# Monetary policy transmission in China: Dual shocks with dual bond markets

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February 24, 2018

**Abstract**

Although China's monetary and financial system differs drastically from its Western counterpart, empirical studies covering this vast economy (the largest by some accounts) have often been simple reestimations or recalibrations of models that have originally been designed to describe US or European monetary policy. In this paper, we aim to provide an assessment of Chinese monetary policy and in particular monetary policy transmission through the bond market into the real economy, which takes into account the peculiarities of the Chinese market. Namely, our model includes both China's modern attempts at a market based policy shock as well as the "authority" based monetary policy that is a relic of the original banking system; it considers the special nature of the Chinese treasury bond market which is separated in two independent markets with very limited direct arbitrage opportunities between almost identical assets, and finally it incorporates the role of real estate, which played an essential role in China during the last decade.

**Keywords**: Monetary policy, yield curve, market segmentation
**JEL**: E52, E43

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# 1 Introduction

In this paper, we reassess monetary policy transmission in China. We argue that the Chinese institutional setup is special in two ways, that warrant some more detailed consideration than merely reestimating models designed for the US (or other Western countries) with Chinese data. First, the People's Bank of China (PBoC) never fully adopted the idea of a single intermediate target indicator, such as the Fed Funds rate in the US monetary system. Contrarily, the PBoC employs its tools with very different intentions and to different ends. Second, the Chinese treasury bond market - where most of the open market operations of the PBoC are conducted - has a quite unique structure. Rather than one market, there are indeed two fairly strictly separated bond markets: The interbank market, where mostly major banks and the PBoC can buy or sell, and the much more liquid exchange market, where other financial institutions trade. Although the bonds traded on both markets are close substitutes in terms of their function, individual bonds are – with very few exceptions – traded on one of those two markets only.

We propose a two step approach. First, we use a state space model using weekly data to estimate the yield curve dynamics. This allows a fairly precise identification of the end of the month yield curves (on both markets) despite very sparse data. Second, we incorporate the yield curve data obtained in a standard monetary structural VAR that includes the two primary indicators of Chinese monetary policy.

Our contribution to the literature is threefold: First, we add to the thriving literature on the quickly developing Chinese bond market. For example for the computation of credit spreads, it is essential to have a valid estimate of the treasury yield curve as benchmark. In a young market, such as China, where many maturities are not available or traded, this is not a trivial matter. We provide a model that is at the same time able to fully exploit the information from both the interbank and exchange market while at the same time acknowledging that the yield curves on both markets can differ significantly. This allows a more efficient estimation of the respective appropriate benchmark yield curve for a corporate bond depending on the market it is traded on. Unlike previous approaches, e.g. Loechel et al. (2016) who assess daily yield curves on the interbank market and the Hong Kong offshore market from 2011 to 2014, our model is able to cope with sparse data.

Second, we provide an analysis of Chinese monetary policy transmission, that accounts for the institutional peculiarities of China, in particular the dual bond market – where monetary policy is conducted on the less liquid one – and the specific tool set used by the PBoC. We are not the first to note the importance of different tools for the PBoC. In a theoretical paper, Chen et al. (2013) argue, that the impact of those policies might differ vastly. Another noteworthy strand of empirical literature also acknowledges this issue but – unlike our approach that tries to identify different effects of different shocks – aims to generate "compound indicators" for the monetary policy stance that encompass the full set of tools at the PBoC's disposal, see in particular Sun (2013) and Sun (2015). Both approaches have their own advantages and disadvantages. The compound indicator approach allows to account for an even broader scope of indicators, while our approach necessarily has to focus on a few major tools to allow identification. However, this focus allows to differentiate between the effect of different indicators, which is impossible when defining a unique indicator of monetary policy. Our paper is most closely related to He and Wang (2012), who – like we do – also explicitly distinguish market based policy and regulation based policies.

Third, we contribute to the growing literature on how monetary policy affects the long end of the yield curve, that gained importance with short term interest rates hitting the zero lower bound in many advanced economies.[1] One of the few other papers, that relates the yield curve to monetary policy in China is Fan and Johansson (2010). However, they focus on the impact of monetary policy (which they measure through changes in the benchmark deposit rate) on the (exchange market) yield curve only. Moreover, since their paper the Chinese financial market and monetary policy have been developing dramatically. Contrarily, we are mostly interested in the yield curve to better understand the transmission mechanism and thus embed both policy decisions and the yield curve into a full fledged monetary macro model.

# 2 Institutional background

## 2.1 Monetary policy instruments of the PBoC

During the past decade, the PBoC has been going through a transition from quantity management (focusing on M2) to price management style monetary policy comparable to the Fed. China made a great effort to liberalize financial markets, in particular

[1]In China, the original reason for the PBoC to address the shape rather than the level of the yield curve was quite different. To combat capital flight caused by the depreciation of the RMB vs the US dollar, the PBoC tried to increase shot term rates while simultaneously flattening the yield curve. This policy was meant to push down the price of short-term liquid assets and thus increasing the cost of capital outflows.

interest rates, in multiple dimensions.

However, the Chinese monetary system is still distinctively different from most of its Western counterparts. First, quantities still play a much more important role, as opposed to the US where monetary aggregates essentially lost their importance after the monetarist experiment (Bernanke, 2006). Second, the PBoC still exerts much closer control over China's major state-owned commercial banks. Third, while the PBoC regulates several interest rates and targets others through its open market operations, there is no unique monetary policy target rate.

