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FROM QUANTITY- TO INTEREST RATE-BASED FRAMEWORK: MULTIPLE MONETARY POLICY INSTRUMENTS AND THEIR EFFECTS IN CHINA

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From a Quantity to an Interest Rate-Based Framework: Multiple Monetary Policy Instruments and Their Effects in China*

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Abstract

In moving from a quantity to an interest rate-based policy framework, the PBoC uses a variety of monetary policy instruments and intermediate targets, which is different from central banks of main industrial countries. Contrary to most studies on overall effects of monetary policy, this research empirically investigates the effects of various types of monetary policy instruments separately by modeling the interactions and relationship among monetary policy instruments and other monetary variables such as monetary policy targets, to draw implications forhighlight the PBoC's attempt to change the monetary policy framework to an interest rate based framework.

Empirical results suggest the effects of the changes in benchmark lending rates and short-term interest rates on loan, M2 and output are larger than those of the changes in reserve requirement ratio, especially in recent years. Non-policy shocks exert substantial effects on intermediate targets, such as loans and M2, under a quantity-based policy framework. These results may imply that monetary policy is more effective under a new interest rate-based policy framework than the old quantity-based policy framework. Empirical results also suggest that the size and effects of short-term interest rate shocks are larger in recent years, which shows the push by the PBoC to move from a quantity-based policy framework to an interest rate-based policy framework has progressed significantly. In addition, short-term interest rates have the strongest effect on property price, among various policy instruments. This could suggest that the PBoC's interest rate based framework is likely more effective in achieving its financial stability objective. Overall, the empirical results support the idea that the new interest rate-based policy framework is more effective in achieving not only traditional macroeconomic objectives, but also new financial stability objectives.

Keywords: Interest Rate-Based Framework, Monetary Policy Instruments, China, Effects of Monetary Policy

1. Introduction

The number of empirical studies on the effects of monetary policy in China is growing. However, analysing these effects can be challenging. The main challenge originates from China using various monetary policy instruments and intermediate targets. Examples of these are reserve requirement ratio; benchmark lending and deposit rates; repo or reverse repo rates; differentiated, dynamic and target reserve requirements; central bank bills; repo or reverse repo amount; total loan growth; M2; and total social financing (TSF). Recently, the PBoC has lifted the deposit rate ceiling and introduced instruments, such as short-term liquidity operations (SLO), standing lending facility (SLF), medium-term lending facility (MLF) and pledged supplementary lending (PSL), to build an interest rate corridor system. These changes reflect the intention of PBoC (People's Bank of China) to move from a quantity-based monetary policy framework to an interest rate-based policy framework. The practice of using multiple policy instruments is strikingly different from that in main industrial countries, which use only one instrument, such as short-term interest rate, at least before the global financial crisis. Therefore, directly applying a conventional approach used in past studies on the effects of monetary policy in main industrial countries is difficult.

The presence of multiple policy instruments and intermediate targets calls for a new methodology, partly because these monetary policy instruments and intermediate targets are inter-related. For example, quantity-based measures likely affect price-based measures and vice versa. In addition, not only various policy instruments but also other factors, such as demand-side factors, likely affect intermediate targets. In such a case, a simple method to analyse the effects of each policy instrument separately and/or the effects of intermediate targets may fail. The effects of each policy instrument should be

analysed by carefully considering the interactions with other policy instruments and other relevant variables, including intermediate targets.

The challenge of multiple policy instruments means past studies on Chinese monetary policy develop an indicator of monetary policy that comprises changes in various policy instruments and/or intermediate targets. He and Pauwels (2008) develop a measure of the Chinese monetary policy stance by indicating tightening and easing actions of different instruments as a series of -1 and +1. Xiong (2012) extends this method. Shu and Ng (2010) and Sun (2015) measure the monetary policy stance of China. Chen, Chow, and Tillmann (2016) develop a Qual VAR that includes the latent policy variable constructed based on policy actions in reserve requirement ratio, benchmark lending and deposit rates. Chen, Higgins, Waggoner, and Zha (2016) identify only one type of monetary policy shock. A few studies, such as He, Leung and Chong (2013) and Fernald, Spiegel and Swanson (2014), analyse the effects of a few policy instruments but do not explicitly consider the realistic interactions among these policy instruments. Fan, Yu, and Zhang (2011) and Sun, Ford and Dickinson (2010) investigate the effects of intermediate targets by directly treating intermediate targets such as M2 growth as policy variables.

Contrary to most studies on overall effects of monetary policy, this research empirically investigates the effects of various types of monetary policy instruments separately by modeling the interactions and relationship among monetary policy instruments and other monetary variables, such as target variables in China. The results aim to draw implications for the PBoC's attempt to change the monetary policy framework to an interest rate-based framework in recent years. In particular, what are the effects of each monetary policy instrument on key macro variables? What is the

relative effectiveness of various monetary policy instruments in achieving traditional objectives as well as the new financial stability objective? What are the relationships and interactions among various monetary policy instruments? How do the effects and dynamic interactions of different policy instruments change over time with the shift in the monetary policy framework of the PBoC? Is a large portion of fluctuations in the traditional intermediate targets, such as growth in total loan and M2, subject to non-policy shocks? What can be expected when the monetary policy framework fully changes to an interest rate-based one?

To identify shocks on each policy instrument and investigate the effects of the identified policy shocks, we use structural vector autoregression (VAR) models, following many past studies on the effects of monetary policy. To model formally the interactions among various monetary policy instruments and identify shocks to various monetary policy instruments, this study uses short-run, non-recursive zero restrictions introduced by Bernanke (1986) and Sims (1986). With such a method, past studies, such as Bernanke and Mihov (1998) and Kim (2003, 2005), develop empirical models of multiple policy instruments that allow interactions with one another and investigate the effects of each policy instrument shock. This study develops an empirical model of Chinese monetary policy with various policy instruments and liquidity measures, including intermediate targets.[1]

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[1] Bernanke and Mihov (1998) develop a model for the US based on the US monetary policy operating procedure. Kim (2003, 2005) proposes a model for the US and Canada to identify conventional monetary and foreign exchange policies. Kim (2016) develops a structural VAR model to identify conventional monetary policy and foreign exchange policy with the interest rate, foreign exchange reserves, and exchange rate by imposing sign restrictions on impulse responses. This study differs from the aforementioned research in that the former considers monetary policy instruments and monetary policy operating procedures of China that are quite distinct from those in these past studies.

Section 2 discusses the relationship and the interactions among various policy instruments and an evolution of PBoC monetary policy frameworks. Section 3 develops an empirical model that incorporates the interactions among policy instruments and monetary variables. Section 4 reports the empirical results. Section 5 summarises the empirical findings with policy implications.

2. Evolution of Monetary Policy Framework in China

This section reviews the evolution of China's monetary policy framework with a focus on the interactions of different policy instruments used by the PBoC.

The deepening of market-oriented economic reform means China's monetary policy framework gradually shifts from a quantity-based framework into a quantity-based plus interest rate-based framework. Recently, the PBoC has added a macroprudential framework to supplement its monetary policy for financial stability, especially macroprudential assessment, to cross border capital flows (Yi, 2018).

From 1984 to 1997, China's monetary policy managed the credit scale. In 1998, credit quota was abolished and an indirect management of credit and monetary aggregates was established. In the meantime, the central bank gradually liberalised interest rates. In June 1996, the interbank rate was liberalised. From 1997 to 2004, the PBoC gradually expanded the lending rate range. In October 2004, the PBoC removed the upper bound of lending rates and lower bound of the deposit rate. In July 2013, the PBoC removed the lending rate floor. Finally, in October 2015, the PBoC removed the deposit rate ceiling. This last step completes the liberalisation of retail lending and deposit rates. After the completion, the benchmark lending and deposit rates serve only as reference rates for retail lending and deposits. To stop banks using a high deposit rate

to compete for retail deposits, which historically causes banks to take excessive risks, and with PBoC support, the commercial banks set up a self-disciplinary system for the deposit rate ceiling. In April 2018, this self-disciplinary system was lifted. After more than 2½ years of deposit rate liberalisation, from the financial stability point of view, the PBoC is more confident to fully let go interest rates. Meanwhile, the PBoC takes measures to guide financial institutions to improve the mechanisms to price credit risk.

Fully liberalised interest rates have led the PBoC to try to establish an interest rate corridor around a short-term policy rate. It guides the market expectation to build the credibility of this short-term rate as the main policy rate so banks start to price credit based on this rate. As the interest rate transmission channel is not smooth and efficient, the PBoC also attempts to establish a yield curve for maturities of less than a year. In China, the PBoC helps in structural adjustment and deleverage, so the central bank sometimes uses differentiated interest rates for different sectors. For example, the rate on PSL is made lower on government housing projects to renovate city slums. The central bank curtails lending to overcapacity sectors or inefficient zombie firms.

The shift of focus in monetary policy framework has led to the central bank changing the way it implements monetary policy. Specifically, the central bank focuses on the use of different instruments at times, by taking into consideration the interactions and effects among the instruments.

