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

Soyoung Kim
Department of Economics
Seoul National University

Hongyi Chen
Hong Kong Institute for Monetary and Financial Research

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Summary:

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 to highlight 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

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[*] Soyoung Kim (corresponding author), Department of Economics, Seoul National University, e-mail: soyoungkim@snu.ac.kr; Hongyi Chen, Hong Kong Institute for Monetary and Financial Research, email: hchen@hkma.gov.hk. All the remaining errors belong to the authors.

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.

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.[1] In such a case, a simple method to analyze the effects of each policy instrument separately and/or the

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[1] For example, an increase in money demand or loan demand can increase M2 or loan if the monetary authority accommodates it.

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.

To address the challenge of multiple policy instruments, 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) try to 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. First, we analyze the

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effects of each monetary policy instruments. 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? Second, we investigate the relationship among various monetary policy instruments and intermediate targets. What are the relationships and interactions among various monetary policy instruments? Is a large portion of fluctuations in the traditional intermediate targets, such as growth in total loan and M2, subject to non-policy shocks? Third, we are also interested in the changes over time. 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? 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.[2]

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 summarizes the empirical findings with policy implications.

2. Evolution of Monetary Policy Framework and Key Monetary Policy Instruments in China

2.1 Evolution of China's Monetary Framework

From 1984 to 1997, China's monetary policy focused on managing the credit quota. On January 1, 1998, direct credit quota was abolished. Instead, the PBoC announced yearly loan growth and M2 growth targets. In 2010, the PBoC developed an indicator of total social financing (TSF), which refers to the total amount of funds provided by China's domestic financial system to the real economy in a given period. It includes loans from the banking system, and direct finance from issuing stocks and bonds in the capital markets. In 2011, the PBoC started announcing the annual TSF growth target and stopped the annual loan growth target. With the development of

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[2] 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 it considers monetary policy instruments and monetary policy operating procedures of China that are quite distinct from those in these past studies.

domestic financial markets, growth of shadow banking and the interest rate liberalization, the PBoC found the correlations of quantity targets, such as M2, loan or TSF growth, with inflation are rather weak (Xu et al., 2018). Therefore, in 2018, the PBoC stopped setting number targets for M2 and TSF growth.

Since 1996, the central bank gradually liberalized interest rates. In June 1996, the interbank rate was liberalized. From 1997 to 2004, the PBoC gradually expanded the interest rate range based on benchmark lending and deposit rate. In October 2004, the PBoC removed the upper bound of lending rate 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 interest rate liberalization of retail lending and deposit. Afterwards, the benchmark lending and deposit rates served only as reference rates for retail lending and deposits. To avoid banks using a high deposit rate to compete for retail deposits, which historically caused banks to take excessive risks, the PBoC supported the commercial banks to set up a self-disciplinary system for the deposit rate ceiling. In April 2018, this self-disciplinary system was abolished. After more than 2½ years of deposit rate liberalisation, from the financial stability point of view, the PBoC is more confident to fully let interest rates be determined in the market. Meanwhile, the PBoC started to develop market-based Loan Prime Rate (LPR) for banks to price credit risk. Finally, in August 2019, the PBoC required commercial banks to use LPR to price all new loans. Table 1 and Figure 1 show the timeline of China's interest rate liberalization.

With the interest rate liberalization, the PBoC gradually moved from a quantity-based to an interest rate-based monetary policy framework. After the global financial crisis in 2008, the PBoC added a macroprudential assessment to supplement its

monetary policy for the objective of financial stability (Yi, 2018). In the following subsection, we summarize the key monetary policy instruments.

2.2 Key Monetary Policy Instruments in China

Short-term interest rate. The PBoC has been trying to develop a short-term target rate like the US Fed Fund rate as its policy instrument. The 7-day repo market R007 is the most liquid market. The market participants include commercial banks, securities companies, fund management companies. Instead of targeting the R007, the PBoC chooses the pledged 7-day interbank repo rate DR007 as its short-term policy rate target, which is the rate among commercial banks. However, this series is very short. The available data only started from May 2017. In the empirical analysis below, we use 7-day repo rate as the short-term policy instrument. The two series are highly correlated. On the short-end, the PBoC tries to establish an interest rate corridor with the interest rate on excess reserve as the lower bound, and the 7-day interest rate on SLF as the upper bound.

Benchmark lending and deposit rate. Up until August 2019, the benchmark lending and deposit rates are the most significant rates for commercial loans and deposits. The PBoC did not make any changes of the benchmark rates after October 2015, however, commercial banks still based on them to price loans and remunerate deposits. They increasingly take into considerations of default risk when pricing loans (Chen, Chen, and Han, 2017). In August 2019, the PBoC required commercial banks to price new loans based on LPR. Chen, Chen and Gerlach (2013) studied the effectiveness of benchmark interest rates. With the interest rate liberalization, the difference between the effective lending rate and benchmark lending rate has widened.

It is generally believed that the PBoC has been trying to maintain a stable gap between the lending and deposit rates so that commercial banks can earn a healthy profit, which helps the financial stability for the banking system. That is why for most of the times in the past, the PBoC adjusted the two benchmark rates in the same direction simultaneously[3].