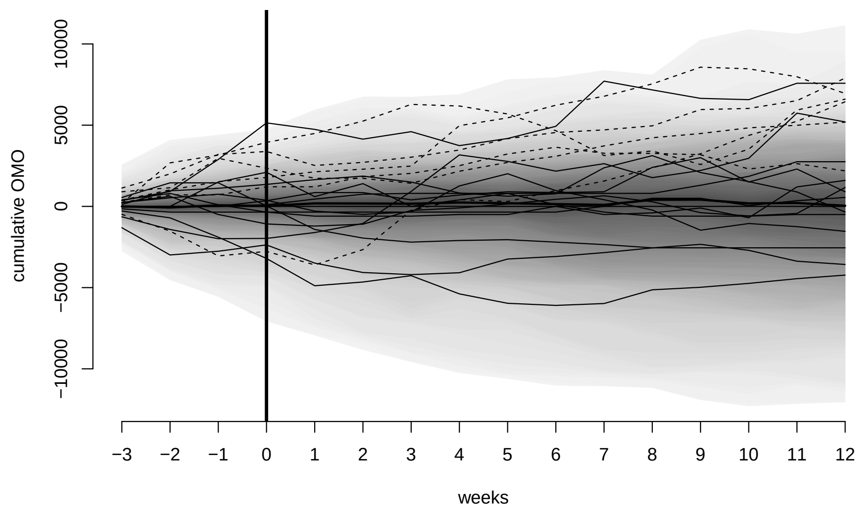
Currently, the PBoC's policy rests on three pillars. First, the PBoC conducts market based "Western style" monetary policy using a battery of tools at its disposal. Through open market operations, issuing central bank bills, and through several liquidity facilities, they provide or reduce liquidity in the banking sector. What those instruments have in common is that the PBoC directly intervenes in the bond market. There is no single official measure of this policy. In the long run, the PBoC aims to establish the interbank rate SHIBOR as target rate. However, since the transition to this system has not yet progressed far enough, we consider the policy instrument itself, namely the PBoC's repo rate. Either way, previous evidence suggests, that the correlation between the repo rate and the SHIBOR became much stronger over time (see Porter and Xu (2009)). [2]

Second, there is a range of benchmark interest rates, most notably the benchmark loan and deposit rates, but also the mortgage target rate. Because of the semantic

[2]The liquidity facilities have been introduced only recently in 2014, including SLF, SLO, MLF and PSL. Regardless of their importance, there are very few observations for rate changes and thus treating them separately is not possible within our econometric framework.

similarity due to their nature as “target” rate, the benchmark rates are frequently used as Chinese counterpart of the Federal Funds rate in empirical studies (see e.g. Fan and Johansson (2010)). However, the term benchmark or target obfuscates the fact that China’s major banks treat it as de facto regulation. Thus, the benchmark rates are essentially enforced through the PBoC’s authority rather than being backed up by corresponding market interventions. Indeed, when looking at open market operations after a change in the benchmark rate, there is no indication for any liquidity injections (or liquidity withdrawals) after a policy change (see Figure 1). Since the deposit rate essentially moves together with the loan rate, and the mortgage rates are adjusted seperately only very infrequently, we use the benchmark loan rate as single proxy for this “authoritarian” policy component. In addition to controling the price, the PBoC has occasionally also implemented some window guidance to directly control the volume of loans (and its growth rate). Because the officers of both state-owned commercial banks and private commercial banks are in the promotion or recruiting pool of the PBoC system, regulation agencies, and state-owned financial companies, anecdotal evidence suggests that they are very cautious and self-disciplined in their compliance to window guidance out of long-run career concerns.[3] Yet, there is no systematic data available on this aspect of policy. We assume that it is mostly used by the PBoC to guarantee that loan developments align with their price policy, and for example avoid, that loans decrease in response to a benchmark reduction, if the new loan rate is below the market equilibrium and increasing loan volume is thus unattractive to banks at the new price.

[3]Additionally, the PBoC occasionally imposes higher reserve ratio on the banks that do not cooperate.




*Note*: The shaded fanchart shows the density of the distribution of cumulative open market operations in a window of corresponding length without a monetary policy shock. The solid black lines represent the development of cumulative open market operations after a benchmark loan rate decreases. Dotted black lines represent the development of cumulative open market operations after the benchmark loan rate increases.

Figure 1: Cumulative open market operations around a benchmark rate change

Table 1: The interest rate policy change by PBoC 2008-2016

| Date | Deposit | Loan | Housing loans $<$5-year | $\geq$5-year | Other rates |
|---|---|---|---|---|---|
| 2008/09/16 | - | -0.27 | -0.18 | -0.09 | - |
| 2008/10/09 | -0.27 | -0.27 | -0.27 | -0.27 | - |
| 2008/10/25 | -0.27 | -0.27 | - | - | - |
| 2008/11/27 | -1.08 | -1.08 | -0.54 | -0.54 | reserve -0.27, re-lending -1.08, discount -1.35 |
| 2008/12/23 | -0.27 | -0.27 | -0.18 | -0.18 | reserve ——, re-lending $-0.27^{\dagger}$,discount -1.17 |
| 2010/10/20 | +0.25 | +0.25 | - | - | - |
| 2010/12/26 | +0.25 | +0.25 | -0.18 | -0.18 | reserve ——, re-lending +0.52, discount +0.45 |
| 2011/02/09 | +0.25 | +0.25 | - | - | - |
| 2011/04/06 | +0.25 | +0.25 | - | - | - |
| 2011/07/07 | +0.25 | +0.25 | - | - | - |
| 2012/06/07 | -0.25 | -0.25 | - | - | $rd_{up}$=1.1, $rl_{low}$=0.8 |
| 2012/07/05 | -0.25 | -0.25 | - | - | $rd_{up}$=1.1, $rl_{low}$=0.7 |
| 2013/07/20 | - | - | - | - | $rd_{up}$=1.1, $rl_{low}$=0 |
| 2014/11/22 | -0.25 | -0.40 | - | - | $rd_{up}$=1.2, $rl_{low}$=0 |
| 2015/03/01 | -0.25 | -0.25 | - | - | $rd_{up}$=1.3, $rl_{low}$=0 |
| 2015/05/11 | -0.25 | -0.25 | - | - | $rd_{up}$=1.5, $rl_{low}$=0 |
| 2015/06/28 | -0.25 | -0.25 | - | - | - |
| 2015/08/26 | -0.25 | -0.25 | - | - | $rd_{1-year,up}=+\infty$, $rl_{low}$=0 |
| 2015/10/24 | -0.25 | -0.25 | - | - | $rd_{all,up}=+\infty$, $rl_{low}$=0 |

*Note:* Deposit and Loan respectively stand for benchmark deposit rate and benchmark loan rate; Housing loans shows the interest rate of housing provident fund loan in below 5-year and above or equal to 5-year categories. In the "Other rates" column, the change of interest rate of reserve, excess reserve, re-lending, and discount can be found. We also track the interest rate liberalization, $rd_{up}$ represents for the upper-bound limit on deposit rate, and $rl_{low}$ represents for the lower-bound limit on loan rate.

