THE EFFECTS OF SHORT-TERM INTEREST RATES ON OUTPUT, PRICE AND EXCHANGE RATES: RECENT EVIDENCE FROM CHINA

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ABSTRACT

This paper utilizes VAR techniques to examine the relationship between a policy related variable and selected macro-variables in China. Johansen's cointegration tests fail to find a moving equilibrium among the related variables. Based on a VAR model in first differences, we find that an unexpected temporary one-off shock to the change in the seven-day money market interbank borrowing rate does not have significant influence on GDP changes but a significant influence on price level changes in a "wrong" direction. Empirical testing demonstrates that the seven-day Repo rate has an insignificant influence on both GDP changes and on the price level changes. Furthermore, the relationships between monetary aggregate (M2) and short-run money market interest rates suggest that the short-run interest rates do not have significant influence on the monetary aggregate. Therefore, we have determined that short-run money market interest rates are ineffective as a monetary policy-operating objective.

JEL: E4, E5, E6

KEYWORDS: monetary, money, macroeconomic policy

INTRODUCTION

Many studies have examined China's monetary policy mechanism, focusing on the effectiveness of intermediate targets, M1 and M2. For example, Xia and Liao (2001), Yu (2001), Xie (2004), and Geiger (2006, 2008) have argued that monetary aggregates (M1 and M2) are no longer suitable as intermediate targets, because the money multiplier is unstable and the monetary aggregates are not controllable by the nation's monetary authority. However, the optimal monetary policy target for China is debatable.

According Kasman (1992)，Morton and Wood (1993), Borio (1997, 2001), and Ho (2008), all central banks in the industrialised countries currently implement monetary policy through market-oriented instruments geared to influence closely short-term interest rates as operating targets. Ho's (2008) research on emerging Asian countries confirmed a number of broad themes across central banks with respect to the main features of policy implementation: focusing on short-term money market interest rates as operating objectives, favouring averaging reserve requirements, using interest rate corridors with penalty rates, and searching for alternative instruments. Therefore, the question of whether China's central bank should switch to short-term interest rate as its operating objective has attracted scholarly attention (see Xie and Luo, 2002; Yang, 2002; Xie and Yuan, 2003; Lu and Zhong, 2003; Wang and Zou, 2006; Wu, 2008). In regards to monetary theory, the precondition for adopting short-term interest rate as an operating instrument is that an effective an interest rate transmission mechanism established in a specific monetary framework and the operating objectives closely correlated to the final policy goal. However, whether short-run interest rates are highly correlated with China's monetary policy goals – price stability and economic growth – remains ambiguous.

This study uses Vector AutoRegressive (VAR) techniques to analyse the monetary transmission mechanism in China. Specifically, the study seeks to answer two questions:

1. How does a monetary policy shock, defined as a temporary and exogenous change in the short-term money market interest rate, affect real output, prices, and the nominal effective exchange rate?
2. How much do variations in short-run interest rates account for fluctuations in output, price level, and the nominal effective exchange rate?

The remainder of this paper is organized as follows. The next section describes the introduction of the study followed by background information on China's monetary framework and the literature review on monetary policy instruments. The data and research methodology present the empirical models and variables used in the study. The empirical results section discusses the relationship between the monetary policy variables and both output and prices in China using a VAR analysis. The last section concludes the paper.

BACKGROUND INFORMATION

The People's Bank of China (PBC) states that the aim of monetary policies is to maintain stability in the value of the currency and thereby promote economic growth. Therefore, the central bank is committed to two objectives: realizing price stability and promoting economic growth. The PBC claims to pursue currency stability as the sole target of its monetary policy, but it is impossible to ignore the goal of economic growth given its decision process is not independent of the state council's directives.

Since exchange rate unification in 1994, China has maintained a manageable floating exchange rate regime, a de facto peg of the renminbi (RMB) to the US dollar (USD), with different floating bandwidths during different periods. A crawling peg regime from 1994 to 1996 followed a de facto peg of the RMB against the USD with a trading band of 0.4 per cent (about RMB/USD 8.28). The trading band tightened to 0.01 per cent around the parity of RMB/USD 8.277. After an immediate appreciation of the RMB against the USD of around 2 per cent on July 21, 2005, China's exchange rate regime changed a peg against a basket of currencies, with a fluctuation bandwidth up to 0.3 per cent of the previous day's exchange rate (Anderson, 2005). On May 21, 2006, the daily floating band of the RMB against the USD trading price expanded to 0.5 percent (People's Bank of China, 2007). Based on this account, one can conclude that another objective of China's monetary policy is to maintain the stability of exchange rate vis-a-vis the USD.

Concerns on the risks of financial sector reform have led to a gradual interest rates liberalization that took place relatively late in the course of economic reform. The liberalization of the interest rates were announced in November 1993 at the Third Plenum of the Fourteenth Communist Party Central Committee (CPCC). The Party recognized that the central bank should promptly adjust the benchmark interest rates according to changes in market supply and demand. This allows the commercial banks to set their loans and deposits rates within a specific range. In 2002, the Sixteenth National Congress reiterated the need to advance interest rates reforms and optimize financial resource allocation. Furthermore, the Third Plenary Session of the Sixteenth Central Committee in 2003 argued the need to establish a robust mechanism for market-based interest rates and monetary policy actions consistent with the country's economic objectives (Bernard and Maino, 2007).

During the period 1986-1993, China's policies included targets on currency in circulation and bank's loans portfolios. In September 1994, the PBC defined and announced three levels of money supply indicators; M0, M1, and M2. In 1996, the PBC formally treated money supply as an intermediate target.

The elimination of credit ceilings in 1998 left M2 (money supply) as the single major intermediate target. The theoretical assumptions underlying China's monetary policy is that the objectives such as the GDP growth rate and the inflation rate correlate with the intermediate targets (money supply), that the intermediate targets are firmly connected to the monetary base. Equivalently, the money multiplier is assumed to be stable, and the central bank can influence intermediate targets by adjusting policy instruments.

LITERATURE REVIEW

Several scholars had devised classification schemes to describe the mechanism central banks have at their disposal for controlling financial activities.