The ultimate goal of China's monetary policy is to maintain currency value stability and promote economic growth. Currency stability includes price and exchange rate stability. Recently, the central bank has added financial stability as one of its policy objectives. To achieve its final goals, the central bank chooses intermediate targets and operational instruments. The two main intermediate targets are the growth of monetary

aggregates and bank loans, such as M2 and loan growth. Since 2010, the PBoC has added TSF growth as an intermediate target. TSF refers to the aggregate volume of funds provided by China's domestic financial system to the real economy in a given period. TSF includes indirect finance via the banking system, as well as direct finance via stocks and bonds on the capital market. The PBoC monitors TSF to help monetary policy formation. TSF and M2 are fundamentally two sides of the same coin. TSF is calculated from the asset side of the balance sheet of financial institutions, whereas M2 is calculated from banks' liability assets. In addition, TSF includes direct financing through capital markets. In 2017, the government set 12% as the M2 and TSF growth target for that year. However, in the 2018 Government Work Report to the People's Congress, no number targets were set for M2 and TSF growth. The reason for this strategy is discussed later.

During the time of quantity-based framework, loan, M2 and TSF growth are intermediate targets. The central bank constantly monitors the changes in these variables. Operationally, the central bank adjusts these variables through lending from discount windows, open market operations (OMOs), changes in reserve requirement ratio (RRR), change in benchmark interest rates and window guidance. Since the global financial crisis in 2008, facing large capital inflow from quantitative easing (QEs) of the Fed, ECB and Bank of Japan, the PBoC has raised RRR to a historical high to sterilise the capital inflows. During this period, the creation of bank reserves was mainly driven by capital inflows. Increase in RRR changed the structure of bank reserves and slowed the money supply growth.

With the development of domestic financial markets, growth of shadow banking and interest rate liberalisation, the PBoC finds the correlations of quantity targets, such

as M2, loan and TSF growth, with inflation are rather weak (Xu et al., 2018). The variables become less useful as intermediate targets, which is the reason that concrete number targets were not set in the 2018 Government Work Report. The PBoC starts to establish an interest rate-based system. However, as the interest rate transmission from the repo market, interbank market towards bond market, the credit market is not efficient and effective. The PBoC subsequently develops different lending facilities to guide interest rates at different maturities. Currently, the PBoC uses OMOs, which are mainly repos and reverse repos at 7, 14, 28 and 63 days; SLF at overnight, 7 days and 1 month; temporary lending facility at 28 days; MLF at 3, 6, and 12 months; and Pledged Supplementary Lending (PSL) for long-term, large-scale financing to policy banks tasked with financing government projects to renovate city slums. SLO was introduced in 2013 but has not been used since January 2016. With all these lending facilities, the PBoC can more or less guide the interest rates up to a year, as well as manage the liquidity in the banking system and smooth the interest rate spikes in the inter-bank market.

The interest rates on OMOs, SLFs, PSLs and MLFs are policy rates. The PBoC uses MLFs and PSLs as monetary policy instruments to manage the balance sheet of the banking system (see Yi, 2017). The 7-day repo market is the most liquid market. However, the repo market has participants other than banks. The PBoC aims to target a 7-day interest rate for transactions between banks. Hence, the PBoC chooses the pledged 7-day interbank repo rate DR007 as its short-term policy target rate. The central bank uses OMOs and SLFs to align the market rate to its target level. This pledged 7-day interbank rate highly correlates with the 7-day repo rate.

For the interest rate corridor that the PBoC tries to establish, the target 7-day

interest rate (DR007) is the key policy rate. The interest rate on excess reserve serves as the lower bound of the "corridor". The 7-day interest rate SLF serves as the upper bound. The interest rates on MLFs are for longer maturities. Besides that, MLFs serve as balance sheet instruments. To build credibility of its policy target, the PBoC encourages market participants to price credit based on its policy target and tries to smooth the interest rate transmission from its short-term policy rate to rates on long-term maturities.

In the following analysis, we use the RRR, benchmark lending and deposit rates, and 7-day repo rate in the interbank market (R007) as the monetary policy instruments. Strictly speaking, the 7-day repo rate (R007) is neither a policy instrument nor a policy target. As pointed out, the pledged 7-day repo rate between banks (DR007) is the policy target. However, this series DR007 is very short, as the policy only started in 2017. The series was introduced in December 2014, and the available data is from May 2017. DR007 is highly correlated with the 7-day repo rate (R007) in the interbank market. We use the 7-day repo rate (R007) as a short-term policy instrument in our analysis. The 7-day reverse repo fixing that comes out of the PBoC's OMOs refers to the direct interest rate controlled by the PBoC. The 7-day reverse repo fixing is close to R007, but a bit lower. Among the three, R007 is the most volatile, the next is DR007, the least is the 7-day fixing. The benchmark lending and deposit rates are important monetary policy instruments until the full liberalisation of retail lending and deposit rates in October 2015. Since then, the PBoC has not changed the benchmark rates. The RRR has not been frequently used. The RRR rate for the big four banks is 16%, which is very high by historical standards and compared with that of other emerging market economies. The latest two RRR changes occurred in April and June 2018.

We use M2, loan and bank reserve as liquidity measures. M2 and loan growth are always intermediate policy targets. Recently, the central bank has added growth in TSF as an intermediate target to monitor. Changes in policy instruments, such as RRR, directly affect bank reserves.[2]

The role of RRR as a monetary policy instrument has changed over the past two decades. RRR is an important policy instrument for the PBoC and traditionally functions as a loosening or tightening monetary policy tool. As RRR does not change the balance sheet of the central bank, i.e., does not change the monetary base, RRR is a structural monetary policy tool. RRR affects the liquidity of the banking system and the money multiplier. In China, because state-owned enterprises are not sensitive to interest rate changes, quantity-based tools have been effective in the past. The PBoC adjusts RRR more often than policy rates. From January 2000 to June 2018, the PBoC has adjusted RRR 49 times; policy rates, 26 times. Before the PBoC fully liberalised interest rates, banks priced credit and mortgages based on benchmark interest rates. Hence, the adjustment of benchmark rates has a huge impact on credit and financial markets, even though not necessarily on bank lending to SoEs. Therefore, the PBoC weighted the impact of different instruments before selecting instruments for policy actions. Only when the PBoC found it necessary would the bank adjust the RRR and benchmark rates

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[2] Exchange rate and capital flow are important considerations for China's monetary policy. Since July 2005, managing exchange rate and capital flow dominates China's monetary policy decision. In the following analysis, we do not analyse the exchange rate and capital flow directly, but their impact on monetary policy is reflected in the changes of the monetary base, RRR, which partly sterilises capital flows, and benchmark interest rates, which maintain a stable interest rate differential between USD and RMB to avoid excessive interest rate arbitrage. We plan to study these open economy aspects in the next project.

at the same time.[3] Interestingly, over the past few years, the PBoC has used RRR change to differentiate sectors, such as providing relief to the agricultural sector or small businesses. The PBoC makes temporary RRR adjustments, such as injecting liquidity for preparing for Chinese New Year holidays. The PBoC's focus on the development of an interest rate corridor system means RRR has not been frequently adjusted. When the PBoC needs to adjust, RRR is used for liquidity management in the banking system. At the same time, smoothing the short-term interest rate as the RRR cut is more generic than changes in instruments, such as SLF, PSL and MLF. One recent example is the 1% RRR cut on April 25, 2018. The PBoC said the RRR cut could free up approximately 1.3 trillion RMB in liquidity, and that 900 billion RMB would be used to repay MLF loans, leaving a net injection of roughly 400 billion RMB. Moreover, swapping MLF with the RRR cut will improve the funding structure, guide the financial institutions to increase loans to micro and small businesses, and lower their financing cost.

Chen, Chen and Gerlach (2013) study the effectiveness of benchmark interest rates. Interest rate liberalisation and shadow banking activity growth mean the benchmark interest rates play less significant roles in total social financing activities. The gap between the effective lending rate and benchmark lending rate is widening. However, a large part of bank loans is still priced based on benchmark interest rates. For example, good SOEs obtain loans with a discount on the benchmark lending rate. In addition, mortgage lending is mostly priced based on benchmark rate. Since mortgage

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[3] Since the start of the global financial crisis until the second half of 2013, facing large capital inflow, the increase in RRR has been mainly for sterilising capital inflows. The PBoC almost tripled the RRR for big banks after the global financial crisis to a historical high of 21.5% in 2011. Given that during this period a large amount of excess reserve was in the banking system, the impact of an increase in RRR was marginal. From the second half of 2013, especially after August 11, 2015, facing large pressure of capital outflow, the PBoC cut RRR several times.

lending is normally long-term lending with a flexible rate, the actual mortgage rate is usually adjusted following changes of benchmark rates. Even if the lending rate floor or deposit rate ceiling is not binding, the adjustment of benchmark interest rates continues to significantly affect commercial lending. Since October 2015, when the PBoC lifted the deposit rate ceiling, the bank has not changed benchmark rates. However, the PBoC endorsed an industry-wide disciplinary system to set the deposit rate ceiling until the system was abolished in April 2018. In 2013, the PBoC launched the loan prime rate (LPR) to foster a market rate that reflects the lending interest rate charged by nine selected banks on loans to their best corporate borrowers. The PBoC tries to maintain a stable gap between benchmark lending and deposit rate for banks to earn a healthy profit, which leads to maintaining financial stability. That is why, most of the time, the PBoC makes both rate adjustments simultaneously.[4]

In the empirical analysis, we consider benchmark lending and deposit rates separately. We first analyse the effect of the benchmark lending rate (RL) in baseline mode. In the extended model, we add benchmark deposit rate (RD). We expect the change of benchmark lending rate is more effective than the change of benchmark deposit rate for the following reasons. First, investment is one of the main drivers of China's economy growth. China's investments are done mostly through bank lending. With market-oriented economic reform, banks are more sensitive to corporate default risk (Chen, Chen, and Han, 2017) and corporations are sensitive to lending rate change, especially in the non-state sector. Therefore, the change in benchmark lending rate has a

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[4] Since the global financial crisis, initially facing large capital inflows and now large capital outflows, the PBoC has tried to maintain a stable interest rate differential between RMB and the US dollar. Hence, when adjusting the domestic interest rates, the PBoC ensures the resulting interest rate differential will not add more pressure to capital flows and exchange rates.

bigger effect. On the other hand, the PBoC keeps the benchmark deposit rate lower than the equilibrium deposit rate (Chen, Chen and Gerlach, 2013) and creates a financial repression for retail depositors. That strategy is among the main reasons behind the rapid growth of wealth management products (WMPs) and shadow banking activities. If the benchmark deposit rate is too low, the effect of change in benchmark deposit rate is marginal in the sense that no change occurs in the binding of the deposit rate ceiling, which will not bring a big portfolio rebalance effect for retail depositors. Therefore, we expect the effect of change in deposit rate to be rather weak.