Finally, regulation, especially the required reserve ratio still plays a more important role in China than it does in most Western countries, where required reserves are rarely a binding constraint. However, during our sample the required reserve ratio does not change frequently enough to allow robust identification of a regulatory shock. Therefore, for the remainder of the paper we will abstract from this component of monetary policy.

## 2.2 Chinese government bond yields

The central government of People's Republic of China began to issue government bonds back in 1950s, but the issuance was suspended for 13 years until 1981. Although central government bonds played an important role in supporting expansionary fiscal policy and facilitating central bank open market operations ever since, the government bond market was fairly small. Only in 2008, financing its expansionary fiscal policy and aiming to create a more complete yield curve, China's bond market was expanded drastically. As of today, there are different categories of central government bonds in China: certificate central government bonds for individual investors, book entry electronic central government bonds for individual investors (saving central government bonds), and book entry central government bonds for institutional investors. The coupon rate can be either fixed or floating, and time to maturity (at issuance) are 3-months, 6-months, 1-year, 3-years, 7-years, 10-years, 15-years, 20-years, and 30-years. Since the initial expansion, the Chinese Ministry of Finance has recently started to continuously issue treasury bonds at all maturities up to 10 years on a fixed schedule and also implemented outstanding volume management rather than issuance volume management.

However, the issuance of Chinese central government bonds is still far less frequent than US Treasury bonds. Correspondingly, the yield curve is still far from complete.

In this paper, we focus on the yield curves implied by the book-entry central government bonds with fixed coupon rate active in either interbank or exchange market from January 2008 to December 2016. Our yield data series for term structure estimation uses daily closing prices and the cash flow schedule of each individual bond.

To estimate a yield curve, we use a quarterly grid with maturities up to 10 years. If there are no bonds available with matching maturity, the yield is interpolated using maturities within 45 days. Despite this interpolation, there still are plenty of missing observations in particular in the earlier part of our sample when the bond market was still developing.

For our econometric analysis we use time series based on the Wednesday yield curves. With the PBoC conducting all its major monetary policy interventions on Fridays, this gives the markets enough time to absorb any information.[4]

## 2.3 The dual Chinese bond market

The Chinese bond market has been developing for more than 30 years since bond trading was reinstalled in 1981. The current bond market system in China consists of three parts: the interbank market where mostly large financial institutions and the PBoC trade, the exchange market(s) where individuals and small and medium size institutions trade, and the over-the-counter market of commercial banks. The former two form the core of the Chinese bond market and are also the objects of interest in this paper. The over-the-counter market primarily serves to grant less sophisticated investors access to the bond market.

Only being established in 1997, the interbank market is now the dominant market for Chinese bond transaction. Almost all bonds can only be traded in one of the two markets, and by now the interbank market accounts for almost 90% of outstanding stocks and correspondingly trading volume. The market is organized as a quote

[4] Weekly average are available from the authors on request.

driven over-the counter market. The PBoC does not only supervise and regulate the interbank market, but is itself responsible for a large share of those transactions (on average about 15%) with its open market operations which are conducted on this market. While a range of financial institutions, including investment banks, security companies, insurances, etc. are allowed to operate on the interbank market, its other name giving feature is that commercial banks are required to exclusively trade bonds on the interbank market. Most participants on the interbank market are only permitted to trade bonds for their own accounts. Only 30 large banks and security companies are recognized by the National Association of Financial Market Institutional Investors as market maker and settlement agents, who can trade on behalf of others who do not have direct access to the interbank market and the bonds traded there otherwise and provide settlement service for the other self traders in the market. While those investors who are granted indirect access may play a minor role quantitatively, they provide an important link to the rest of the financial market and more importantly the real economy.

The exchange market is operated through China's two stock exchanges in Shanghai and Shenzhen, which were established mainly for stock transactions. Bond have been traded in both markets since the early 1990s. The exchange market lost its monopoly on bond trading in China, after a serious speculative attack on the Chinese central government repo. This caused the PBoC to intervene, and require (commercial) banks and credit unions to trade under its closer supervision on the newly founded interbank market ever since. The bonds active in exchange markets include some Chinese treasury bonds and corporate bonds.

There are two parallel trading mechanisms for investors to freely choose from. The traditional approach was collective bidding trading, which is now mainly used for small-volume retail-style transactions and works like stock trading mechanism. In 2007, both Shanghai and Shenzhen introduced quote-driven over-the-counter style trading which is used for major transactions.

At first glance, it might seem odd to pay the same attention to the (older) exchange market as to the younger but an order of magnitude larger interbank market. The reasons making this market so relevant for our analysis are twofold. First, its larger distance to the PBoC's careful eyes, the absence of major trades as they occur in the form of monetary policy actions, and its more flexible trading system make it a better reflection of the current market situation than the interbank market where strategical trades and policy trades play a major role. Second, the small and medium sized agents who are active on this market provide a major link to the real economy and are thus essential in understanding monetary policy transmission.

The separation between the interbank market and the exchange market is less strict for government bonds than it is for corporate bonds. The government issues bonds on both markets, and although most of those can only be traded within the market, there are close substitutes available on both markets. Additionally, some few selected treasury bonds can be traded across markets. Although monetary policy is primarily conducted on the interbank market, it thus seems necessary to account for the exchange market to fully understand monetary policy transmission to the real economy.