In the empirical analysis, we first analyze the effect of the benchmark lending rate (RL) in baseline model. 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 investment is 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 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.

Required Reserve Ratio (RRR). RRR is a structural monetary policy tool. Changes of RRR do not change the monetary base. However, they affect the liquidity of the banking system and the money multiplier. In this sense, it is a more quantity-based

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[3] 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.

monetary policy tool. With the large capital inflows after the global financial crisis, the PBoC raised RRR significantly to sterilize the capital inflows. From January 2000 to June 2018, the PBoC has adjusted RRR 49 times[4]. In the empirical analysis below, we use RRR as a policy instrument.

To summarize, in the following empirical analysis we use RRR, 7-day repo rate and benchmark lending and deposit rates as policy instruments; and quantity variables, such as M2, total loans and bank reserve, as liquidity measures and/or intermediate targets and consider the interactions among these variables. It should be emphasized that PBoC uses different instruments at different times, taking into consideration the interactions and effects among them.[5]

We expect that the PBoC has similar objectives to those of other advanced

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[4] Since the start of the global financial crisis until the second half of 2013, the increase in RRR has been mainly for sterilizing 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 there was a large amount of excess reserve of 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. Currently the PBoC maintains a three-tier RRR system with two additional incentives to support the bank lending to SMEs.

[5] Besides the above major policy instruments, the PBoC also conducts open market operations (OMOs) to adjust the liquidity in the banking system, which includes MLF and PSL (Yi, 2017). In our empirical analysis, such policy actions are reflected in shocks to the short-term interest rate, which will be further explained in Section 3.2.

On the other hand, 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 sterilizes 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.

economies' central banks, such as stabilizing inflation and output, 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 liberalization 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 $var(e_t) = \Lambda$. 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)

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

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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.

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

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

$$\Sigma = G_0^{-1} \Lambda G_0^{-1'}. \qquad\qquad\qquad (6)$$

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) are included, including two traditional intermediate targets (LOAN, M2). 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}
\qquad (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

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(1996, 1999). In the third equation, 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 this 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, policy instruments, such as RL and the 7-day repo rate, are allowed to

contemporaneously affect intermediate targets, such as loan and M2, and demand

shocks and demand factors, such as CPI and IP, are also allowed to contemporaneously

affect intermediate targets. Therefore, we can infer the degree of endogeneity of

intermediate targets in the empirical analysis.[7]

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 cointegration relations.

Table 2 reports the estimated contemporaneous structural parameters. The

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[7] When the fifth and the sixth equations are interpreted as demand equations, then the shocks to the fifth
and the sixth equations can be interpreted as demand shocks. However, to the extent that M2 and loan are
used as a kind of policy instruments, some parts of the shocks to the fifth and the sixth equations can be
interpreted as policy shocks.

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 lending rate decreases loans and rises in 7-day repo rate decreases 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 2 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.[8]

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.[9] 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

[8] CPI slightly increases significantly in the short-run. This response can be regarded as the price puzzle found in many past studies. Refer to Sims (1992); Kim (1999); and Christiano, Eichenbaum and Evans (1999) for explanations on the price puzzle. IP also slightly increases in the first few months but IP responses are not significantly different from zero for almost all horizons. A slight increase in IP in the first few months after monetary contraction is found in some past studies such as Uhlig (2005).

[9] The lending rate did not change frequently during the sample period. Some caution may be needed in interpreting the results of the lending rate shocks.

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 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 rate.[10] The first four columns in Figure 3 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, we estimate the baseline model from October 1997 but policy change occurred in July 2005. The Chinese RMB had been rigidly fixed to the US dollar since the Asian financial crisis in 1997. On July 21, 2005, the PBoC made a one-time revaluation of the RMB exchange rate for 2% and let the exchange rate appreciate.[11] 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. The fifth to the seventh columns of Figure 3 report the results. The results are qualitatively similar to the baseline model.

Third, stock price (SP) is additionally included in the baseline model. For identification, we assume that all variables contemporaneously affect stock price but not

[10] 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.

[11] This appreciation 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, while during this period 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.

the other way around, as in the case of property price. The results are reported in the first four columns of Figure 4. The effects of three policy variables on stock price tend to be positive but insignificant in most cases. The only significant effect is in the case of the immediate effect of RL variable. In response to positive stock price shocks, three policy variables tend to increase, which can be interpreted as stabilizing attempts by the PBoC.

Fourth, property price is additionally included in the baseline 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 the last four columns of Figure 4. 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 stabilize the housing market, an increase in the 7-day repo rate is clearly more effective than changes in other policy tools.

In the eighth columns of Figure 4, the responses of three policy variables to

property price shocks also show some interesting patterns. In response to positive property price shocks, three policy variables increase, which is different from zero at 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.

Fifth, government spending, total social financing, and foreign exchange reserves are added one by one in the model. Fiscal policy can also affect monetary and financial condition, so government spending (in real term) is included to control for the influence of fiscal policy.[12] We include foreign exchange reserves because foreign exchange reserves has sometimes affect required reserve ratio substantially and we would like to control for the endogenous response of required reserve ratio to foreign exchange reserves. We include total social financing in the model because total social financing has been an important indicator and intermediate targets of monetary policy in recent years.