The 7-day repo rate (R007) is sometimes volatile. Certain spikes are driven by events, such as big IPOs, holiday liquidity demand, tax payment, government fiscal outlay, change in RRR and MLF. The high volatility of R007 drives the PBoC to choose DR007 as its policy target. DR007 is the pledged repo rate between banks and is more stable than R007. Given the need for a longer series, our study uses R007, which reflects liquidity conditions in the interbank market. The RRR and benchmark interest rate changes affect R007 in present and future periods. Some analysts argue that the SLF, PSL and MLF make R007 more volatile. The RRR cut is more homogenous in releasing liquidity and may smooth R007. The latest swap between MLF and RRR cut is an example.[5]

To summarise, we consider RRR, 7-day repo rate R007 and benchmark interest rates as policy instruments; and quantity variables, such as M2, total loans and bank reserve, as liquidity measures and/or intermediate targets in the following empirical analysis and consider the interactions among these variables. We expect that China's

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[5] In addition, to maintain a stable interest rate differential, when the Fed raises the Fed Fund rate, the PBoC will adjust the OMO rates in the same direction. This strategy occurred in the past year when the Fed normalised the Fed Fund rate.

monetary policy follows a similar reaction function as other advanced economies, such as tightening when inflation pressure is high, loosening when growth is low, with increasing attention paid to financial stability, such as housing price stability. However, with the large share of state-owned enterprises, the transmission channel of China's monetary policy may differ from that of advanced economies (Chen, Li and Tillmann, 2018). We expect that, with the full liberalisation of interest rates and the development of an interest rate corridor system, the policy rate plays an increasingly significant role in monetary transmission. Next, we perform the formal empirical analysis to confirm the conjectures.

3. Empirical Model

3. 1. Structural VAR Modeling with Contemporaneous Restrictions

We assume the economy is described by a structural form equation

$$G(L)y_t = e_t, \tag{1}$$

where $G(L)$ is a matrix polynomial in the lag operator L, y_t is an $n \times 1$ data vector, and e_t is an $n \times 1$ structural disturbance vector.[6] e_t is serially uncorrelated and $\text{var}(e_t) = \Lambda$. Λ is a diagonal matrix where diagonal elements are the variances of structural disturbances. Hence, structural disturbances are assumed mutually uncorrelated.

We estimate a reduced form equation (VAR)

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[6] For simplicity, we present the model without the vector of constants. Alternatively, we can regard each variable as a deviation from the steady state.

$$y_t = B(L)y_{t-1} + u_t, \tag{2}$$

where $B(L)$ is a matrix polynomial in lag operator L and $var(u_t)= \Sigma$.

Several ways can be used to recover the parameters in the structural form equation from the estimated parameters in the reduced form equation. Certain methods give restrictions on only contemporaneous structural parameters. A popular and convenient method is to orthogonalise the reduced form disturbances (u_t) by the Cholesky decomposition (as in Sims, 1980). However, in this approach, we assume only a recursive structure, that is, a Wold causal chain. Blanchard and Watson (1986), Bernanke (1986), and Sims (1986) suggest a generalised method in which non-recursive structures are allowed while still giving restrictions only on contemporaneous structural parameters.

Let G_0 be the contemporaneous coefficient matrix in the structural form and $G^0(L)$ be the coefficient matrix in $G(L)$ without the contemporaneous coefficient G_0. That is,

$$G(L) = G_0 + G^0(L). \tag{3}$$

Then, the parameters in the structural and reduced form equations are related by

$$B(L) = - G_0^{-1} G^0 (L), \tag{4}$$

In addition, the structural disturbances and the reduced form residuals are related by

$$e_t = G_0 u_t, \tag{5}$$

which implies

$$\Sigma = G_0^{-1} \Lambda G_0^{-1'}. \tag{6}$$

Maximum likelihood estimates of Λ and G_0 can be obtained only through the sample estimate of Σ. The right-hand side of equation (6) has $n \times (n+1)$ free parameters to be estimated. As Σ contains $n \times (n+1)/2$ parameters, by normalising n diagonal elements of G_0 to 1's, we need at least $n \times (n-1)/2$ restrictions on G_0 to achieve identification. In the VAR modeling with Cholesky decomposition, G_0 is assumed triangular. However, in the generalised structural VAR approach, G_0 can be any structure (non-recursive).

3.2. Model

The data vector is (RRR, RL, REPO, LOAN, RES, M2, CPI, IP) where RRR is reserve requirement ratio, RL is the lending rate, REPO is the 7-day repo rate R007, RES is bank reserves, which are approximated by subtracting M0 from monetary base, CPI is the consumer price index, and IP is the industrial production index. Three policy instruments (RRR, RL and REPO) are included. Three measures of liquidity (LOAN, RES and M2), including two traditional intermediate targets (LOAN, M2), are included. In addition, two key macro variables (IP and CPI) that monetary policy and/or liquidity measures are likely to react to are included.

The following is the restriction on the contemporaneous structural parameters G_0, based on Equations (1) and (3).

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\begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & g_{17} & g_{18} \\
0 & 1 & 0 & 0 & 0 & 0 & g_{27} & g_{28} \\
g_{31} & g_{32} & 1 & 0 & 0 & 0 & g_{37} & g_{38} \\
g_{41} & g_{42} & 0 & 1 & 0 & 0 & g_{47} & g_{48} \\
0 & g_{52} & 0 & 0 & 1 & 0 & g_{57} & g_{58} \\
0 & 0 & g_{63} & 0 & 0 & 1 & g_{67} & g_{68} \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & g_{78} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{bmatrix}
\begin{bmatrix}
RRR \\ RL \\ REPO \\ RES \\ LOAN \\ M2 \\ CPI \\ IP
\end{bmatrix}
= -G^{0}(L)
\begin{bmatrix}
RRR \\ RL \\ R \\ RES \\ LOAN \\ M2 \\ CPI \\ IP
\end{bmatrix}
+
\begin{bmatrix}
e_{RRR} \\ e_{RL} \\ e_{REPO} \\ e_{RES} \\ e_{LOAN} \\ e_{M2} \\ e_{CPI} \\ e_{IP}
\end{bmatrix}
\tag{7}
$$

where e_{RRR}, e_{RL}, e_{REPO}, e_{LOAN}, e_{RES}, e_{M2}, e_{CPI} and e_{IP} are structural disturbances, namely, reserve requirement ratio shocks (policy shock one), lending rate shocks (policy shock two), 7-day repo rate shocks (policy shock three), shocks to loan market (or demand shocks in loan market), demand shocks to reserves, demand shocks to M2, CPI shocks and IP shocks. All restrictions are zero restrictions on the contemporaneous structural parameters and no restrictions are imposed on lagged structural parameters. Not imposing zero restrictions does not necessarily imply that the coefficients are non-zero. Rather, possible non-zero interactions are allowed.

The first three equations represent the monetary policy sector (policy reaction functions). The first equation shows reserve requirement ratio setting policy, the second equation, lending rate setting policy, and the third, 7-day repo rate setting policy. In the first equation, the monetary authority is assumed to set reserve requirement ratio after observing current and lagged values of two key macro variables (CPI and IP) and lagged values of all other variables in the model. Similarly, in the second equation, the monetary authority is assumed to set the lending rate after observing current and lagged values of two key macro variables (CPI and IP) and lagged values of all other variables

in the model. This assumption is similar to that of Christiano, Eicheunbaum and Evans (1996, 1999). Second, the monetary authority is assumed to set a 7-day repo rate after observing current values of reserve requirement ratio and lending rate in addition to CPI and IP. The PBoC uses various types of policy instruments. Two frequently used policy instruments (reserve requirement ratio and lending rate) are modeled separately in the first two equations. Then, changes in policy instruments, including various repos and reverse repos from OMOs, other than reserve requirement ratio and lending rate are modeled in the third equation. Those changes in other policy instruments will affect the 7-day repo rate. The third equation comprises all other policy instrument changes that affect the 7-day repo rate. We control for reserve requirement and lending rates in the third equation since those two policy instruments can affect the 7-day repo rate but we would like to exclude the effects of shocks to those two policy instruments as they are already modeled in the first two equations.