Yet, despite their interaction there is no arbitrage between the markets, mostly

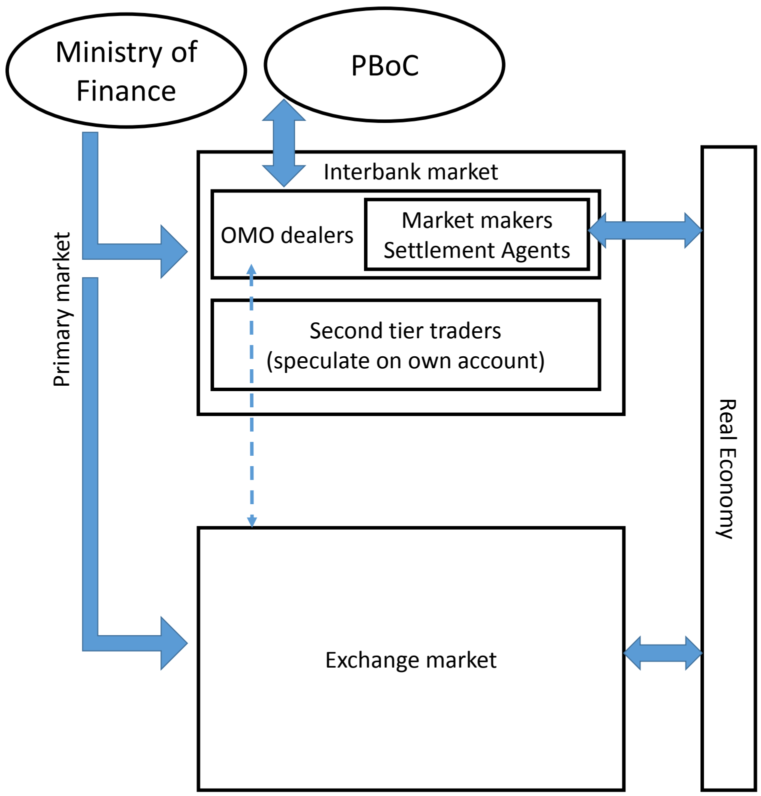



Figure 2: Structure of the Chinese Bond Market

Table 2: The Comparison of interbank market and exchange market

| | Interbank Market | Exchange Market |
|---|---|---|
| Participants | Large institutions with banks | Small and Medium institutions with no banks |
| Regulators | People's Bank of China | China Security Regulatory Committee |
| Trading Rules | Over-the-Counter | Auction and Over-the-Counter |
| Common Bonds | Central government bonds | Central government bonds |
| Different Bonds | Mid-term notes | Corporate bonds |
| Open Market Operations | Yes | No |

due to vastly different regulation. While the interbank market is closely monitored and supervised by the PBoC, the exchange market is regulated by the CSRC that focuses foremost on the primary market - i.e. bond issuing - rather than on the secondary market, i.e. bond sales. A detailed analysis, why – and when – the rates differ is provided by Fan and Zhang (2007). The interaction of the two markets is summarized in Figure 2.

# 3 Method and model

## 3.1 Yield curve estimation

**The two market yield curve model** Like most of the literature our model is built upon the seminal work by Nelson and Siegel (1987) who model the yield curve by explaining each interest rate as a function of three underlying parameters, usually dubbed level ($L$), slope ($S$) and curvature ($C$) of the yield curve.[5]

[5]There are notable exceptions such as Dahlquist and Svensson (1996) who use a four factor model that allows for a richer term structure with two humps, and Diebold et al. (2008) who use two factors (level and slope) per country in their panel approach to estimate the yield curve.

$$r_t(\tau) = \begin{bmatrix} 1 & \frac{1-e^{-\lambda\tau}}{\tau\lambda} & \frac{1-e^{-\lambda\tau}}{\tau\lambda} - e^{-\tau\lambda} \end{bmatrix} \begin{bmatrix} L_t \\ S_t \\ C_t \end{bmatrix} + \varepsilon_t, \tag{1}$$

where $r_t(\tau)$ is the spot rate of a treasury bond of maturity $\tau$ at time $t$, $\varepsilon_t$ is the residual vector and $\lambda$ is a shape parameter. Rather than estimating this equation for every point in time, Diebold et al. (2006) propose to assume an autoregressive process for the underlying parameters, thus explicitly modeling them as latent factors. That is, they interpret equation 1 as measurement equation of a state space model with the corresponding state equation:

$$\begin{bmatrix} L_t \\ S_t \\ C_t \end{bmatrix} = \begin{bmatrix} \mu_L \\ \mu_S \\ \mu_C \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} L_{t-1} \\ S_{t-1} \\ C_{t-1} \end{bmatrix} + \eta_t = \mu + A \begin{bmatrix} L_{t-1} \\ S_{t-1} \\ C_{t-1} \end{bmatrix} + \eta_t. \tag{2}$$

Since the relationship between observed interest rates of different horizons is meant to be captured through the yield curve parameters, in this line of research the covariance matrix of $\varepsilon$ is usually assumed to be diagonal, while shocks to the latent factors can be contemporaneously related. For the optimality of the Kalman filter, we also have to assume that there is no correlation between the shocks to the latent factors and the shocks to the measurement equation. Denoting the number of different maturities considered by $M$ we can thus write:

$$VarCov\begin{pmatrix}\varepsilon_t\\ \eta_t\end{pmatrix}=\begin{bmatrix}R & 0\\ 0 & Q\end{bmatrix}=\begin{bmatrix}h_1 & 0 & \cdots & 0 & 0 & 0 & 0\\ 0 & h_2 & & \vdots & & \vdots & \\ \vdots & & \ddots & 0 & 0 & 0 & 0\\ 0 & \cdots & 0 & h_M & 0 & 0 & 0\\ 0 & & 0 & 0 & q_{11} & q_{12} & q_{13}\\ 0 & \cdots & 0 & 0 & q_{21} & q_{22} & q_{23}\\ 0 & & 0 & 0 & q_{31} & q_{32} & q_{33}\end{bmatrix} \tag{3}$$

Yet, the Chinese situation is slightly different. At every point in time, we don't have one but two yields for every maturity, the first one obtained from the interbank market the second one from the exchange market. Correspondingly we have two highly related, yet potentially different yield curves. This gives as a slightly more complex model taking the shape, with the measurement equation:

$$\begin{bmatrix} r_{ib,t}(\tau_1) \\ r_{ib,t}(\tau_2) \\ \vdots \\ r_{ib,t}(\tau_M) \\ r_{ex,t}(\tau_1) \\ r_{ex,t}(\tau_2) \\ \vdots \\ r_{ex,t}(\tau_M) \end{bmatrix} = \begin{bmatrix} 1 & \frac{1-e^{-\lambda\tau_1}}{\tau_1\lambda} & \frac{1-e^{-\lambda\tau_1}}{\tau_1\lambda} - e^{-\tau_1\lambda} & 0 & \cdots & 0 \\ 1 & \frac{1-e^{-\lambda\tau_2}}{\tau_2\lambda} & \frac{1-e^{-\lambda\tau_2}}{\tau_2\lambda} - e^{-\tau_2\lambda} & 0 & \ddots & \vdots \\ & & & \vdots & & \vdots \\ 1 & \frac{1-e^{-\lambda\tau_M}}{\tau_M\lambda} & \frac{1-e^{-\lambda\tau_M}}{\tau_M\lambda} - e^{-\tau_1\lambda} & 0 & \cdots & 0 \\ 0 & \cdots & 0 & 1 & \frac{1-e^{-\lambda\tau_1}}{\tau_1\lambda} & \frac{1-e^{-\lambda\tau_1}}{\tau_1\lambda} - e^{-\tau_1\lambda} \\ 0 & \ddots & \vdots & 1 & \frac{1-e^{-\lambda\tau_2}}{\tau_2\lambda} & \frac{1-e^{-\lambda\tau_2}}{\tau_2\lambda} - e^{-\tau_2\lambda} \\ \vdots & & \vdots & & & \\ 0 & \cdots & 0 & 1 & \frac{1-e^{-\lambda\tau_M}}{\tau_M\lambda} & \frac{1-e^{-\lambda\tau_M}}{\tau_M\lambda} - e^{-\tau_1\lambda} \end{bmatrix} \begin{bmatrix} L_{ib,t} \\ S_{ib,t} \\ C_{ib,t} \\ L_{ex,t} \\ S_{ex,t} \\ C_{ex,t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{ib,t} \\ \varepsilon_{ex,t} \end{bmatrix}, \tag{4}$$

and the corresponding state equation:

$$\begin{bmatrix} L_{ib,t} \\ S_{ib,t} \\ C_{ib,t} \\ L_{ex,t} \\ S_{ex,t} \\ C_{ex,t} \end{bmatrix} = \begin{bmatrix} \mu_{ib} \\ \mu_{ex} \end{bmatrix} + \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} L_{ib,t-1} \\ S_{ib,t-1} \\ C_{ib,t-1} \\ L_{ex,t-1} \\ S_{ex,t-1} \\ C_{ex,t-1} \end{bmatrix} + \begin{bmatrix} \eta_{ib,t} \\ \eta_{ex,t} \end{bmatrix}, \tag{5}$$

where $A_{11}$, $A_{12}$, $A_{21}$ and $A_{22}$ are $(3 \times 3)$ coefficient matrices corresponding to the matrix $A$ in equation 2. The purpose of this model extension is twofold. First, it allows us to test whether the two markets interact, by testing Granger causality between the latent variables, i.e. testing $H_{0,A} : A_{12} = \mathbf{0}$ and $H_{0,B} : A_{21} = \mathbf{0}$. Second, if there exists some kind of relationship, we can obtain a more efficient estimate of the yield curve parameters by fully accounting for the relevant information. This is particularly relevant due to the sparse Chinese yield curve. This approach differs from Diebold et al. (2008) who model several countries simultaneously thereby essentially also modeling several markets. However, contrary to us they model a global factor and market (country) specific factors that can load on the global factors but not vice versa. The reason that we chose a different approach is our interest in the bilateral causality.

**Dealing with missing observations** As mentioned before, the Chinese government bond market has only fully developed quite recently. For a large part of our sample, the market was not very deep, and correspondingly we have a lot of missing observations for specific maturities at varying points in time. Generally, the Kalman filter is well suited to deal with missing observations. If all data is missing for a specific observation, the extension is fairly straightforward and boils down to simply omitting the update step in the corresponding periods (since there is no information to base the update on). This method is fairly widespread for example when the Kalman filter is used in imputation (see e.g. Mönch and Uhlig, 2004). Yet, things are slightly more complex in our case, where the missing data is scattered across observations. That is, we would like to update, but base the update merely on the data that is observable. Liu and Goldsmith (2004) suggest to manipulate the covariance of the measurement equation $Q$, by setting the variance of the missing observations to infinity. This guarantees that the corresponding residual has no impact on the estimation and can thus be treated as if it did not exist (simply treating it as zero without the appropriate correction in the covariance matrix, would cause too much confidence in the Kalman forecast that seemingly produced a very low residual).

Applying this method allows us to use the model we propose using weekly data starting in 2008.

## 3.2 The monthly structural VAR model

**Model setup and structural identification** We estimate a 13 variable VAR including macroeconomic indicators, monetary policy, and financial market indicators, in particular the states describing the yield curves on interbank and exchange markets. The macroeconomic block includes industrial output (*ip*), consumer prices (*cpi*), and - due to the special importance of real estate in China - housing sales (*hsales*) (see e.g. Chen and Wen (2017) and Chen et al. (2017)). In 2008, the Chinese government launched its famous 4 trillion RMB stimulus plan, that mainly focused on infrastructure and housing construction. We use housing sales instead of housing prices in our estimation for two reasons. First, there is no reliable house price index covering the entire nation for our sample period. Second, and more importantly, this does also allow to capture the increased housing sales, in particular of houses that are yet under construction, i.e. not covered by current production. Monetary policy is included through the loan benchmark rate (*brate*)[6] and the repo rate (*repo*)[7], the two core policy rates of the PBoC.

Finally, the financial market impact is captured through two quantity indicators

[6]Particularly, we use the 6-month to 1-year benchmark loan rates. However, the PBoC almost always adjusts their benchmark rates on deposits and loans simultaeously. The choice of the proper indicator among the different benchmark rate is therefore mostly inconsequential to our analysis.

[7]The repo rate in this paper refers to 7-day treasury bond repo rate in interbank market, which is claimed by PBoC report 2015 as the policy rate.

- namely loans and money -, and the yield curve. We consider money and loans separately, mostly due to the importance of loans in Chinese monetary policy. Since there is policy that directly affects the credit market (i.e. loan benchmark rate changes), and policy that works through liquidity provision to banks, one might easily imagine a situation where loans and money are not affected in the same way. In the baseline specification, money is measured as M2 ($m2$) due to its prominence in PBoC communications. In a robustness test, we use Divisia M3 ($dm3$) as reported by Barnett and Tang (2016). Finally, using the estimated states from our weekly model is equivalent to including the interest rates from the estimated yield curves at specific maturities. Given the high volatility of individual bond prices in the Chinese market, and the corresponding volatility of the observed (non smoothed / non estimated) interest rates at specific horizons, this seems to better capture the underlying financial market conditions. Contrarily, using observed bond yields would not only substantially reduce our sample due to missing observations, but also import unnecessary uncertainty into the macroeconomic model. A list of all variable used in the model including their source is found in Table 3. [8] Except interest rates and the underlying factors, all variables are used in natural logarithms. Since cointegration between the non stationary $I(1)$ variables included in the model is confirmed by a Johansen test, we estimate the VAR in levels.