Bernard (2004) has noted that monetary policy instruments fall into two broad categories: rules-based instruments and monetary market operations. The first category refers to the regulatory power of the central bank, which includes liquidity asset ratio, reserve requirements, and standing facility. The second category, market operations, is used at the discretion of the central bank. These bear an interest rate linked to money market conditions and aim to influence the underlying demand and supply conditions of the central bank. This includes open market–type operations, auction techniques, and fine–tuning operations (Bernard, 2004).

Xie (2004) classified the PBC's 13 monetary policy instruments into four categories relevant to 1983-2002: (1) instruments with ratios such as required reserve ratios; (2) interest rates, such rediscount rates, central bank interest rates on reserve requirements, central bank lending rates, deposits and lending interest rates of financial institutions; (3) quantity instruments, such as central bank lending, open market operations (on treasury bonds and foreign exchange), rediscounting; and (4) other instruments, such as central bank bills, central bank bonds, special deposits to the central bank, standing facilities, and moral suasion.

Geiger's (2006, 2008) classification of the PBC's monetary policy instruments is different from Xie's classification. He identifies two main categories of PBC's instruments, price-based and quantity-based. Price-based instruments are indirect and incorporate PBC lending and deposit rates, discount and rediscount rate, reserve requirements, and open market operations (OMOs). Quantity based instruments are direct and include window guidance, direct PBC lending, and capital control.

Bernard and Maino (2007) summarized China's main monetary policy instruments as standing facilities, OMOs, reserve requirements, interest rates control, window guidance, and other administrative measures. "The PBC has developed a set of monetary instruments which conform to best practices and which place the PBC in a relatively strong position to rely primarily on market-based instruments in the conduct of money policy. Open market operations in the form of issuance of PBC bills play an important role in the sterilization of excess liquidity and reserve requirements provide important support to OMOs" (Bernard and Maino, 2007, pp. 14).

Based on Bernard's (2004) theoretical framework, we can conclude that the current choice of China's monetary policy is a mix of rules-based instruments and money market operations. In 1993, the PBC introduced the OMO into its monetary policy toolbox. Following the abolishment of the credit rationing policy in 1998, the OMOs became the PBC's main monetary policy instrument. The PBC benchmark lending rates - rediscount rates, the interest rate on required reserves, and excess reserves constitute an upper and a lower limit in the money market interest rates. The central bank bill rates serves as a target rate in setting the money market interest rate, such as the federal fund rate in the U.S (Xie, 2004; Wu, 2008). Automatic collateralized lending and the excess reserves facility constitute China's standing tools for monetary control.

Xie (2004) investigated the relationship between the monetary aggregate (M1, M2) and the monetary base, from the first quarter of 1994 through the fourth quarter of 2002. The results of the quarterly cross-correlation coefficients and Granger-causality tests for the base money and monetary aggregates indicate that the impact of the monetary base on M1 is not strong, and the impact of the monetary base on M2 is even weaker. Among the four different liquidity injecting channels, namely, the PBC's lending to financial institutions, foreign exchange purchase by the monetary authority, OMOs on treasury bonds, and the rediscount window, only the central bank lending Granger causes M1, and none Granger causes M2. Therefore, monetary aggregates are endogenously determined and have strong correlations with monetary policy.

Xie (2004) also explored the dynamic relationships between monetary aggregates, economic growth, and inflation rates using data from the first quarter of 1992 to the third quarter of 2002. The author argues that the money supply affects output and money is not neutral in the short run. Nevertheless, the impacts of money supply on output last no more than eleven quarters. Money is neutral in long run and the impacts of money supply on output are not of a permanent nature. In both the short run and long run, money supply and inflation correlate, where changes in the money supply have permanent effects on the inflation rate and the price level. Geiger (2006, 2008) documents severe deviations of the targeted and the actual values from 1994-2004 and 1994-2006.

Table 1 compares the targeted with the actual values of China's monetary aggregates, M1 and M2 from 1994 to 2006. The targeted and the actual values fell only three times in the case of M1, and four times in the case of M2. Strong deviations of more than four percentage points occurred several times for both M1 and M2, and this raises the doubt on the controllability of the monetary aggregates.

Table 1: Targeted and Actual Values of PBC Monetary Aggregates (1994-2006)

Year	M1 growth (per cent)		M2 growth (per cent)	
	Target	Actual	Target	Actual
1994	21	26.2	24	34.5
1995	21-23	16.8	23-25	29.5
1996	18	18.9	25	25.3
1997	18	16.5	23	17.3
1998	17	11.9	16-18	15.3
1999	14	17.7	14-15	14.7
2000	15-17	16	14-15	14.7
2001	13-14	12.7	15-16	14.4
2002	13	16.8	13	16.8
2003	16	18.7	16	19.6
2004	17	13.6	17	14.6
2005	15	11.8	15	17.6
2006	14	17.5	14	16.9

This table shows the comparison of the targeted and the actual values of the China's monetary aggregates of the M1 and M2 from 1994 to 2006 (Geiger, 2008).

The systematic liberalization of the interest rates involved the lifting of the restrictions on wholesale transactions followed by liberalization of the retail transactions. Interest rates on foreign currencies deposits and lending were eliminated before those for local currency (Bernard and Maino, 2007). The reform on market interest rates progressed steadily from 1996. By the end of 1999, the interbank borrowing rates, discount rates for commercial paper, and repos and spot trading rates in the interbank bond market were fully liberalized. The purchasers' bids determined the interest rates on policy financial bonds and treasury bonds (Xie, 2004). The PBC also adjusted the refinancing rate to a reference rate for the money market.

Reform of the retail banking operations involved first allowing banks to price counterpart risks on customers within a floating margin before fully liberalizing the lending and deposit rates (Mehan, Quintyn, Nordman, and Laurens, 1996). The authorities reduced the number of administered interest rates, adjusted bank lending rates on industrial and commercial enterprises more frequently to reflect changes in the PBC benchmark rate, and allowed financial institutions to price their lending operations within a floating margin. The discretionary bands on lending rates expanded in 1998(Xie, 2004). In October 2004, the PBC removed ceilings on lending rates and floors on deposit rates. A floor for lending rates and a ceiling for deposit rates protect the banks' intermediation margins. The PBC reduced about 120 administered interest rates from 1996 to 2007 (Wu, 2008).