For identification, government spending is assumed to be exogenous to all variables in the model but allowed to affect all variables contemporaneously. This assumption, proposed by Blanchard and Perotti (2002), has been frequently used in past studies that identify government spending shocks. Foreign exchange reserves (in terms of RMB) is assumed to be allowed to affect required reserve ratio. In addition, all variables are assumed to be allowed to affect foreign exchange reserves in terms of RMB because all variables may affect the exchange rate and foreign exchange reserves in terms of RMB contemporaneously. Total social financing is a kind of monetary aggregate so identifying assumption for total social financing is similar to M2. The repo rate, IP, and CPI are assumed to be allowed to affect total social financing

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[12] We deflate nominal government spending data by using CPI.

contemporaneously. In addition, M2, which is narrower than total social financial, is also assumed to be allowed to affect total social financial contemporaneously. In the case of the model with total social financing, we estimate the model from 2002 because total social financing data is available from 2002. Therefore, the sample period for the model with total social financing is relatively short, so we exclude CPI to increase the degree of freedom.

The results are reported in Figure 5. The first three, the next three, and the last three columns of graphs show the impulse responses to three policy instrument shocks in the model with government spending, foreign exchange reserves, and total social financing, respectively. The results are qualitatively similar to those of the baseline model.

Sixth, we consider an alternative identifying assumption. In the baseline model, monetary policy instruments are not allowed to be contemporaneously affected by the 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. The first three columns of Figure 6 report the results, which are similar to the results of the baseline model.

Seventh, we add the global financial crisis dummy (2008:9-2009:8) in the model to check the robustness of the results. The fourth to sixth columns of Figure 6 reports the results. The results are qualitatively similar to the baseline model.

Eighth, China went through a number of interest rate liberalization over the sample period, for example, the removal of formal floors and ceilings on deposit rates. To control for such policy changes, we construct a dummy variable for such policy

changes. The months of policy changes are: 1997:6, 1998:2, 1999:10, 2000:9, 2003:7, 2003:11, 2004:10, 2005:3, 2006:8, 2007:1, 2012:6, 2012:7, 2013:7, 2014:3, 2015:5, 2015:8, and 2015:10. The last three columns of Figure 6 report the result, which is qualitatively similar to the baseline model.

Finally, effects of monetary policy shocks may change over time because economic environment and structure and policy regimes changed over time. In this regard, we provide results from rolling regressions. We consider the window of 12 years. We start from the period of 1997:1-2008:12, then 1997:2-2009:1, 1997:3-2009:2, and up to 2005:1-2016:12. Sample periods are relatively short, so we consider only two lags and drop CPI from the empirical model to save the degree of freedom.

Figure 7 reports the impulse responses with 90 percent probability bands for various sub-periods. The x-axis shows the starting date of each sample period. Each column of graphs show the impulse responses to each policy shock. The first row of graphs show the impulse responses of own variable to each policy shock at 1 month horizon. The second to the fourth rows of graphs show the impulse responses of loan, M2, and IP at 12 month horizon. We show the impulse responses of policy variable at 1 month horizon because the maximum responses of policy variables are found at 1 month horizon. We show impulse responses of other variables at 12 month horizon but the results for other medium run horizons (at which substantial effects are observed) are qualitatively similar.

In the earlier sample periods, 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 some initial periods. However, in the later sample

periods, 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 later sample periods. 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.[13] The size of the effects of three policy shocks on themselves also changes over time. RRR and RL shocks tend to have stronger effects on RRR and RL, respectively, in the earlier than in the later periods. However, REPO shocks have a stronger effect on REPO in the later than in the earlier periods. This finding supports the idea that PBoC uses the short-term interest rate as the policy instrument in recent periods.

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 a 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

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[13] On the other hand, the rising of shadow banking system in China may make have made monetary policy less effective in recent years to some extent. Our empirical finding may suggest that monetary policy becomes more effective in the counterfactual case of no shadow banking activities.

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, which may suggest that the monetary authority may not control the 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 the effect of the short-term interest rate shock on itself 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 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 instruments 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 objectives.

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Table 1: Timeline of China's interest rate liberalization