To identify monetary policy shocks and assess monetary policy transmission we build on the seminal blockwise recursive framework introduced by Christiano et al.

[8] The existing literature on Chinese bond yields occasionally uses averages of all bonds with the same maturity at issuance, rather than aggregating over bonds with the same actual time to maturity. However, this makes it difficult to interpret the results since the interpretation of a single time series is changing quite substantially over time.

Table 3: Data and sources

| Variable | Description | Source |
|---|---|---|
| ip | Industrial value added, quantity index. Seasonally adjusted (by authors). | NBS |
| cpi | Consumper price index, national average. Seasonally adjusted (by authors). | NBS |
| hsales | Housing sales in 10000 RMB. | NBS |
| loans | Outstanding loans of all financial institutions. | PBoC |
| M2 | M2. | PBoC |
| DM3 | Divisia M3, Divisia weighted monetary aggregate with the PBoC's M3 components. | BT(2016) |
| brate | benchmark loan rate for loans from 6 to 12 months. | PBoC |
| repo | 7-day interbank repo rate. | PBoC |
| Yield curve* | Yield curve factors, authors' estimation. | |

*Note:* * The yield curve factors $L_{ex}$, $S_{ex}$, $C_{ex}$, $L_{ib}$, $S_{ib}$, and $C_{ib}$ for the last week of each month as estimated through Equation 5. NBS = National Bureau of Statistics. BT(2016) = Barnett and Tang (2016).

(1999).[9]

They have shown, that in a recursive identification, where the order is given by $[A\,x\,B]$ and $A = [a_1, a_2, \ldots]$, $B = [b_1, b_2, \ldots]$ and $X = [x_1, x_2, \ldots]$, neither the sorting of variables within block $A$, nor within block $B$ matters for the identification of the shocks to $X$. That is, there is no need for a specific recursive structure to be true for correct identification, as long as there are blocks of variables that definitely react slower or faster than monetary policy, which is our shock of interest.

Following the literature, we assume that variables in the monetary policy block are affected by the state of the macroeconomy (*ip*, *cpi*, and *hsales*), but can not contemporarily affect those rather sluggish variables. Contrarily, the financial market indicators (*loans*, *m2*, and the yield curve states) can respond immediately (i.e. within the month) to monetary policy, but monetary policy cannot respond to those very volatile markets immediately due to the necessary decision process. In other

[9] A recent noteworthy application in the context of monetary policy includes Keating et al. (2014).

words, what matters for identification of the two monetary policy shocks is merely the order of those two. In our baseline specification, we allow the benchmark rate to affect the repo rate, reasoning that the repo rate is a market rate, which could theoretically respond to a regulatory change. Yet, we find a contemporaneous effect that is quantitatively small and statistically insignificant. We test the reverse order in a robustness check, finding almost identical results, i.e. even when allowing the repo to immediately affect the benchmark rate, the estimated effect is very close to zero. That is, as predicted, the two monetary policy shocks are mostly orthogonal. Although relevant theoretically, the order of the two is thus inconsequential in our specific setup. The results we report below are obtained from our baseline specification. However, all results roughly hold for the reverse order.

That is our baseline model takes the form:

$$\begin{bmatrix} \mathbf{macro} \\ brate \\ repo \\ \mathbf{liquidity} \\ f_{ib,t} \\ f_{ex,t} \end{bmatrix}_t = \sum_{l=1}^{p} B_l \begin{bmatrix} \mathbf{macro} \\ brate \\ repo \\ \mathbf{liquidity} \\ f_{ib,t} \\ f_{ex,t} \end{bmatrix}_{t-p} + C\varepsilon_t, \qquad (6)$$

where $\mathbf{macro} = [ip\, cpi\, hsales]^T$ and $\mathbf{liquidity} = [loans\, m2]^T$, $\varepsilon_t$ is a vector of orthogonal standard normal structural shocks, and $C$ is a block triangular matrix that maps structural shocks on reduced form shocks.

**Small sample issues and parameter proliferation** Due to the limited availability of Chinese treasury bonds before 2008, our sample is limited to merely 108 monthly observations from January 2008 to December 2016.

Even when considering at most three lags, the number of parameters we would have to estimate in our system of 13 equations is considerable. Therefore, following El-Shagi and Kelly (2017) we run a Least Absolute Shrinkage and Selection Operator (LASSO) based lag selection. I.e. rather than selecting a fixed number of lags for each variable and each equation, every individual coefficient is assessed, whether it contributes sufficiently to the model or not. This implies that the equations no longer use identical regressors, which is necessary for a VAR to be consistently estimated by (blockwise) OLS (Sims, 1980). Therefore, we reestimate the model with the parameters selected by LASSO using a seemingly unrelated regressions (SUR) approach. Our LASSO approach allows to reduce the number of estimated coefficients from 520 to merely 164.

In the more common quarterly studies, 108 observations per equation would be a fairly reasonable sample size. However, El-Shagi (2017) shows that finite sample bias can still be considerable with this sample size when using monthly data, because – despite the number of observations – only one or at most two business cycles are covered.[10] Following his suggestion, we thus apply a small sample correction bootstrap to our estimator. We use the indirect inference bootstrap proposed by Bauer et al. (2012). Contrary to most previously used bootstrap based bias corrections, this method does not assume the bias to be linear. Using SUR makes the bootstrap

[10] In fact, this plagues a lot of studies on the Chinese economy, because of data quality and availability issues.

computationally substantially more demanding. Therefore, rather than using a bootstrap after bootstrap approach in the spirit of Kilian (1998) (which is extended to an indirect inference after indirect inference bootstrap by El-Shagi and Zhang (2016)), but use a simple parametric bootstrap based on the results obtained with the bias corrected estimator.[11]

# 4 Results and interpretation

## 4.1 Weekly yield curve estimation

In equilibrium we find the expected results. The yield curve on both markets is almost coinciding (see Figure 3), moderately positively sloped with an equilibrium short rate around 2.6% and an equilibrium long rate around 3.5%. There is a very small difference in the point estimates at the very short end, however, this difference is statistically insignificant. A Granger causality test clearly rejects the exclusion of either of the off-diagonal blocks of $A$ (from Equation 2), strongly indicating that the interbank and the exchange market mutually affect each other.