Both the depth and breadth of the money markets in China have improved significantly over the past decade. Currently, China's money market comprises of three sub-markets. The first sub-market is the interbank money market. Originating in the 1980s and modified in 1993, a reformed and unified national interbank market started operation in January 1996, where banks lent and borrowed funds among themselves for terms from overnight to four months. The amount of lending and borrowing are fixed in proportion to the balance of deposits. In contrast, non-bank financial institutions lend and borrow funds among themselves for a maximum of seven-days and the trading volumes depend on the capital level. The seven-day loan rate is the China's inter bank offered rate (CHIBOR) (Xie, 2002).

By the end of 2007, the number of market participants reached 717, fourteen times greater than when markets began operation. As of November 28, the trading volume reached RMB13,700 billion. The interbank markets rules and regulations were enforced in August 2007. Stephen (2007a, 2007b) argues that the introduction of a more market driven reference rates such as the Shanghai interbank offered rate (SHIBOR) for the onshore money market is a critical step in terms in improving China's money market.

The second sub-market is the interbank bond market, which functions as a liquidity market. The China inter-bank bond market began operation in June 1997. By the end of 2007, the number of participants was 7095 (The People's Bank of China Annual Report, 2007). Both the turnover and the liquidity of the interbank bond market have expanded significantly, with a total turnover exceeding RMB100,000 billion in 2008. The tradable stocks increased from RMB72.3 billion in 1997 to RMB9,024 billion by June 2008 (China Monetary Policy Report, 2008). It is currently the biggest bond market in China.

China's interbank bond market currently has three characteristics added since its initial development. First, the trading participants in the interbank bond market is diversified by allowing non-banking financial institutions (such as funds companies, securities companies, and insurance companies) and other enterprises to trade in this market. Second, with Treasury bonds and PBC bills as the main trading products, the debts issued by policy banks and commercial banks, and commercial papers issued by the financial companies and other big corporations have increased significantly. Issuers of bonds in this market have included the Ministry of Finance, the central bank, policy banks, commercial banks, nonbanking financial institutions, and corporations. The central bank uses the term structure of bond yields and long-term interbank rates as reference rates to predict inflation trends. This also serves as an important basis for pricing other financial products through the market.

Finally, the bond repo market, the third sub-market of the money market, is used for short-term borrowing. Turnover reached RMB51,580 billion by the end of November 2008. Since 1997, the repo rate has been set by the market, with the most active contracts between one and seven days. The seven-day repo in effect became the bond benchmark rate and it became the official reference indicator for the money market from October 12, 2004. Because commercial banks, securities companies, and other financial institutions trade in this market, frequent changes in the repo rate reflect changes in the stock and money loans markets (ChinaNet). This market is less volatile and liquid than the CHIBOR and its successor SHIBOR. Compared with interbank markets, repo markets are more active and the interest rates are more stable (Xie, 2002; Loretan and Wooldridge, 2008).

The segmentation in the money markets is the result of regulations, because the initial operations of the money markets led to disorder in the financial industry in the early 1990s. Instead of using it as a means to manage reserves by commercial banks, it is abused by both financial and other nonfinancial institutions to obtain short-term funds to invest in securities and real estate (Xie, 2002; Bernard and Maino, 2007). In order to prevent bank funds being used to participate in the stock market, the PBC ruled that commercial banks would withdraw from repo trading on the stock exchange. Beginning in 1997, commercial banks were only allowed to carry out repo trading on the interbank market, with the goal of building a firewall between the money and capital markets (Xie, 2002; Bernard and Maino, 2007). Short-term borrowing by securities companies in the interbank market led to contagion, as changing conditions in the capital market had a direct impact on the interbank markets. From 2000, securities companies, funds management companies, and other non-banking financial institutions were permitted to trade into the inter-bank markets under certain conditions. However, the coexistence of the interbank bond market and the stock exchange bond market, and the limits on RMB interbank market activity for commercial banks funded in foreign currencies remain the source of market segmentation (Wu, 2005; Bernard and Maino, 2007).

In 1994, China adopted a managed floating exchange rate regime against the USD, coupled with a move to partial convertibility on the current account (Zhang, 2001). Further, in December 1996, China adopted current account convertibility, but maintained administrative controls on the capital account (Xie, 2004). Following the 1997 Asian financial crisis, China implemented a fixed foreign exchange regime. This was in place until July 2005, when they announced a switch to a new exchange rate regime. The exchange rate would be set with reference to a basket of other currencies, with numerical weights unannounced. This allowed movement within any given day towards increased flexibility (Frankle, 2009). However, some researchers argued that China's current foreign exchange policy was still "fixed" instead of "floating" (see McKinnon and Schnabl, 2006; Frankle and Wei, 2007; Prasad, 2007).

Previous studies argue that for one country unfettered movement of international capital, independent monetary policy and a fixed exchange rate policy cannot coexist. In theory, capital controls can prevent large inflows (outflows) when domestic interest rates are higher (lower) than foreign rates. This allows the PBC to operate an independent monetary policy. In practice it is difficult to maintain effective capital controls over time, particularly in an economy like China's, that is not only open to trade but trades extensively (Goldstein and Lardy, 2007; Wu, 2006). With a large current account surpluses, the PBC faces the challenge of sterilizing the increase in the domestic money supply resulting from the large purchase of foreign exchange (i.e. sale of domestic currency).

China's balance of payments has remained strong since 1996, and its global current account surplus has expanded substantially over recent years. The current account surplus was $72.4 billion in 1996, rising to $68.7 billion (3.6 percent of GDP) in 2004, $160.8 billion (7.2 precent of GDP) in 2005, and $371.8 billion in 2007 (11.3 precent of GDP) (National Bureau of Statistics, 2008; IMF Statistic Database, 2007; State Administration of Foreign Exchange). Since then, China's account surplus (in absolute terms) is the largest of any country.

The build-up of official holding of foreign exchange reserves has accelerated since 2005. In the 12 months from June 2005 to June 2006, the foreign exchange reserves rose by $240 billion and $230 billion, respectively (Goldstein and Lardy, 2007). However, in the 12 months through June 2007, foreign exchange reserves rose by $391 million, about three-fifths more than in the previous two 12 month periods, In the 12 months through June 2008, the foreign exchange reserves rose by an astonishing $467 billion. At the end of September 2008, total foreign exchange reserves reached $1,905.5 billion (People's Bank of China, 2008).