The fourth equation shows how bank reserves are determined by commercial banks. In the fourth equation, RRR and RL are allowed to affect the amount of bank reserves contemporaneously. Changes in RRR likely affect the bank reserves by directly affecting the required reserves. The RL likely affects the bank reserves negatively as banks likely hold less excess reserves if they can receive more interest by lending. The fifth equation shows the demand (or equilibrium) for loan markets in which the lending rate is allowed to contemporaneously affect the loan amount. The sixth equation shows the demand for M2 in which the 7-day repo rate, the opportunity cost of holding money, is allowed to contemporaneously affect M2 demand. In the fourth, fifth and sixth equations, current IP and CPI are included, given that aggregate activities and prices likely affect the demand for liquidity and the decision on bank reserves. In this model,

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policy instruments, such as RL and the 7-day repo rate, are allowed to contemporaneously affect intermediate targets, such as loan and M2, but demand shocks and demand factors, such as CPI and IP, are also allowed to contemporaneously affect intermediate targets. Therefore, we may infer the degree of endogeneity of intermediate targets in the empirical analysis.

The last two equations represent the sluggish real sector. Real activity is assumed to respond to monetary policy and liquidity variables only with a lag. One motivation for this identifying assumption is that firms do not change their output and price unexpectedly in response to unexpected changes in monetary policy and liquidity within a month due to inertia, adjustment costs and planning delays. Such assumptions are used by Christiano, Eichenbaum and Evans (1996, 1999), Sims and Zha (2006), and Kim (1999).

The model is estimated from October 1997 to December 2016 by using monthly data. The earliest monthly date for the 7-day repo rate R007 is October 1997. All data is from the CEIC database. Three lags and a constant term are assumed. All variables are in the form of logarithms (multiplied by 100), except for RRR, RL and REPO. Given that we follow the Bayesian inference, our statistical inference is not problematic in the presence of unit roots and cointegrating relations. We follow Sims and Zha (1999) to construct posterior probability bands for impulse responses. Sims (1988) and Sims and Uhlig (1991) present a general discussion on Bayesian inference in the presence of unit roots and cointegrating relations.

Table 1 reports the estimated contemporaneous structural parameters. The estimated signs of most parameters are consistent with standard economic theory. Monetary policy tends to take a contraction when IP and CPI increase, which is not

different from monetary policy reactions in advanced countries, as we expect. Liquidity demand tends to increase when IP and CPI increase. In the third equation, rises in reserve requirement ratio and lending rate increase the 7-day repo rate. This result is reasonable as contractionary monetary policy of increases in reserve requirement ratio or lending rate is likely to increase the interest rate of the interbank market, reflecting contractionary tendency. In the fourth equation, a rise in reserve requirement ratio increases reserves (because it increases required reserves), but a rise in lending rate decreases reserves (because it decreases excess reserves). In the fifth and sixth equations, rises in the 7-day repo rate decrease loans and rises in lending rate decrease M2, respectively, given that opportunity cost increases. In the fifth and sixth equations, rises in IP and CPI tend to increase demand for loans and M2, respectively, which confirms that intermediate targets, such as M2 and loans, are affected by demand factors.

4. Empirical Results

4.1. Baseline Model

Figure 1 reports the impulse responses for over 48 months with 90% probability bands. Each column shows the impulse responses to each shock. The names of shocks are denoted at the top of each column. The name of each responding variable is displayed at the far left of each row. For easy comparison, the scales of the graphs are the same for each row.

In response to reserve requirement ratio shocks, the reserve requirement ratio increases to approximately 0.4% points and decreases to the initial level in nearly four years. The lending rate does not respond significantly but the 7-day repo rate increases up to 0.18% points in two months, which is different from zero with more than 95%

probability. Bank reserves increase, as reserve requirement ratio increases. Loan and M2 decline in the short-run given that the increase in reserve requirement ratio has a negative effect on liquidity and credit in the economy. The short-run falls of those variables are different from zero with more than 95% probability. Industrial production does not change much.[7]

In response to lending rate shocks, the lending rate increases up to 0.2% points initially and then decreases to the initial level in nearly four years. The 7-day repo rate increases about 0.13% points in two months, and the reserve required ratio tends to decline up to 0.1% points in the short-run. Bank reserves, loan and M2 decline over time up to 0.5%. The short and medium-run declines of these measures are different from zero with more than 95% probability. An increase in the lending rate gives an incentive for commercial banks to decrease bank reserves. An increase in the lending rate decreases the demand for loans, which leads to declines in loan and M2. CPI decreases in the long run, which is different from zero with more than 95% probability. The short- and medium-run declines of industrial production, which is a nearly 0.3% decline from the initial level, are different from zero with more than 95% probability.

In response to 7-day repo shocks, the rate increases up to 0.5% points and then decreases to the initial level in nearly two years. The lending rate tends to increase in the short run up to 0.05% points. The reserve requirement ratio and bank reserves do not change significantly. Loan and M2 decrease persistently up to 0.5%. The declines of these variables are different from zero with more than 95% probability for most horizons. CPI tends to decrease in the long run, although the decline is not significantly

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[7] CPI slightly increases in the short-run. This response may be regarded as the price puzzle. Refer to Sims (1992); Kim (1999); and Christiano, Eichenbaum and Evans (1999) for explanations on the price puzzle.

different from zero. IP decreases up to 0.6%. The medium-run and long-run declines in IP are different from zero with more than 95% probability.

Among three shocks to policy instruments, the 7-day repo and lending rate shocks have stronger effects on loan, M2 and IP than reserve requirement ratio shocks. The negative effects of these two shocks on loan, M2 and IP are different from zero with more than 90% probability for most horizons up to four years. However, the effects of reserve requirement ratio shocks are relatively small and short-lived. In response to reserve requirement ratio shocks, significant declines in loan and M2 are found only in the short-run. Significant negative effects on industrial production are not observed at any horizon.

Finally, impulse responses of intermediate targets, such as loan and M2, under a quantity-based framework show that non-policy shocks, such as demand shocks, have substantial effects on loan and M2. This finding may suggest that controlling intermediate targets tightly at the desired levels may not be an easy task. In addition, different shocks generate varied relations between these intermediate targets and macro target variables (e.g., CPI and IP), which may further suggest that using intermediate targets to achieve macro objectives is a challenging task.

4.2. Extended Models

The baseline model is extended in various ways. First, we include an additional monetary policy instrument, deposit rate (RD). We assume that IP, CPI and lending rate are allowed to contemporaneously affect deposit rate, whereas deposit rate is allowed to

contemporaneously affect 7-day repo.[8] Figure 2 reports the results. Deposit rate shocks tend to increase reserves, loan, M2, CPI and IP over time. Given lending rates, an increase in deposit rate is likely to increase deposit and reserves, which may lead to increases in reserves and liquidity.

Second, property price is additionally included in the empirical model to infer the effects of shocks to three policy instruments on property price (PROPP). This analysis is particularly interesting given that the PBoC has had concerns regarding financial stability in recent years. For identification, we assume that all variables contemporaneously affect property price (because financial variables are likely to reflect all information immediately) but not the other way around. The results are reported in Figure 3. The 7-day repo rate shocks have significant negative effects on property price for many horizons, but the other two shocks tend to have insignificant effects on property price. M2 and loan, in addition to property price, respond significantly and persistently to 7-day repo shocks. As discussed before, interest rate shocks have larger and more persistent effects on loans than reserve requirement shocks. These results may imply that the transition from a quantity to an interest rate-based framework has supported the financial stability objective introduced by the PBoC. The result on property price may suggest that 7-day repo rate is the most important policy tool for financial stability purpose. For example, to stabilise the housing market, an increase in the 7-day repo rate is clearly more effective than changes in other policy tools.

In Figure 3, the responses of three policy variables to property price shocks also show some interesting patterns. In response to positive property price shocks, three

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[8] We assume that lending rate is allowed to affect deposit rate contemporaneously but not the other way around, given that lending rate seems to be more important than deposit rate in policy making, as explained in Section 2.

policy variables increase, which is different from 95% probability at some horizons. This result may suggest that the PBoC has been trying to stabilise the housing market by adjusting these policy instruments.

Third, stock price (SP) is additionally included in the empirical model. For identification, we assume that all variables contemporaneously affect property price but not the other way around, as in the case of property price. The results are reported in Figure 4. The effects of three policy shocks on stock price tend to be negative but insignificant in most cases. The only significant effect is in the case of the immediate effect of RL shocks. In response to positive stock price shocks, three policy variables tend to increase, which may be interpreted as stabilising attempts by the PBoC.

Fourth, we estimate the baseline model from October 1997 but policy change occurred in July 2005. The Chinese RMB has been rigidly fixed to the US dollar since the Asian financial crisis in 1997. On July 21, 2005, the PBoC made a one-time appreciation of the RMB exchange rate for 2% and let the exchange rate appreciate.[9] We would like to see if the dynamics between different monetary policy instruments and their effectiveness are different from the overall sample period. Hence, we re-estimate the model starting from August 2005. As the degree of freedom decreases, only two lags are assumed. Figure 5 reports the results. The results are similar to the baseline model.