However, when comparing the state estimates obtained from a model where the two markets are considered individually, and our two market model, we find that it is mostly the estimates regarding the exchange market that are changed, while the estimates for the interbank market are almost indistinguishable between the two models.

[11]When using a residual bootstrap to generate the coefficient distribution, the bias that has been previously corrected would be reintroduced again. This is why residual bootstrap based IRFs require bootstrap after bootstrap methods for bias correction.

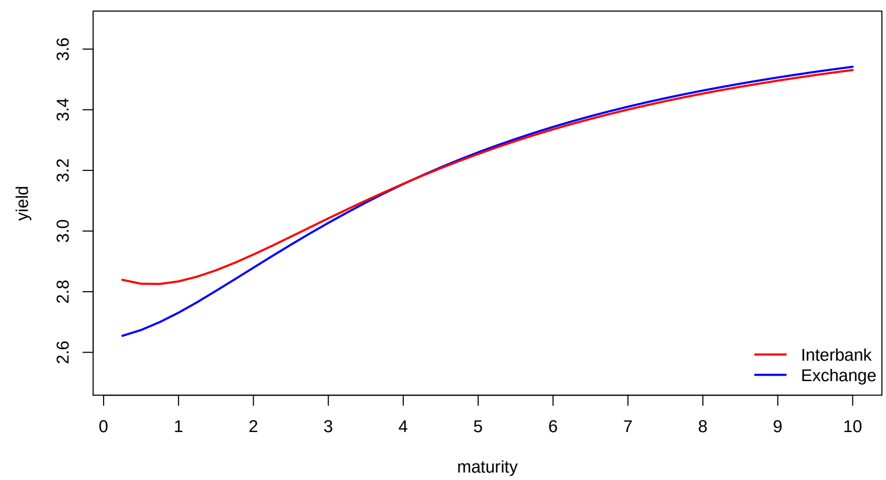
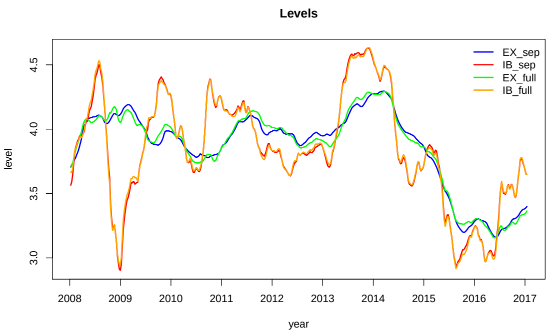



Figure 3: Yield curve(s) in equilibrium

## 4.2 Monthly SVAR model

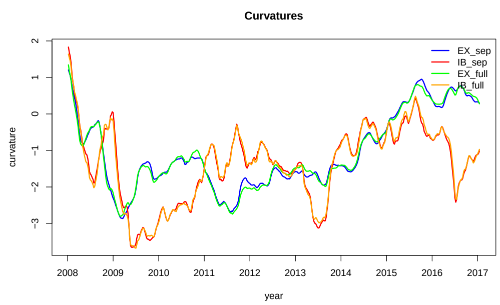
**Market based policy shock (repo shock)** At a first glance the results look unusual. We find some evidence for both price and output puzzles, and while output quickly turns around and moves into the expected (negative) direction after an interest rate increase, the price response just becomes insignificant after a short period of high volatility. This is stunning insofar, as we observe the expected clearly negative effect on both money and loans. It seems, that the main effect of the changed monetary conditions goes into the housing sector. Unlike the counter-intuitive results for prices and (to some extent) industrial production, we observe a clear and significant decline in housing sales that remains robust for a few years.

On both the interbank market and the exchange market, it seems that the impact on the yield curve is mostly a parallel shift, i.e. all yields (in one market) move in




(a) Level


(b) Slope

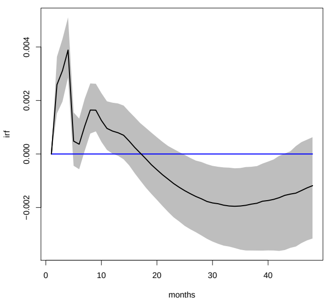



(c) Curvature

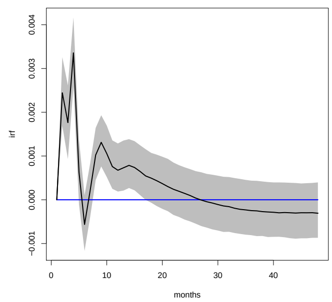
Figure 4: State estimates (Level, slope and curvature) for both markets

the same direction with a similar order of magnitude. There is only very moderate evidence of a slightly flattening yield curve. There is, however, a very clear difference in the response of the interbank market and the exchange market. Unsurprisingly, the interbank market – where the monetary policy is actually conducted – responds immediately. The impact gradually declines over the coming years, while the yield curve slowly returns to equilibrium. Contrarily, the exchange market takes much longer to fully respond. The initial effect is extremely small (although generally going into the right direction). The interest rates on the exchange market peak after roughly two years, when they have almost converged to the rates on the interbank market at this time. After that, they slowly decline in line with the rates on the interbank market. While this generally supports that there is some interaction between the markets, it also highlights the substantial frictions within the Chinese financial sector that slow down the direct monetary transmission in financial markets immensely. It seems, that the bond market segmentation only allows an adjustment through the "real economy", i.e. the firms and other agents who can transact with the dealers on both the interbank and the exchange market.

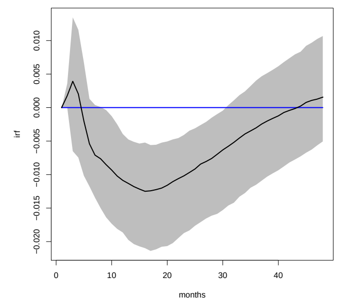
**Authority based policy shock (Benchmark rate shock)** Although a (positive) benchmark shock is similar to a (positive) repo in the sense that it works as an overall contractionary shock, the details could not be more different. The impact on consumer prices is insignificant allover, and the impact on (industrial) production more moderate. However, – as to be expected given the importance of loans for housing – housing sales react much more sharply and quickly. The effect is not very long lived, but neither is the interest rate change.