Since the unification of China's exchange rate in 1994, the RMB has been under pressure to appreciate, except during the 1997 Asian financial crisis year. To maintain stability in the RMB, the PBC adopted several comprehensive measures. These have included improving the foreign exchange purchase-and-sale system via foreign exchange designed banks, changing interest rate policy and shifting to OMOs (Xie, 2004). Following 2000, the appreciation pressure was fueled by expanding capital inflows and foreign trade surpluses. Thus, the PBC has more pressure to intervene in the market.

Anderson (2004, 2005) and Stephen (2007a, 2007b) suggest that China can run an independent monetary policy under any foreign exchange regime and have little difficulty in retaining control of the growth of its domestic money supply. They argue that this can be absorbed with relatively effective capital control and successful stabilization via the sale of central bank bills and an increase in the required reserve ratio for banks. In contrast, Goldstein and Lardy (2006), Lardy (2006), and Prasad, Rumbaugh, Wang (2005) argue that China's (quasi) fixed exchange rate has weakened the effectiveness of its monetary policy. They believe that the resulting policy mix has left China with an interest rate structure that is far from optimum. Since a low real interest rate contributes to an underlying excess demand for credit and rapid growth of lending from banks, low deposit interest rates have been a major contributing factor to the boom in the property market.

DATA AND METHODOLOGY

This section examines the relationship between the monetary policy variables and both output and prices in China using VAR analysis. Since Sims's seminal paper in 1980, the VAR framework has been widely used in macroeconomics research as it allows the direct estimation of the joint stochastic process describing the variables under consideration. If one is unclear on which variable is endogenous and which is exogenous, the VAR method allows the researcher to treat all variables as jointly endogenous. Researchers using VAR to identify transmission of monetary policy in advanced economies include Christiano, Eichenbaum, and Evans (2000) for the United States, Kim and Nouriel, (2000) for the G-7 economies, and Peersman and Smets (2003) for the Euro area. Armenia by Era and Holger (2007) and Kenya by Cheng (2006) use the VAR framework to study the monetary policy transmission mechanism in developing countries. In this study, we use quarterly data from 1996:Q1 to 2008:Q1 to examine the macroeconomic dynamics of the unified interbank market operation in China. We first test all time series for unit roots using the augmented Dickey-Fuller method, and then estimate a reduced form VAR, indentifying money policy shocks through the assumptions about variable ordering.

Data and Variable Description

First, we consider the effects of short-term interest rates on GDP, general price level, monetary aggregate, and exchange rates. We assume the 7-day interbank money market rate (INTm), and the CHIBOR market's benchmark, as the PBC's policy stance (i.e., a 7-day repo rate (INTr), which is another benchmark short-term interest rates used in the interbank bond market). Another policy-related variable in our study is the domestic monetary aggregate M2 (M), which is the intermediate target of the PBC. We use the nominal effective exchange rate (NEER) to examine effects on output and prices. The output measure is real GDP with the consumer price index (CPI) as the general price level. All data are expressed in natural logs and are seasonally adjusted using ARIMAX12, with the exception of short-term interest rates. Table 2 display the unit root tests for the time series. The unit root tests show that INTm and INTr are trend stationary variables.

Table 2: Unit Root Tests for Time Series

Variable	(C,T,K)	ADF-Statistic	1% critical value	5% Critical Value	P-Value
GDP	(C,0,1)	0.590	-3,563	-2.921	0.98
CPI	(C.0.0)	2.581	-3.5654	-2.919	1.00
M	(C,0,0)	-0.712	-3.565	-2.919	0.83
INTm	(C,0.0)	-3.962	-3.563***	-2.919	0.00
INTm	(C,T,0)	-1.709	-4.148	-3.500	0.73
INTr	(C,0.3)	-3.024	-3.605	-2.936**	0.04
INTr	(C,T,3)	-2.908	-4.205	-3.526	0.17
NEER	(C,0,1)	-0.474	-3.568	-2.921	0.88

*This table reports the unit root tests results. (C,T,K) indicates constant, trend, and lag-length included in the unit root test. The unit root tests show that INTm and INTr are trend stationary variables. *** and ** stand for the significance at 1 and 5 percent respectively.*

The variables in the model should be stationary in displaying the relationships among the output, prices, and policy-related variables in a VAR. However, the unit root tests show the instability of the time series used in our study. Sims (1980) and Sims, Stock and Watson (1990) recommend against differencing when the related variables are cointegrated, even if the variables contain a unit root. They argue that the goal of a VAR analysis is to determine the interrelationships among the variables, not to determine the parameter estimates. Conducting the analysis in levels allow for implicit cointegration relationship in the data. However, if the related $I(1)$ variables are not cointegrated, it is preferable to use the first difference. There are three consequences if the $I(1)$ variables are not cointegrated and one estimates the VAR in level. The first consequence is the test loses its power because we estimate n^2 with more than one parameter. The second is the test for Granger causality on the $I(1)$ variables, which do not have a standard F distribution for a VAR in levels. The last is when the VAR has $I(1)$ variables, the impulse responses at long forecast horizons are inconsistent estimates of the true response.

Enders (2004) notes that the lag length test can be performed regardless of the variables in question are stationary or integrated. Eviews 6 selects the lag length of the VAR model using the VAR lag order selection criteria. All the information criteria select a lag order of one. The residual test suggests that we can reject autocorrelation and heteroskedasticity at the conventional 5% significance level. Based on the selected lag length, we perform two cointegration tests: one for the same five variables in the level VAR, and exclude the short-term interest rates in the second test. The results show that when short-term interest rates are included into the VAR, we fail to reject the null hypothesis of no cointegration (see table 3).

Table 3: Johansen Cointegration Test Results

Variables: GDP, CPI, M, INTm, NERR (p=1)				
H_0	Trace	5% Critical Value	Max-Eigen	5% Critical Value
$r = 0$	76.72	88.03	27.07	38.33
Variable: GDP, CPI, M, NEER (p=1)				
H_0	Trace	5% Critical Value	Max-Eigen	5% Critical Value
$r = o$	67.50	54.07	35.99	28.58

This table reports two Johansen Cointegration test results, one for the five variables in the level VAR, excluding the short-term interest rate variable.

In this study, we use the first order difference of the related variables to construct a VAR model. The basic concepts underlying the VAR modelling process can be summarised as follows.