Fifth, we consider an alternative identifying assumption. In the baseline model, monetary policy instruments are not allowed to be contemporaneously affected by the

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[9] This trend continued until January 2014. Over this period, China had experienced large capital inflow, which forced the PBoC to raise RRR to a historical high. At the same time, the PBoC refrained from raising interest rates to prevent any increase in interest rate differential between RMB and US dollar, when the Fed fund rate was close to zero. In 2014, the RMB exchange rate finally broke from one-side appreciating trend and started to move both ways, while the Fed had not started normalisation until December 2015.

corresponding liquidity measures. Now, such possibilities are allowed. Reserve requirement ratio is allowed to contemporaneously respond to reserves, lending rate is allowed to contemporaneously respond to loan, and 7-day repo rate is allowed to contemporaneously respond to M2. Figure 6 reports the results, which are similar to the results of the baseline model.

Sixth, we split the sample into two sub-periods, from 1997 to 2006 and from 2007 to 2016. Sample periods are relatively short, so we consider only two lags and drop CPI from the empirical model to save the degree of freedom. Figures 7 and 8 report the results. In the first sample period, the effects of monetary policy tend to be weak. In particular, lending rate and 7-day repo rate shocks do not have significant negative effects on loan, M2 and IP. The effect of RRR tends to be larger than the effects of lending and 7-day repo rates in the first period. However, in the second sample period, lending and 7-day repo rates have significant effects on loan, M2 and IP. The effects of lending and 7-day repo rates are larger than effects of RRR in the second period. These results suggest that the effects of policy instruments on the economy change over time. These changes may reflect changes in monetary policy framework in China. As China shifts from a quantity to an interest rate-based framework, the effects of changes in policy interest rates on the economy become stronger. The size of three policy shocks also changes over time. RRR and RL shocks tend to have stronger effects on RRR and RL, respectively, in the first than in the second period. However, REPO shocks have a stronger effect on REPO in the second than in the first period. This finding supports the idea that PBoC uses the short-term interest rate as the policy instrument in recent periods.

Finally, we add the global financial crisis dummy (2008:9-2009:8) in the model

to check the robustness of the results. Figure 9 reports the impulse responses. The results are similar to those of the baseline model.

5. Conclusion

Moving from a quantity to an interest rate-based policy framework, the PBoC uses a variety of monetary policy instruments and intermediate targets, which is different from central banks of main industrial countries. This study constructs the structural VAR model that explicitly considers interactions of a variety of policy instruments and liquidity measures, including intermediate targets. By estimating the model, this study analyses the effects of various monetary policy instruments in China, such as reserve requirement ratio, benchmark lending and deposit rates, and short-term interest rate.

The main empirical findings are as follows. First, the effects of the benchmark lending rate and the short-term interest rate on output as well as liquidity measures, such as loan and M2, are stronger than those of reserve requirement ratio. In addition, non-policy shocks have substantial effects on loans and M2 that are intermediate targets under a quantity-based policy framework. This result may imply that monetary policy can be more effective as the PBoC moves from a quantity to an interest rate-based policy framework.

Second, the size of short-term interest rate shocks becomes larger in recent periods. In addition, the effects of short-term interest rate shocks on loan, M2 and output become stronger in recent periods. The PBoC's transition to an interest rate-based policy framework in recent years may have increased the size and effect of short-term interest rate shocks. These results may suggest that, as PBoC completes the

transition to the interest rate-based policy framework, the monetary policy is likely more effective.

Third, the short-term interest rate has the strongest effect on property price, among various policy instruments. No other policy instrument but the short-term interest rate has a significant effect on property prices. In recent years, the PBoC introduced the financial stability objective. This result, together with significant and persistent effects of the short-term interest rate shocks on loans, may suggest that an interest rate-based policy framework is likely to be more effective in achieving financial stability objectives than quantity-based policy framework.

Overall, the empirical result supports the idea that a new interest rate-based policy framework seems more effective in achieving not only traditional macroeconomic objectives but also new financial stability objective.

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**Table 1. Estimated Contemporaneous Structural Parameters**

$$
\begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & \underset{(.023)}{-.017} & \underset{(.008)}{-.039^{**}} \\
0 & 1 & 0 & 0 & 0 & 0 & \underset{(.012)}{-.0165} & \underset{(.004)}{-.007} \\
\underset{(.09)}{-.19^{*}} & \underset{(.18)}{-.47^{**}} & 1 & 0 & 0 & 0 & \underset{(.031)}{.035} & \underset{(.011)}{.016} \\
\underset{(.72)}{-1.37^{*}} & \underset{(1.28)}{.03} & 0 & 1 & 0 & 0 & \underset{(.24)}{.10} & \underset{(.090)}{-.034} \\
0 & \underset{(.20)}{.25} & 0 & 0 & 1 & 0 & \underset{(.036)}{-.030} & \underset{(.013)}{.022} \\
0 & 0 & \underset{(.07)}{.19^{**}} & 0 & 0 & 1 & \underset{(.033)}{-.020} & \underset{(.012)}{-.008} \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & \underset{(.024)}{-.030} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{bmatrix}
\begin{bmatrix}
RRR \\ RL \\ REPO \\ RES \\ LOAN \\ M2 \\ CPI \\ IP
\end{bmatrix}
= -G^{0}(L)
\begin{bmatrix}
RRR \\ RL \\ R \\ RES \\ LOAN \\ M2 \\ CPI \\ IP
\end{bmatrix}
+
\begin{bmatrix}
e_{RRR} \\ e_{RL} \\ e_{REPO} \\ e_{RES} \\ e_{LOAN} \\ e_{M2} \\ e_{CPI} \\ e_{IP}
\end{bmatrix}
$$