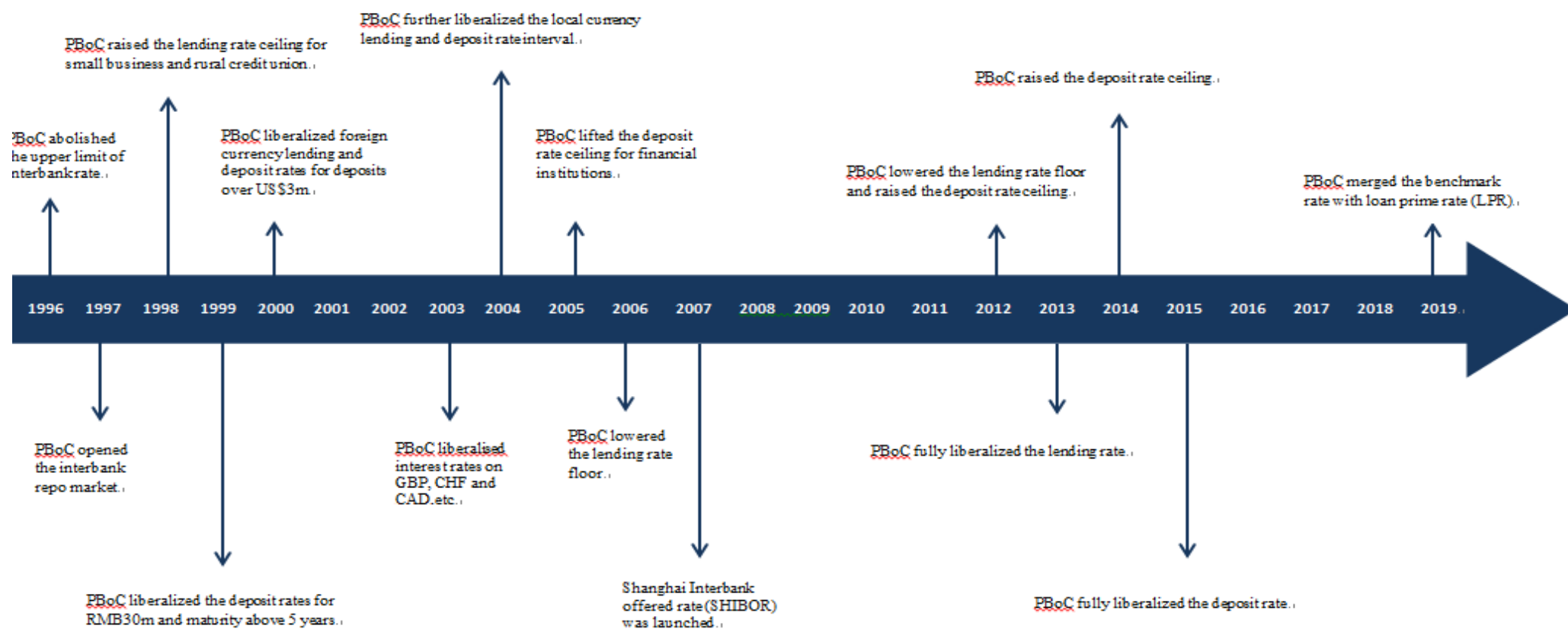| Date	Description
June 1996	PBoC abolished the upper limit of interbank rate
June 1997	PBoC opened the interbank repo market
Feb. 1998	PBoC raised the lending rate ceiling for small business and rural credit union
Oct. 1999	PBoC liberalized the deposit rates for RMB30m and maturity above 5 years
Sept. 2000	PBoC liberalized foreign currency lending rates and deposit rates for deposits over US$3m
July, 2003	PBoC liberalized interest rates on GBP, CHF and CAD
Nov. 2003	PBoC liberalized interest rates on USD, JPY, HKD and EUR, and enlarged the local currency lending rate interval
Jan. 2004	PBoC further liberalized the local currency lending rate interval
Oct. 2004	PBoC lifted the lending rate ceiling and deposit rate floor
March 2005	PBoC lifted the deposit rate ceiling for financial institutions
August 2006	PBoC lowered the lending rate floor
Jan. 2007	Shanghai Interbank offered rate (SHIBOR) was launched
June 2012	PBoC lowered the lending rate floor and raised the deposit rate ceiling
July 2012	PBoC further lowered the lending rate floor
July 2013	PBoC fully liberalized the lending rate
March 2014	PBoC raised the deposit rate ceiling
May 2015	PBoC further raised the deposit rate ceiling
Aug. 2015	PBoC liberalized deposit rate for maturity over one year
Oct. 2015	PBoC fully liberalized deposit rate
Aug. 2019	PBoC merged the benchmark lending rate with loan prime rate(LPR)

