delta deposit$	0.11	0.09	0.14	0.31
	$\Sigma\, \Delta RRR$	0.00	-0.00	0.08	0.06
Ratio deposit to RRR		60.7	-23.6	1.8	5.2

This corresponds to equation (3) (we report the coefficients of control variables in Appendix 2), which is estimated jointly with equation (5). First difference of yields in all cases in the mean equation. Exponential GARCH estimation with Generalized Error Distribution. Coefficients presented are all significant at the 5% on the basis of the z-stats.





To conclude this empirical analysis, Table 4 presents the impact of policy shocks (in absolute value) on the conditional volatiliy of bond yields in China. We do not report insignificant effects. Even if results are contrasted over the whole sample and across maturities, they globally show that monetary policy operations conducted by the PBoC generate an increase in bond-rate volatilities. Then, it is worth nothing that, again, changes in deposit rates have a major role in explaining the increase in conditional volatility but its effects increase and then decrease across the yield curve.

Table 4: Impact of policy shocks on bond yields volatility (EGARCH estimation)

Variance equation	2 years	5 years	7 years	10 years
$\Delta Adeposit$	2.36	3.78	3.53	1.54
$\Delta ARRR$	1.36			0.79

This corresponds to equation (5) where we do not report the coefficients of control variables (see Appendix 2), and which is estimated jointly with equation (3).First difference of yields in all cases in the mean equation. The table presents the response on the same day. EGARCH estimation with Generalized Error Distribution. We only report coefficients which are significant at the 5% level..

6. Conclusion

The results of this study improves our understanding of the way in which in China the combination of price and quantity instruments of monetary policy transmit across the yield curve and thus through market expectations.

Even if the bond market is now market-oriented, a key question was to understand how monetary policy is effective in a system where interest rates are regulated. Then, as a key component of the analysis, the special features of monetary policy in China prevent from conducting a similar analysis than in advanced economies.

Three broad conclusions can be drawn based on our empirical analysis:

First, the analysis highlights the different impact of each instruments on the yield curve in China. It shows that the potency of each main monetary instrument across the yield curve varies over time and the magnitude of the effects also differs.

The empirical work was undertaken with an EGARCH model, using daily bond market data to evaluate the transmission of monetary policy instruments to the interbank market in China. The estimations show that bond rates are most sensitive to changes in the benchmark deposit interest rate and respond also to changes in the Reserve Requirement Ratio. However, bond yields do not particularly react to open market operations.

More precisely, this result is especially true during periods of tightening monetary policy. Over the 'post crisis' period, the ratio of the deposit rate elasticity to the RRR elasticity is between 3 and 6 for all segments of the Chinese bond yield curve (short-, medium- and long-term).

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Appendix 1: Unit root tests

We use the Augmented Dickey-Fuller test and one alternative test, the General-Least-Squares version of the Phillips-Perron (1988) unit root test, suggested by Ng and Perron (2001), denoted Mza. In both tests, the null hypothesis is the presence of a unit root.

The tests are conducted over the whole sample on bond rates at different maturities: 2, 5, 7 and 10 years.

In all cases, the hypothesis of a unit root is accepted, confirming the non-stationarity of our indicators.

Table 5: Unit root tests over the whole period (2006-2011)

Maturity (years)	ADF	Ng and Perron (MZa)
2	-1.3	-2.3
5	-1.8	-2.4
7	-1.7	-1.8
10	-1.8	-1.6

Appendix 2: Detailed results of EGARCH models

Table 6: EGARCH results over the whole period (2006-2011)

Variables	2 years	5 years	7 years	10 years
Mean equation				
Intercept			0.00	
$\Sigma AR(12)$	0.05*	0.10*	0.12*	0.12*
$\Delta deposit$	0.18***	0.13***	0.13***	0.11***
$\Delta drrr$		-0.01***	0.00*	
$\Delta drrr\ (announced)$	0.03***		0.00***	0.00*
DumOct	0.02***			
DumCNYear	0.00	0.03***		0.03***
DumMay		-0.01**	0.01***	0.00***
Variance equation				
a_0	-1.25***	-0.88***	-2.22***	-0.78***
γ	0.48***	0.38***	0.62***	0.33***
α				
λ	0.88***	0.91***	0.74***	0.92***
$A\Delta deposit$	2.36*	3.78**	3.53***	1.54*
$A\Delta drrr$				
$A\Delta drrr\ (announced)$	1.36***			0.79*
GED	0.60***	0.71***	0.67***	0.72***
Observation	1254	1254	1254	1254
Log likelihood	3284	2875	2743	3047
Adj. R2	0.34	0.21	0.04	0.12

Note: reported resuls only concern significant variables in the models. *** significant at 1%, ** at 5% and * at 10%.

Table 7: EGARCH results over the whole period (2006-2011)

Variables	'Crisis-period' (Jul 2008 – March 2009) 2years	5years	7years	10years	'Post crisis period' (Jan 2011 – May 2011) 2years	5years	7years	10years
Mean equation								
Intercept	0.00				0.00			
$\Sigma AR(12)$	0.07*	-0.15*	0.16*	0.38*	0.07*	0.29*	0.34*	0.45*
$\Delta deposit$	0.08***	0.05***	0.02*	0.14***	0.32***	0.19***	0.10*	0.31**
$\Delta drrr$	0.04***	0.07***	0.02***	0.03**	0.01*			
$\Delta drrr\ (announced)$	0.24***	0.12***	0.08*	0.05**	0.04***	0.03***	0.03***	0.06**
DumOct					0.00**			
DumCNYear	0.07***						0.03***	
DumMay							0.01***	
Variance equation								
a_0	-1.20*	-1.92*	-2.12**	-1.42*	-5.62***	-2.75**	-3.46***	-6.96***
γ	0.77**	0.47*	0.61**	0.42*	0.53***	0.46**	0.44**	
α								
λ	0.88***	0.73***	0.72***	0.82***	0.36*	0.68***	0.57***	
$A\Delta deposit$					12.50*		6.59*	9.18**
$A\Delta drrr$							2.17*	
$A\Delta drrr\ (announced)$							-2.97*	-2.98*
GED	0.48***	0.98***	0.91***	0.93***	0.71***	0.77***	0.93***	1.32***
Observation	162	162	162	162	326	326	326	326
Log likelihood	375	278	303	283	895	793	772	781
Adj. R2	0.20	0.27	0.23	0.30	0.23	0.18	0.12	0.23

Note: reported resuls only concern significant variables in the models. *** significant at 1%, ** at 5% and * at 10%.