* and **indicate that the coefficients are estimated at the 5% and 1% significance level, respectively.
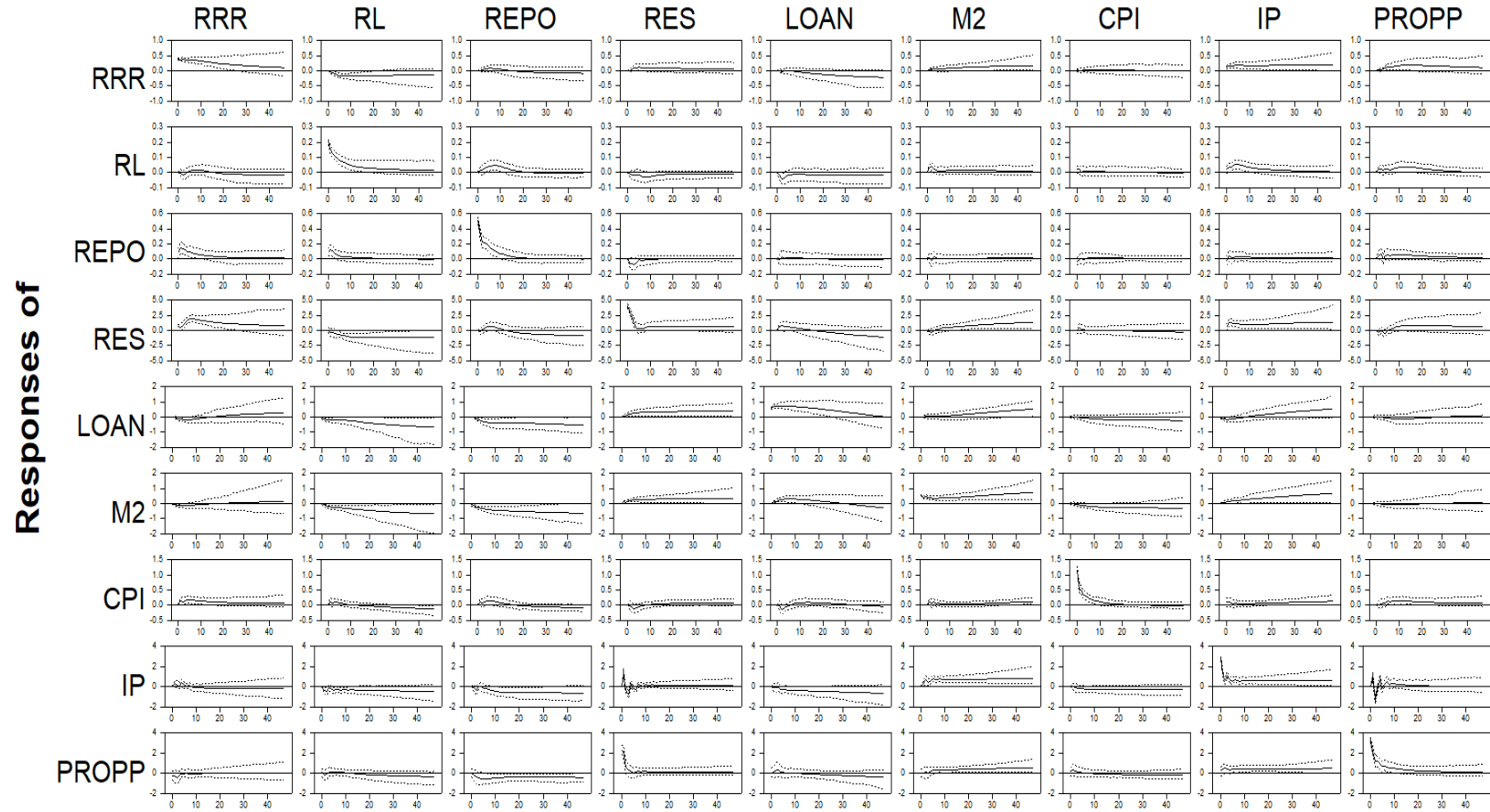
Figure 1. Impulse Responses in the Baseline Model
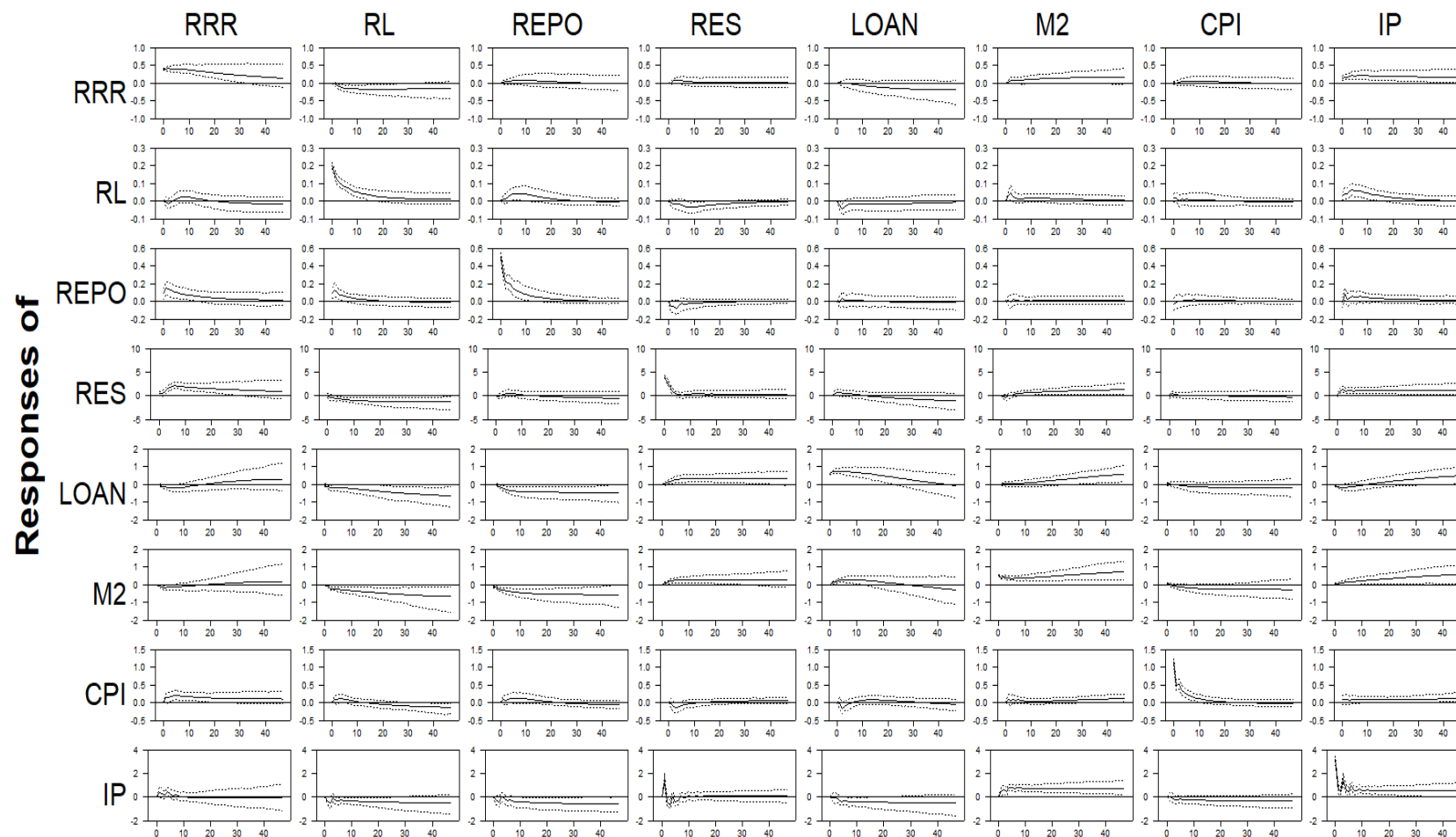
Figure 2. Impulse Responses in the Model with Deposit Rate
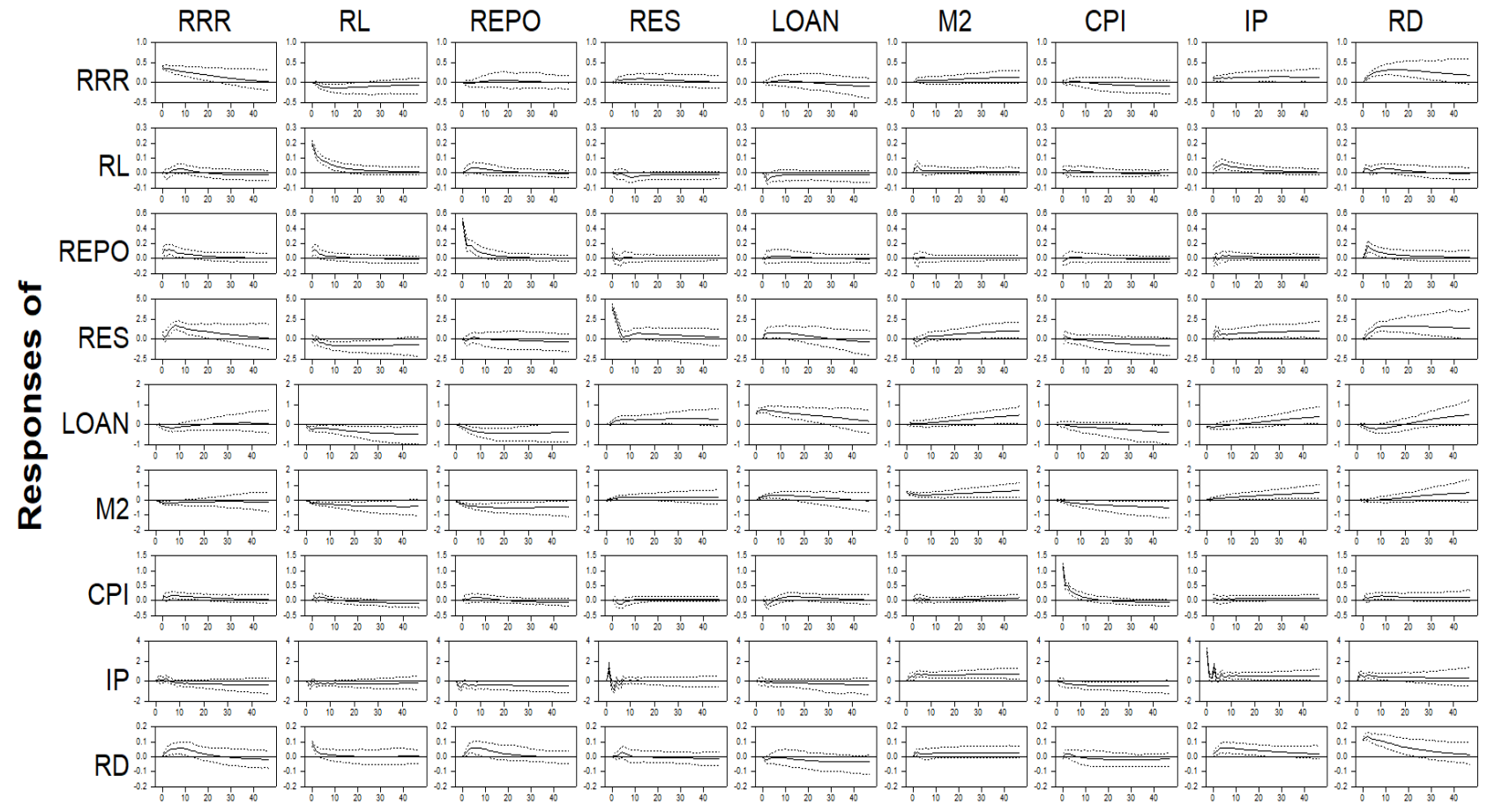
Figure 3. Impulse Responses in the Model with Property Price