Let Y_t be a $n \times 1$ vector of variables, ε_t a $n \times 1$ vector of mean zero structural innovations and $B(L) = B_0 - B_1 L - B_2 L^2 - \ldots B_p L^p$ a $n \times n$ matrix polynomial in the lag operator. The pth order structural VAR model is written as:

$$B(L) = \varepsilon_t \text{ ; } E\varepsilon_t \varepsilon_t^{'} = \Lambda \text{ ; } E\varepsilon_t \varepsilon_{t+s}^{'} = 0 \text{ , } \quad \forall \neq 0 \tag{1}$$

where Λ is a diagonal matrix. B_0 is a non-singular normalized matrix with ones on the diagonal. This matrix summarizes the contemporaneous relationships between the variables of the model. Since the coefficients are the unknown and the variables have contemporaneous effects, we therefore transform equation (1) into a reduced form VAR:

$$Y_t = A(L) Y_t + \mu_t \text{ ; } E\mu_t \mu_t^{'} = \Sigma \text{ ; } E\mu_t \mu_{t+s}^{'} = 0 \text{ , } \forall \neq 0 \tag{2}$$

where $A(L) = B_0^{-1} B(L) = I - AL - A_2 L^2 - \ldots A_p L^p$ and $\mu_t = B_0^{-1} \varepsilon_t$.

The error terms μ_t are composites of the underlying shocks ε_t . The model must be exactly or over-identified in order to estimate the structural model. In order to recover the structural parameters from the reduced form model, there must be the same number of parameters in B_0 and Λ as there are in Σ , the covariance matrix of the reduced form. Hamilton (1994) called this the order condition.

Combining equation 1 and 2, the variance-covariance matrix, Σ can be expressed as follows:

$$\Sigma = (B_0^{-1}) \Lambda (B_0^{-1})^{'} \tag{3}$$

Consistent estimates of F ($F = B_0$) and Λ can be obtained through the sample estimation of Σ , which can be obtained by maximum likelihood estimation. The right hand side of equation (3) contains $n \times (n+1)$ parameters to be estimated, while the left-hand side contains only $n \times (n+1)/2$ parameters; we need $n \times (n+1)/2$ restrictions to achieve identification. If the n diagonal elements of Λ are set to one, all that is required is a further $n \times (n+1)/2$ restrictions on B . There are only a few methods to recover the parameters of the structural form from the parameters in the reduced form. The most widely used approach in recursive VAR models is the Cholesky decomposition (Don and O'Reilly, 2004; Cheng, 2006).

The vector of endogenous variables in our benchmark model, equation (4), consists of real GDP (GDP), the consumer price index (CPI), monetary aggregate (M), interbank market borrowing rate (INTm), and nominal effective foreign exchange rate (NEER). We replaced interbank market bond repurchase rate (INTr) with INTm in equation (5) to test the robustness of our results.

$$Y_t = \left[GDP, CPI, M, INTm, NEER \right] \tag{4}$$

$$Y_t = \left[GDP, CPI, M, INTr, NEER \right] \tag{5}$$

Equation (4) shows the ordering of the variables. Intuitively, we assumed that prices (CPI) have no immediate effects on output (GDP), money stock (M) has no immediate effect on prices, monetary policy shock (INTm) has no immediate effect on the money stock, and the nominal effective exchange rate (NEER) has no immediate effect on the money policy. Technically, this amounts to first estimating the reduced form of the benchmark model equation (4), then computing the Cholesky factorization of the reduced form VAR covariance matrix. In other words, the relations between the reduced form errors and the structural disturbances are given as follows:

$$\begin{bmatrix} \varepsilon_t^{GDP} \\ \varepsilon_t^{CPI} \\ \varepsilon_t^{M} \\ \varepsilon_t^{INTm} \\ \varepsilon_t^{NEER} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ f_{21} & 1 & 0 & 0 & 0 \\ f_{31} & f_{32} & 1 & 0 & 0 \\ f_{41} & f_{42} & f_{43} & 1 & 0 \\ f_{51} & f_{52} & f_{53} & f_{54} & 1 \end{bmatrix} \begin{bmatrix} \mu_t^{GDP} \\ \mu_t^{CPI} \\ \mu_t^{M} \\ \mu_t^{INTm} \\ \mu_t^{NEER} \end{bmatrix} \quad (6)$$

The standard practice in VAR analysis is to report results from Granger-causality tests, impulse responses, and forecast error variance decompositions (Stock and Watson, 2001). Because of the complicated dynamics in the VAR, these statistics are more informative than are the estimated VAR regression coefficients or R^2 statistics, which typically go unreported (Stock and Watson, 2001). Granger-causality statistics examine whether the lagged values of one variable help to predict another variable. Table 4 summarizes the Granger-Causality results for the five-variable VAR and shows the P-values associated with the F-statistics for testing whether the relevant sets of coefficients are zero.

Table 4: VAR Granger-Causality/Block Exogeneity Wald Tests

	Dependent Variable in Regression				
Regressor	ΔGDP	ΔCPI	ΔM2	ΔINTm	ΔNEER
ΔGDP		0.56	0.74	0.20	0.86
ΔCPI	0.45		0.51	0.29	0.37
ΔM	0.21	0.95		0.07*	0.55
ΔINTm	0.61	0.06*	0.90		0.49
ΔNEER	0.84	0.01**	0.86	0.71	

*This table summarizes the Granger-Causality results for the five-variable VAR. * and ** indicates significance level of 10 and 1 percent levels respectively.*

The result shows increases in the growth rate of INTm and NEER were significant to predict the CPI growth rate at 10% and 1% significance levels respectively, but did not Granger-cause GDP. An increase in the growth rate of the monetary aggregate Granger-causes the growth rate of INTm at the 10% significance level, but not vice versa.

RESULTS

Impulse responses trace out the response of current and future values for each of the variables to a one-unit increase in the current value of one of the VAR errors. This assumes that errors return to zero in subsequent periods and that all other errors are equal to zero (Stock and Watson, 2001). In other words, the interpretation of the impulse response requires that the innovations be contemporaneously uncorrelated across equations. However, the innovations in a VAR are correlated and may be viewed as having a common component, which cannot be associated with a specific variable (Eviews 6). Thus, we use the inverse of the Cholesky factor of the residual covariance matrix to orthogonalize the impulses.