Source: Liu, Jin and Yu (2019) and Author's Research

Table 2: Estimated Contemporaneous Structural Parameters

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

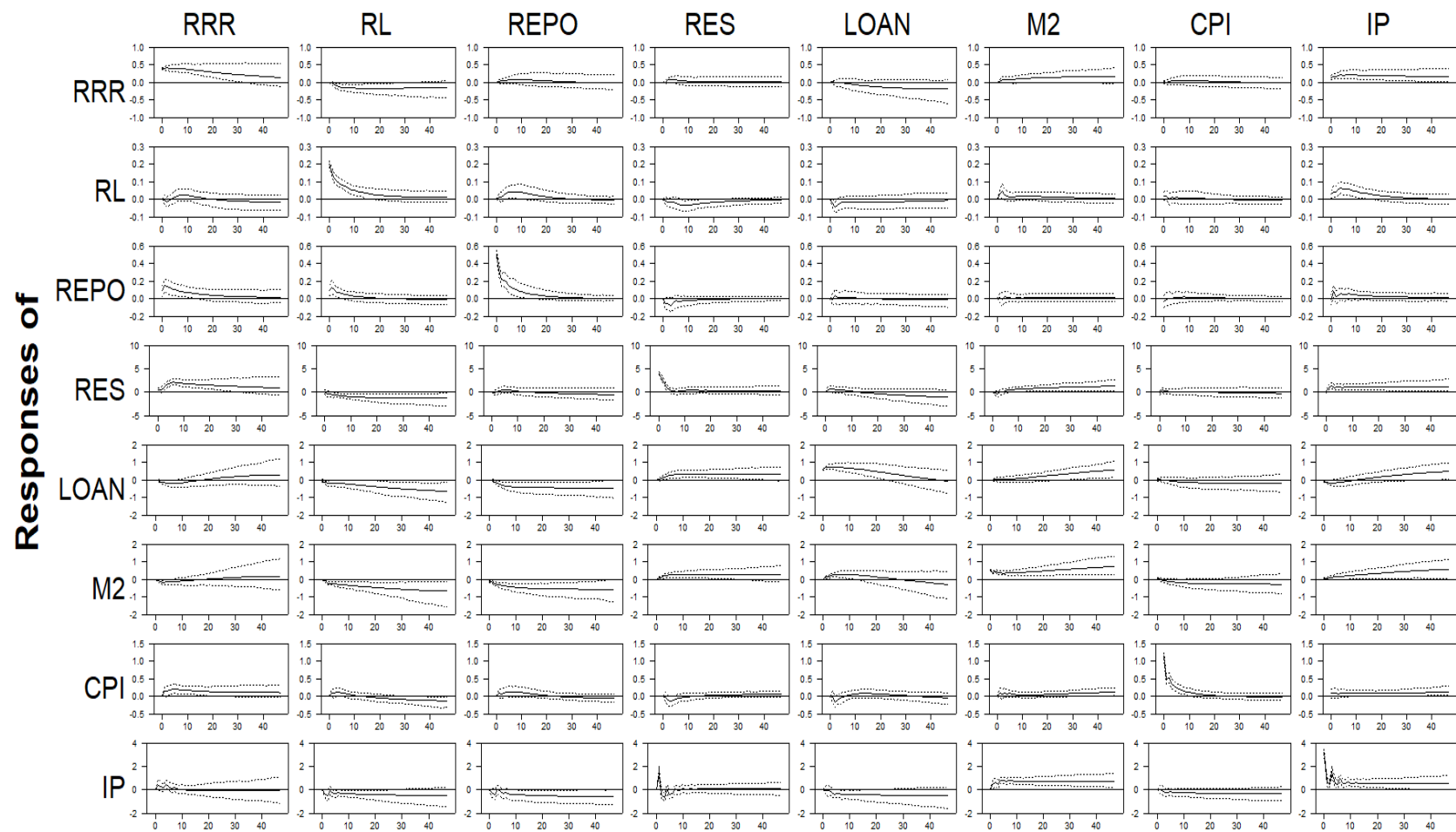* and **indicate that the coefficients are estimated at the 5% and 1% significance level, respectively.

Figure 1: Timeline of China's interest rate liberalization

PBoC further liberalized the local currency lending and deposit rate interval.

PBoC raised the lending rate ceiling for small business and rural credit union.

PBoC raised the deposit rate ceiling.

PBoC abolished the upper limit of interbank rate.

PBoC liberalized foreign currency lending and deposit rates for deposits over US$3m.

PBoC lifted the deposit rate ceiling for financial institutions.

PBoC lowered the lending rate floor and raised the deposit rate ceiling.

PBoC merged the benchmark rate with loan prime rate (LPR).

1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019.

PBoC opened the interbank repo market.

PBoC liberalised interest rates on GBP, CHF and CAD.etc.

PBoC lowered the lending rate floor.

PBoC fully liberalized the lending rate.

PBoC liberalized the deposit rates for RMB30m and maturity above 5 years.