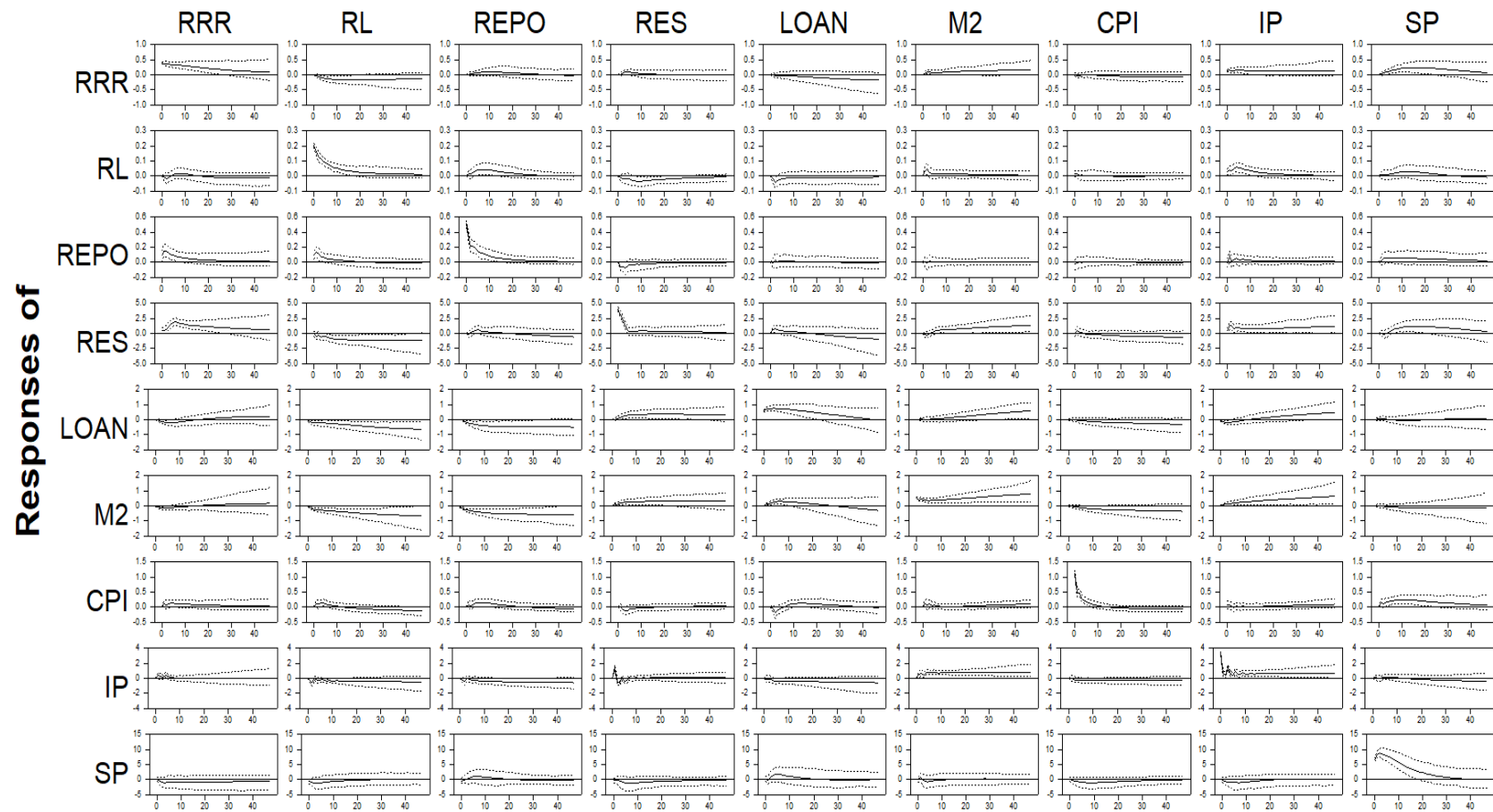**Figure 4. Impulse Responses in the Model with Stock Price**
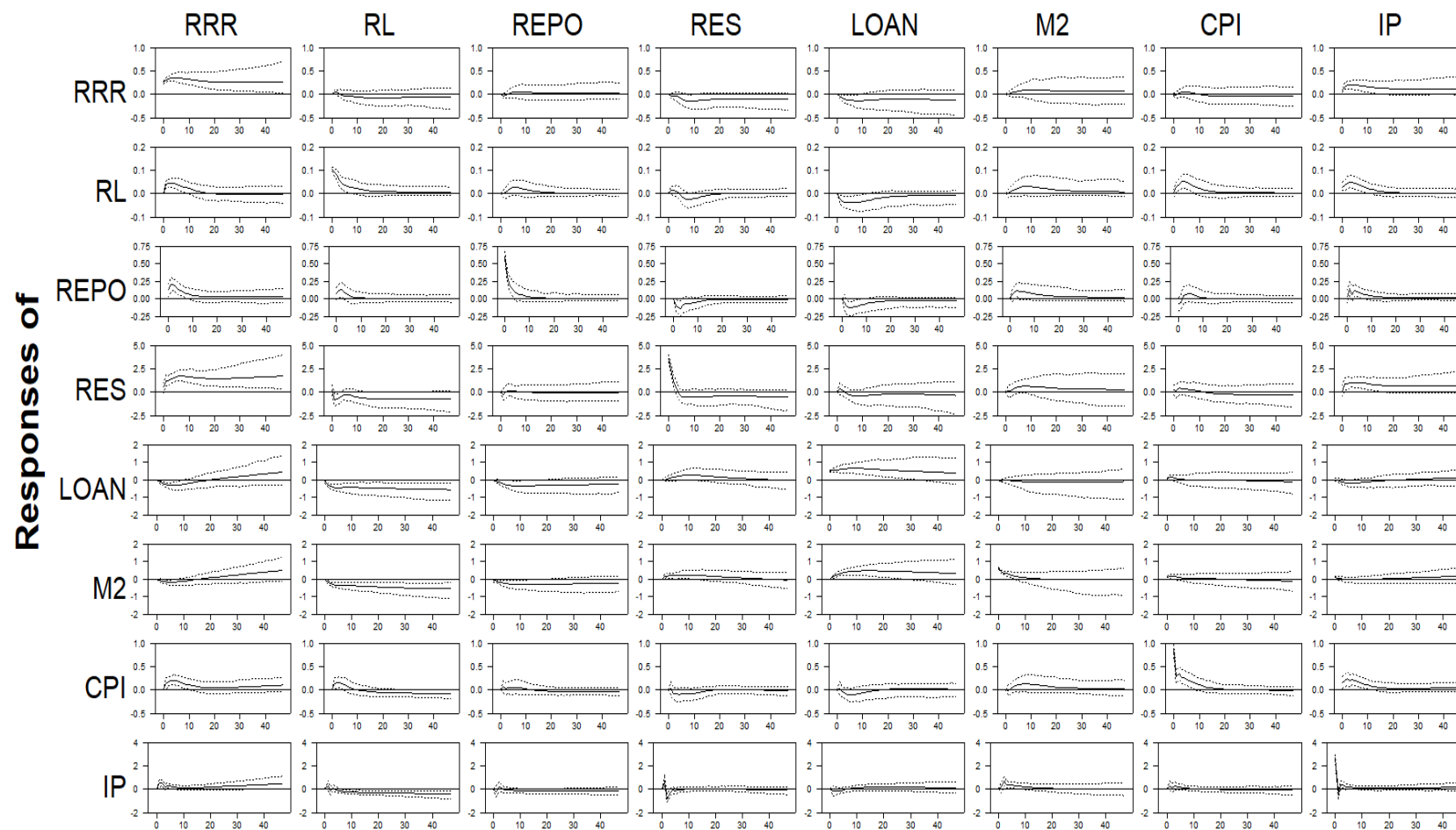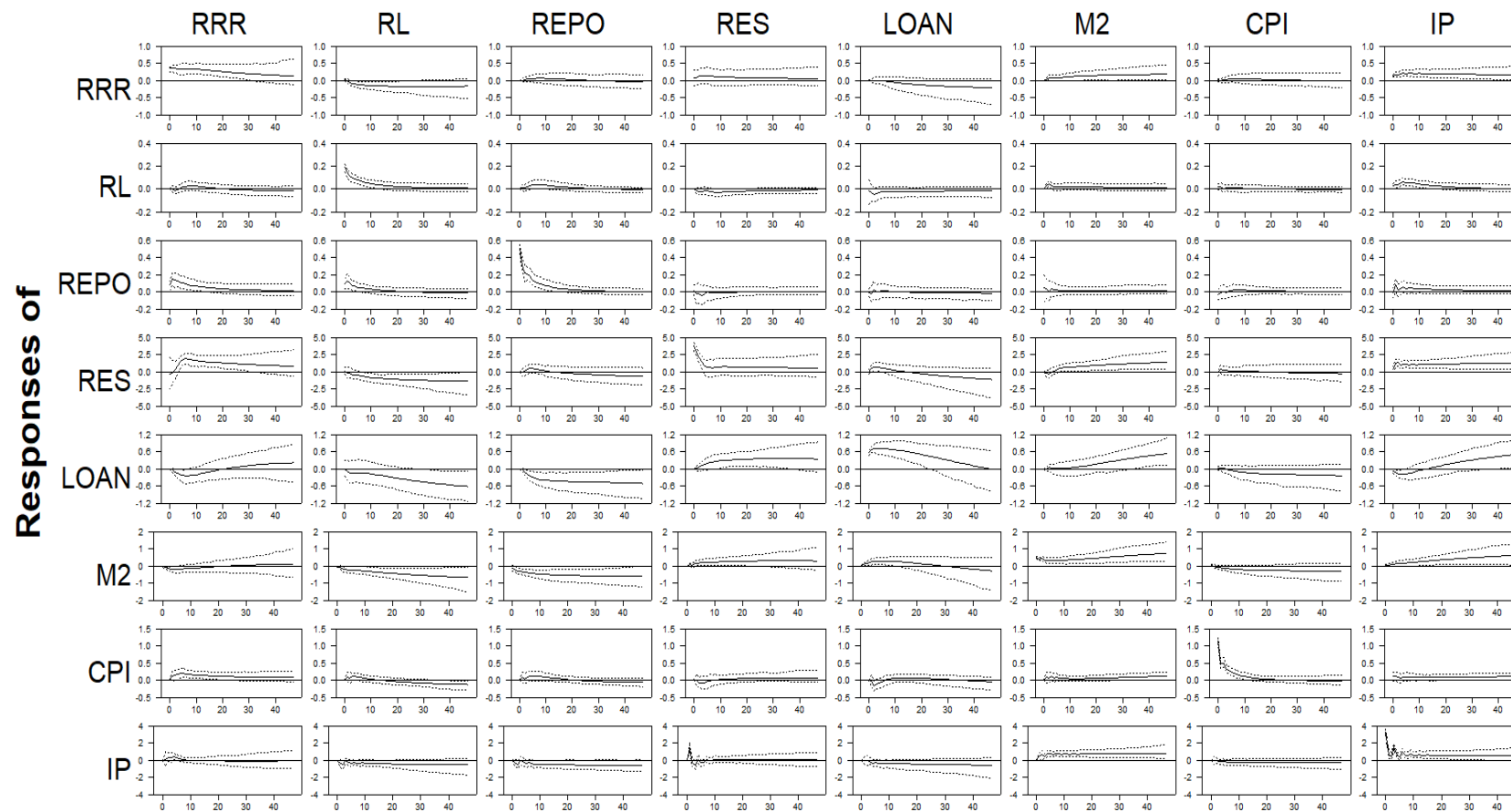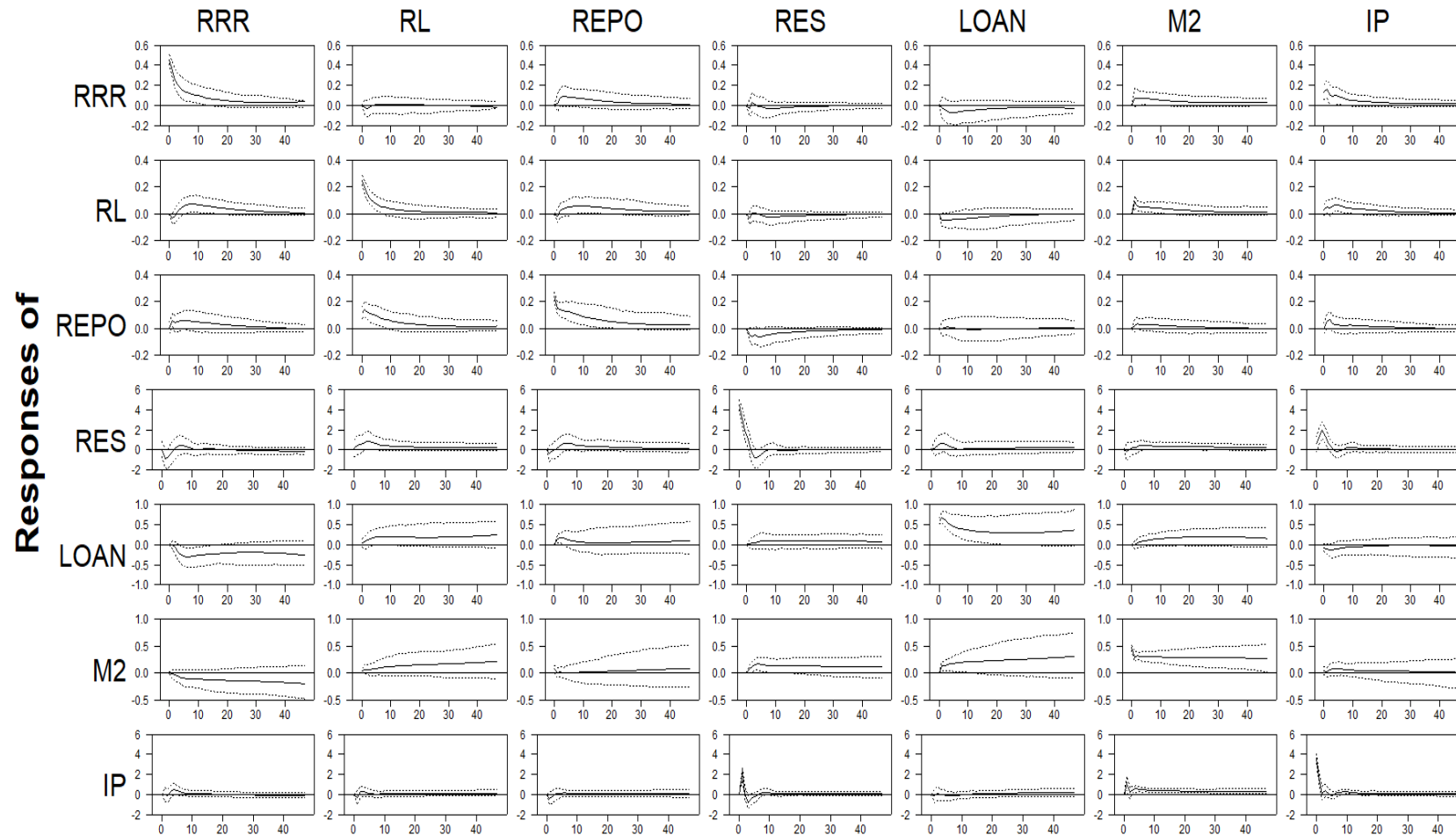
Figure 5. Impulse Responses from August 2005