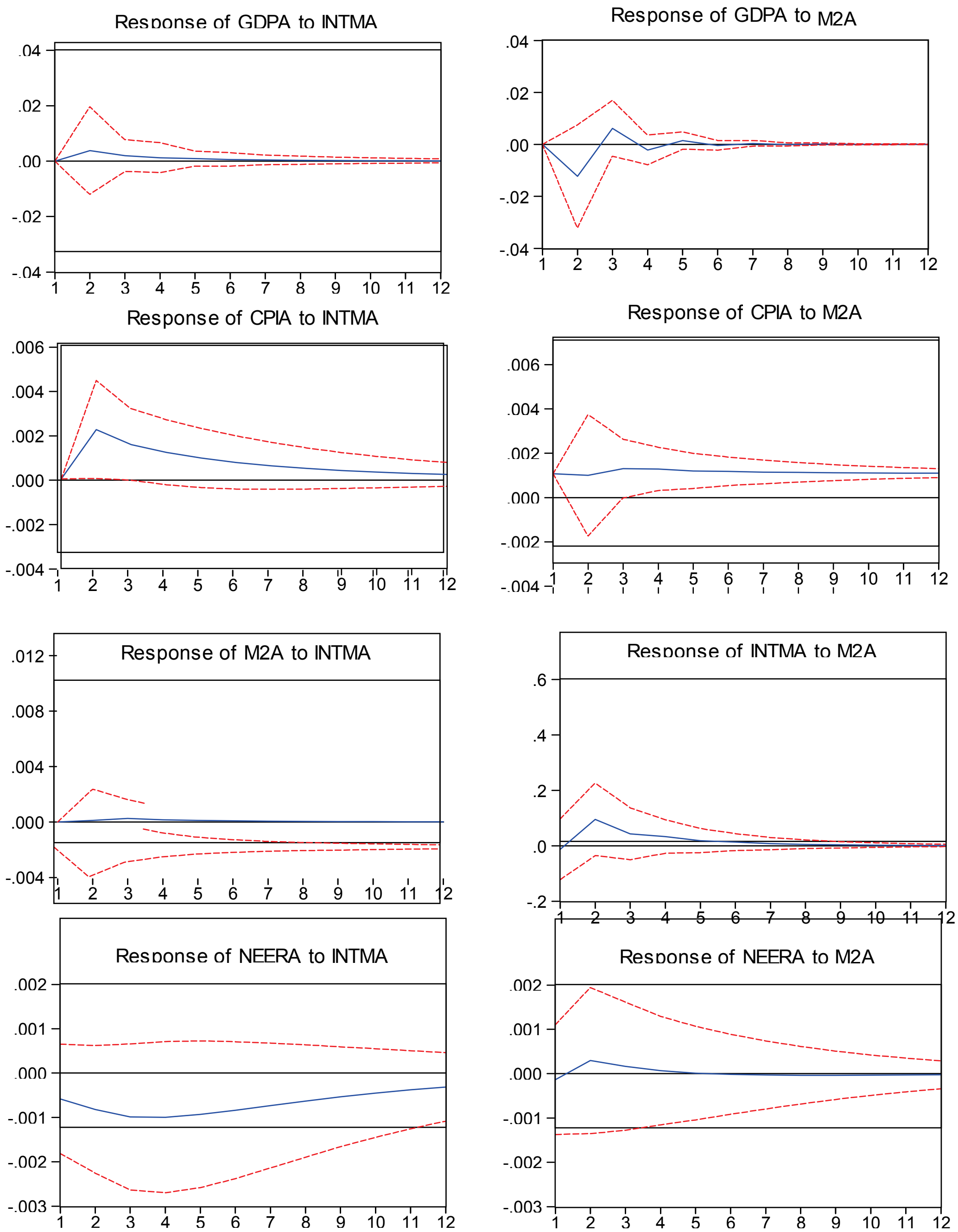
Figure 1 presents the impulse response functions, showing the impact of a one-off rise in the INTm growth rate on output, prices, monetary aggregate and exchange rate. The dotted lines represent the 95% confidence levels and the impact of a unit rise in the growth rate of monetary aggregate on other variables. Output growth rate changes by about 0.4%, peaking at the second quarter and vanishing completely at the seventh quarter following the monetary contraction. The CPI growth rate changes by about 0.2%, peaking at the second quarter and decreasing to below 0.1% at the fifth quarter after contraction. The response of the monetary aggregate growth rate to the interest rate growth shock appears to be insignificant. However, an inspection of these impulse response functions shows that the response functions of GDP growth rate and CPI growth rate are inconsistent with what we expected to be the effects of a contraction in monetary policy. Only the impulse response function of the nominal effective exchange rate appeared to be consistent with the theoretical prediction that an increase in the interest rate growth rate leads to an appreciation of the nominal exchange rate, but is statistically insignificant.

Furthermore, we examine the impacts of the shocks of monetary aggregate growth rate on the other variables. A rise in a one-unit monetary aggregate growth rate results in a 1% decline in GDP growth rate, reaching the trough at the second quarter and reverting to 0.5% at the peak of third quarter. An increase in monetary aggregate leads to a decline in real GDP within two quarters, and then promotes economic growth with four to six quarters' lag. There is an insignificant impact on both the CPI and NEER growth rates. However, the impact on the short-term interest rate is significant at the 10% level after one quarter.

The forecast error decomposition is the percentage of the variance of the error made in forecasting a variable due to a specific shock at a given horizon (Stock and Watson, 2001). The relative importance of monetary policy fluctuations in the other variables can be measured through variance decomposition. Table 5 reports the variance decomposition of the five VAR, variables covering 1 to 12 quarters. The second column in each sub-table shows the forecast errors of the variable for each forecast horizon. The remaining columns present the percentage of the variance due to the shock of the variable appearing as the column heading, with each row adding up to 100. The results show that innovations in INTm growth rate account for about 0.34 percent of the forecast error variance in the output growth rate and about 9 percent in the price level growth rate in a year. Innovations in the monetary aggregate growth rate explain about 3.24 percent of the output growth rate forecast error, and only about 0.1 percent in the price level growth rate. The innovations of money supply growth rate and interest growth rate explain each other, at about 4.7 and 0.1 precent respectively. Our results confirm the insignificant influence of changes in short-run interbank bank borrowing interest rate on GDP growth rate, and the statistically significantly influence on price level growth rate, but in the "wrong" direction. This further confirms that monetary aggregate growth rates have no influence on both the GDP and price level fluctuations. Another interesting result is that shocks to the monetary aggregate growth rate, which significantly influence the INTm change rate rather than the reverse.