Shanghai Interbank offered rate (SHIBOR) was launched.
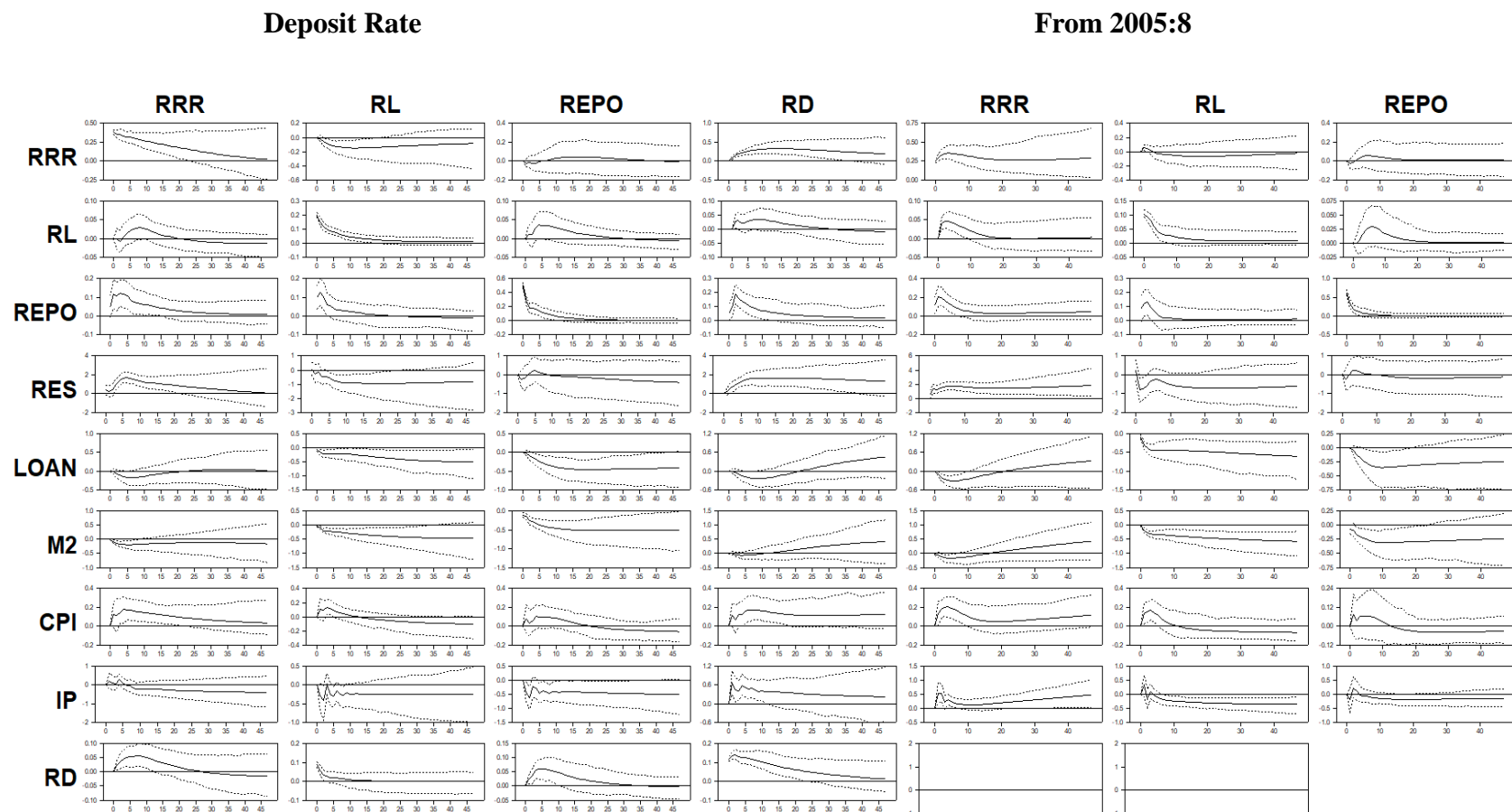
PBoC fully liberalized the deposit rate.