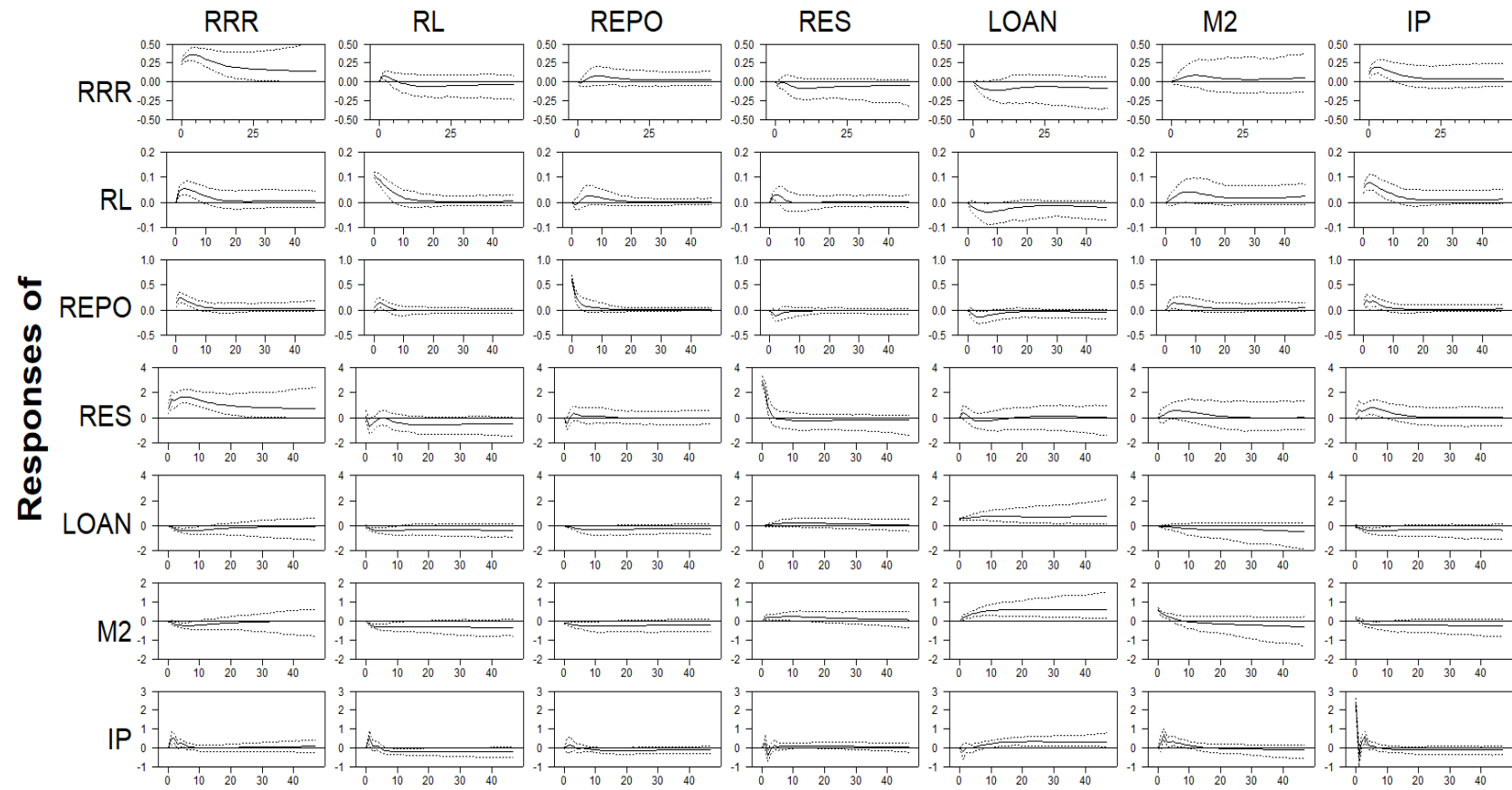**Figure 6. Impulse Responses under Alternative Identifying Assumptions**

Figure 7. Impulse Responses (1997–2006)

Figure 8. Impulse Responses (2007–2016)

Figure 9. Impulse Responses in the Model with Crisis Dummy