Figure 2 displays the impulse responses to monetary policy shocks defined as temporary, unexpected and exogenous rises in Repo growth rate, with the variance decomposition of the forecast errors shown in Table 6. The results support our conclusion. For a one-unit rise in Repo growth rate, the GDP growth rate rises by about 0.4% at the second quarter peak and decreased to 0.08% in the fourth quarter; the CPI growth rate rose at the peak by 0.2% in the second quarter. The directions of the changes are similar to those in the benchmark VAR. Within one year, the innovations in the Repo growth rate explained about 0.35 percent of the GDP growth rate forecast error and about 7.7 percent for the price level growth rate forecast error. However, the impact of the Repo and monetary aggregate on GDP is statistically insignificant

Figure 1: Impulse Response in Recursive VAR



This figure shows the impulse response functions showing the impact of a one-off rise in INTm growth rate on output, prices, monetary aggregate and exchange rate, with the dotted lines representing 95% confidence level and the impact of a unit rise in the growth rate of monetary aggregate on other variables.

Table 5: Variance Decomposition (Percent of Total Variance)

Variance Decomposition of GDPA						
Period	**S.E.**	**GDPA**	**CPIA**	**M2A**	**INTMA**	**NEERA**
1	0.067191	100.0000	0.000000	0.000000	0.000000	0.000000
4	0.077274	95.61735	0.747174	3.247708	0.337880	0.049888
8	0.077403	95.55325	0.755237	3.277852	0.359609	0.054049
12	0.077405	95.55067	0.755621	3.277949	0.361010	0.054747
Variance Decomposition of CPIA						
Period	**S.E.**	**GDPA**	**CPIA**	**M2A**	**INTMA**	**NEERA**
1	0.008903	1.015293	98.98471	0.000000	0.000000	0.000000
4	0.009952	1.899751	81.56250	0.100684	8.907859	7.529210
8	0.010235	1.914807	78.09226	0.128086	10.33863	9.526215
12	0.010288	1.917015	77.46623	0.130873	10.55684	9.929040
Variance Decomposition of M2A						
Period	**S.E.**	**GDPA**	**CPIA**	**M2A**	**INTMA**	**NEERA**
1	0.009551	0.308828	1.161612	98.52956	0.000000	0.000000
4	0.009617	0.678184	1.982264	97.19940	0.107697	0.032459
8	0.009620	0.685572	1.988073	97.15250	0.133768	0.040086
12	0.009620	0.685725	1.988910	97.14739	0.136041	0.041934
Variance Decomposition of INTMA						
Period	S.E.	GDPA	CPIA	M2A	INTMA	NEERA
1	0.389118	0.700276	0.140861	0.108984	99.04988	0.000000
4	0.505393	3.529952	3.985635	4.734654	87.66348	0.086276
8	0.512978	3.528730	4.259895	4.819651	87.29407	0.097652
12	0.513331	3.529012	4.276629	4.819884	87.26525	0.109224
Variance Decomposition of NEERA						
Period	**S.E.**	**GDPA**	**CPIA**	**M2A**	**INTMA**	**NEERA**
1	0.004518	0.283709	5.497382	0.090923	1.655793	92.47219
4	0.007174	0.545544	10.47459	0.265867	5.794468	82.91954
8	0.007993	0.731029	11.54858	0.218461	8.591484	78.91045
12	0.008165	0.777887	11.77393	0.215670	9.328558	77.90395

This table shows the variance decomposition of the five variables VAR covering 1 to 12 quarters. The second column in each sub-table shows the forecast errors of the variable for each forecast horizon. The remaining columns present the percentage of the variance due to each shock, with each row adding up to 100.

Table 6: Variance Decomposition of VAR (Repo)

Variance Decomposition of GDPA:						
Period	**S.E.**	**GDPA**	**CPIA**	**M2A**	**INTRA**	**NEERA**
1	0.071468	100.0000	0.000000	0.000000	0.000000	0.000000
4	0.082012	94.62480	1.382626	3.424394	0.355899	0.212286
8	0.082096	94.59207	1.390798	3.435846	0.359099	0.222188
12	0.082097	94.58933	1.391206	3.435795	0.359456	0.224209
Variance Decomposition of CPIA:						
Period	**S.E.**	**GDPA**	**CPIA**	**M2A**	**INTRA**	**NEERA**
1	0.009595	1.302966	98.69703	0.000000	0.000000	0.000000
4	0.010676	1.775495	81.55952	1.970865	7.730516	6.963607
8	0.010884	1.730996	79.14847	1.915285	8.505136	8.700115
12	0.010921	1.723015	78.72026	1.905542	8.610425	9.040754
Variance Decomposition of M2A:						
Period	**S.E.**	**GDPA**	**CPIA**	**M2A**	**INTRA**	**NEERA**
1	0.008841	0.701716	0.345849	98.95243	0.000000	0.000000
4	0.008876	0.762420	0.413269	98.41496	0.037637	0.371711
8	0.008882	0.762074	0.425920	98.30062	0.048837	0.462552
12	0.008883	0.761997	0.429913	98.27425	0.054278	0.479562
Variance Decomposition of INTRA:						
Period	**S.E.**	**GDPA**	**CPIA**	**M2A**	**INTRA**	**NEERA**
1	0.352308	0.308717	0.466141	1.921718	97.30342	0.000000
4	0.413797	2.023479	5.832656	1.886932	89.95875	0.298180
8	0.415126	2.024507	5.909361	1.876778	89.88886	0.300489
12	0.415136	2.024533	5.909992	1.876696	89.88830	0.300480
Variance Decomposition of NEERA:						
Period	**S.E.**	**GDPA**	**CPIA**	**M2A**	**INTRA**	**NEERA**
1	0.004997	0.453490	6.613098	0.393814	17.40211	75.13749
4	0.007863	0.405743	11.70457	0.392003	17.68611	69.81157
8	0.008662	0.421778	12.40114	0.407970	18.38188	68.38723
12	0.008814	0.425498	12.52219	0.410484	18.52898	68.11285

This table 6 shows the variance decomposition of the forecast error in the VAR. The results shows a one-unit rise in Repo growth rate, the GDP growth rate rises by about 0.4% at the peak at the second quarter and decreases to 0.08% in the fourth quarter; the CPI growth rate rises at the peak by 0.2% in the second quarter.