Source: Liu, Jin and Yu (2019) and Author's Research

Figure 2: Impulse Responses in the Baseline Model
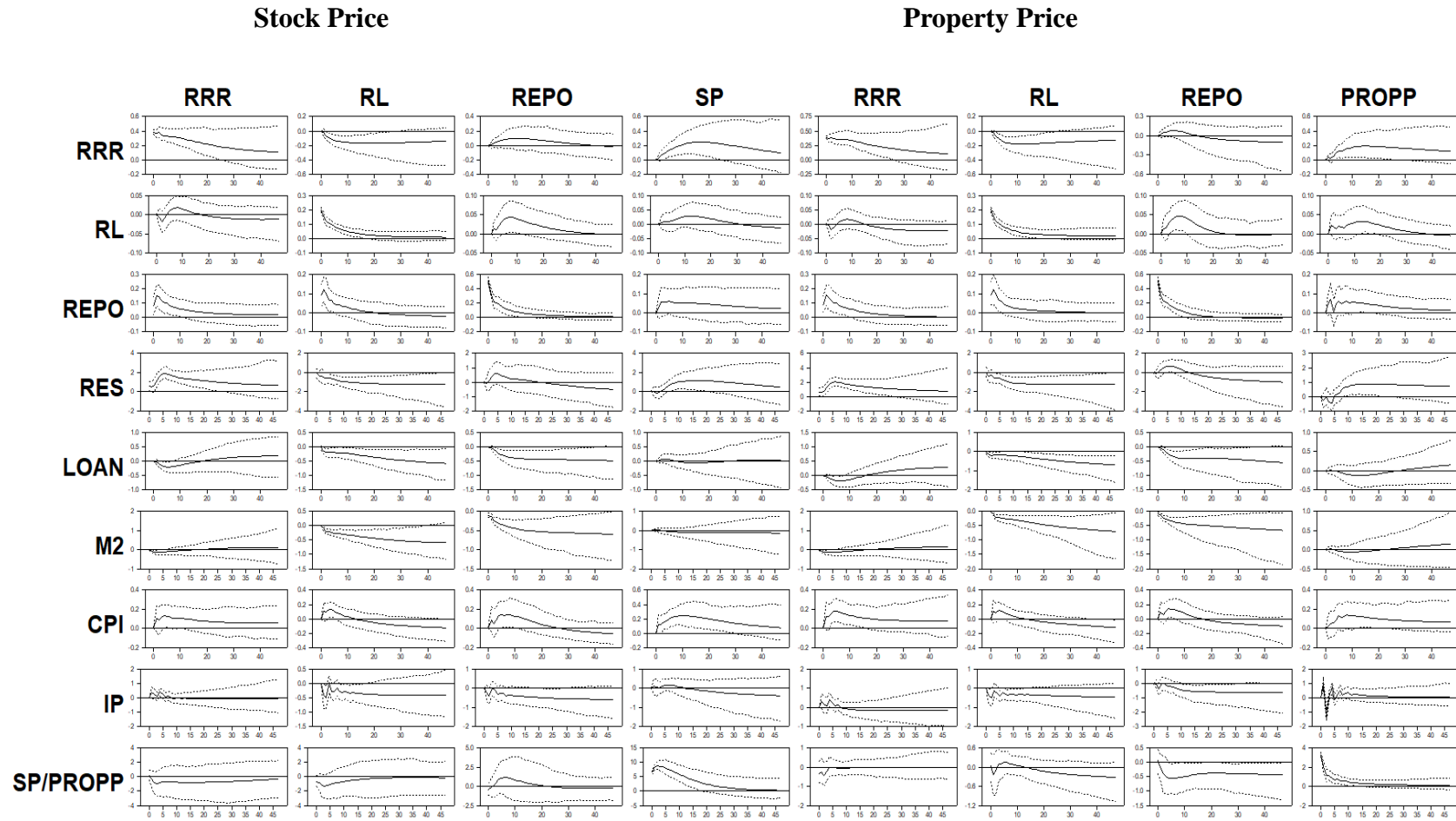
Figure 3: Impulse Responses in the Model with Deposit Rate and the Model for the period from 2005:8
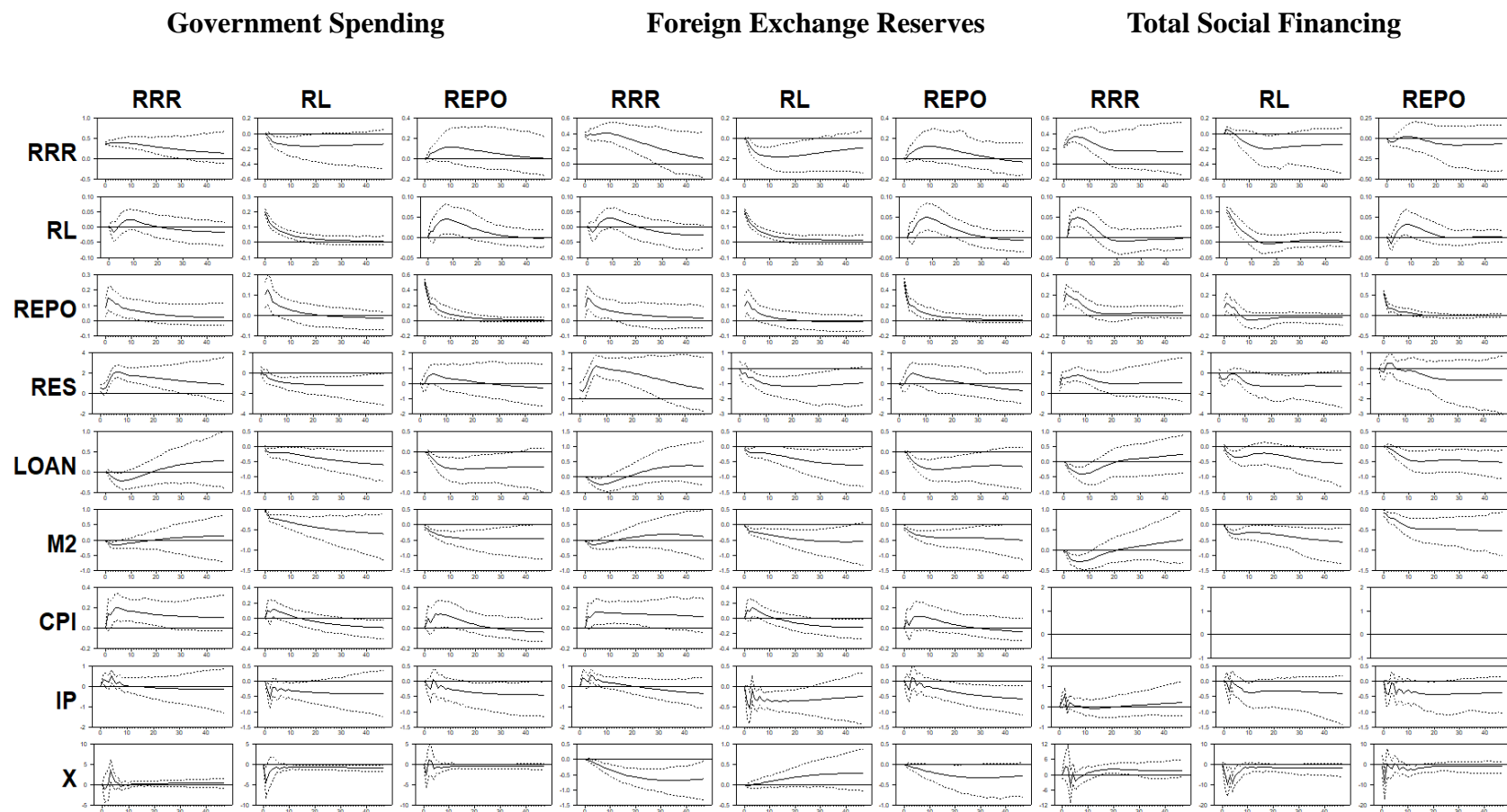
Deposit Rate   **From 2005:8**

Note: In the model estimated from 2005:8, RD is not included to save the degree of freedom. Therefore, we don't report the impulse responses of RD.