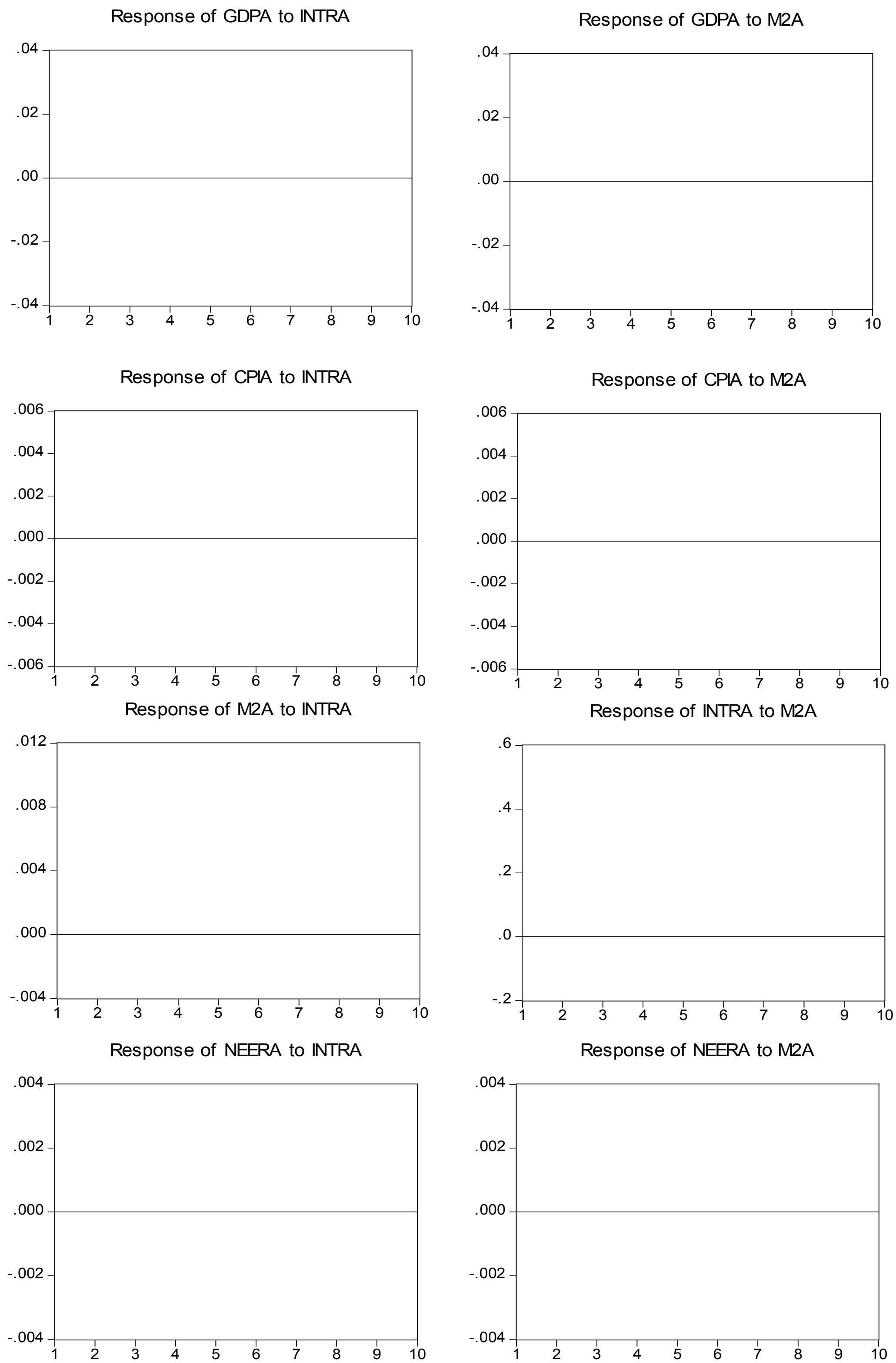
CONCLUDING COMMENTS

This study examines the transmission mechanisms of monetary policy in China, based on a VAR framework. Our findings suggest that level moving equilibrium did not exist among short-term money market interest rates, monetary aggregate, nominal effective exchange rates, and macro-economy variables (GDP and price level). However, in a differenced VAR, an exogenous, unexpected and temporary rise in the growth rate of money market short-term interest rates shows insignificant effect on the change rates of the real GDP and the price level. The impulse response functions and variance decompositions show that short-term money market interest change move along with money aggregate change rate, not the reverse. These findings show that under the current monetary aggregate targeting regime in China, a move in the short-term money market interest rate has not been able to reflect the changes in macro-economy variables. In other words, the response of the central bank's benchmark interest rate to macro-economy fluctuations fails to transfer effectively to the money market. The weak link between the short-term interest rate and the macro-economy variable implies that China cannot use the short-term money market interest rate as it operation target. An institutional reason for this failure is the existence of two cut-off separate interest rate systems: the central bank interest rate system and the commercial bank loan and deposit interest rates system.

After 2003, the PBC has adopted a contractionary monetary policy, namely, increasing the central bank bills to reduce the money supply. Therefore, the PBC could not influence the money market short-run interest rate. In this situation, the interest rate on the central bank bills rather than the money market interest rate, acts as the central bank target interest rate (Wu, 2008). To switch to an official interest rate as a policy instrument and to adopt a short-term money market rate as operation target, China needed first to establish an effective interest rate transmission channel, so that the PBC can effectively influence the short-term money market rate through OMOs.

It should be noted that the sample size in the study is not particularly large, which may limit the robustness of the tests and estimates presented here. The small sample has also prevented a reliable structural break analysis when it comes to cointegration testing. Therefore, future research that addresses similar issues should conduct with a sufficiently large sample so that one can investigate if structural breaks have taken place, and, if they have, what are their impacts on the long-run relationships between the variables.

Figure 2: Response Impulse in the Recursive VAR (Repo)



This figure shows impulse responses to a monetary policy shocks defined as a temporary, unexpected and exogenous rises in Repo growth rate

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