Figure 4: Impulse Responses in the Models with Stock Price and Property Price

Stock Price   **Property Price**

Figure 5: Impulse Responses in the Model with Government Spending, Foreign Exchange Reserves, and Total Social Financing

Note: In the model with Total Social Financing, CPI is not included to save the degree of freedom. Therefore, we don't report the impulse responses of CPI.

Figure 6: Impulse Responses for the Models with Alternative Identifying Assumption, Global Crisis Dummy, Interest Rate Liberalization Dummy
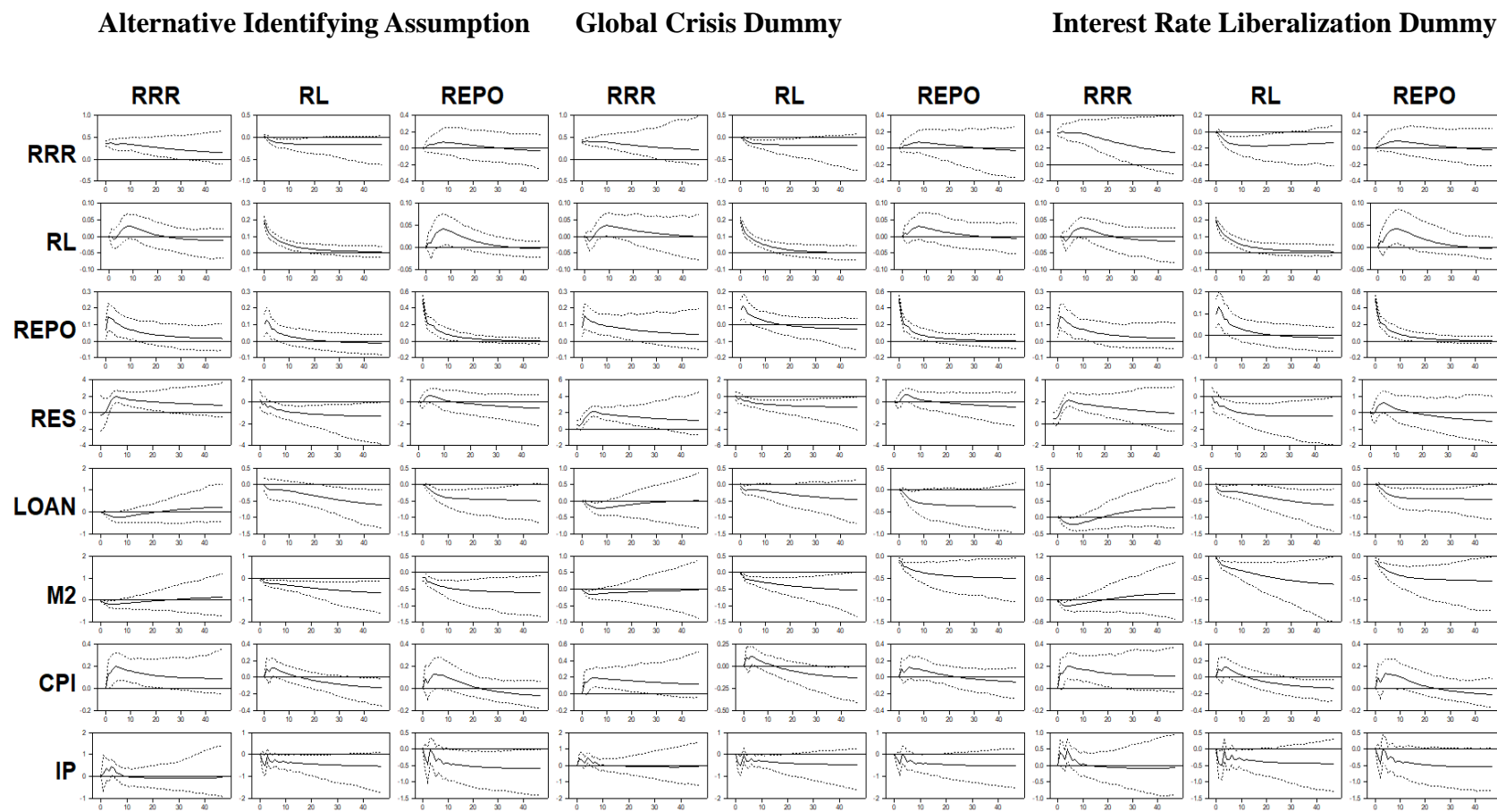
Figure 7: Rolling Regression: Impulse Responses over Various Sub-Sample Periods