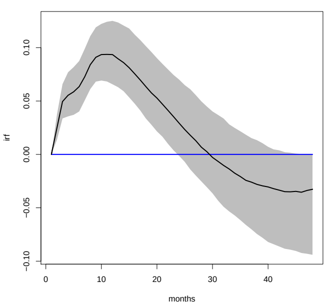

(a) Industrial Production



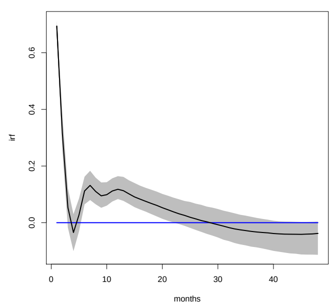

(b) CPI



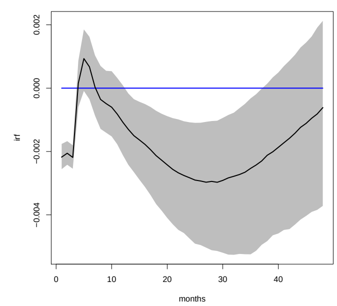

(c) House sales



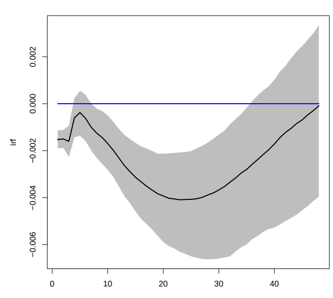

(d) Benchmark rate




(e) Repo rate

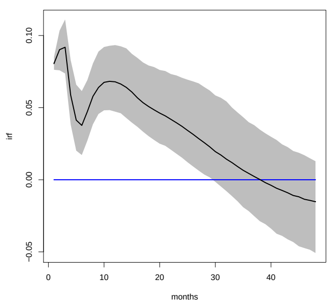



(f) M2

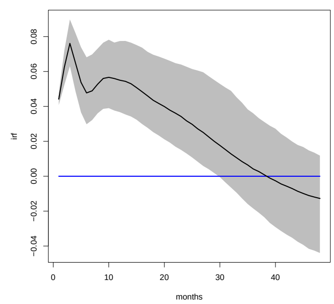



(g) Loans

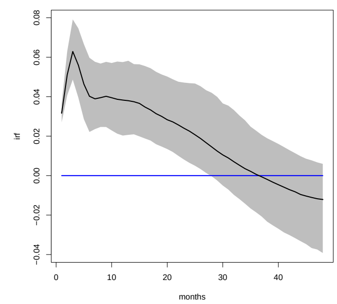
Figure 5: Impact of the market based shock (Repo) on the macroeconomy



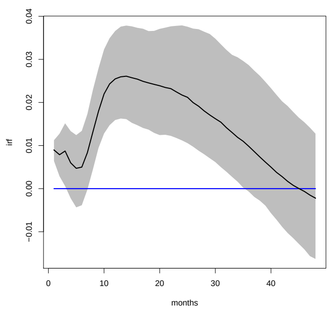

(a) IB, 1 year



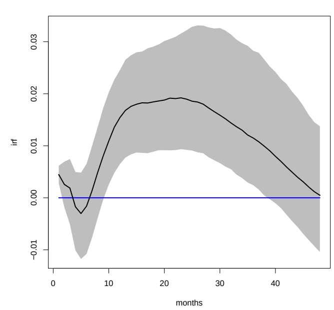

(b) IB, 3 year



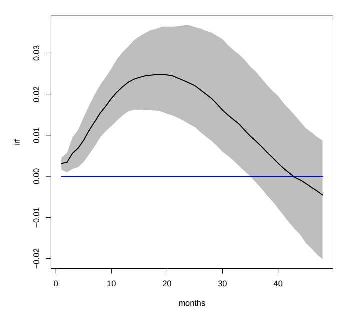

(c) IB, 10 year




(d) EX, 1 year




(e) EX, 3 year

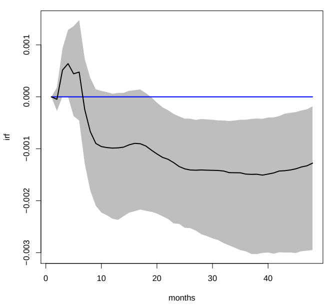



(f) EX, 10 year

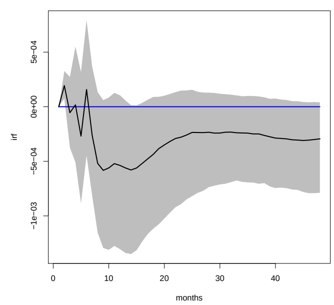
Figure 6: Impact of the market based shock (Repo) on the yield curve

One very interesting feature is the "loan" puzzle on impact. The initial impact of a benchmark rate change on loans is positive (and highly significantly so) before it quickly turns strongly negative. However, this can easily be explained by the regulatory nature of the benchmark rate. As discussed above, while being labeled a target, there is no evidence for immediate monetary accommodation of the new interest rate. However, banks seemingly immediately comply. If the interest rate is kept below its long term equilibrium (which seems plausible given the interest rate of China which is fairly low for an emerging market), there might be credit rationing because banks aim to limit loans. When the interest rate increases and this constraint is alleviated, banks initially supply more loans. As mentioned before, the PBoC has been known to backup its loan rate policy with more specific guidance, if the desired quantity effects are not achieved, which explains the quick turnaround into the expected direction.

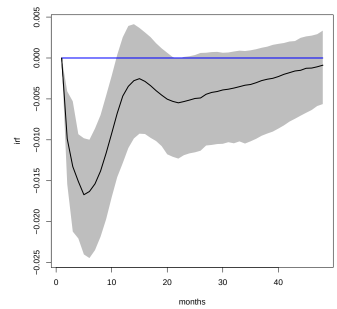
Like the shock itself, the impact on the yield curve is fairly short lived. Most interestingly, the effects now show immediately on both markets. While the exchange market's response is slightly more moderate, both the interbank market and the exchange market respond clearly within the same order of magnitude. Since, the direct effect of the repo change (which is enacted through open market operations on the interbank market) is missing, and both markets are only indirectly affected through the portfolio rebalancing of market participants, this matches our theoretical prediction.



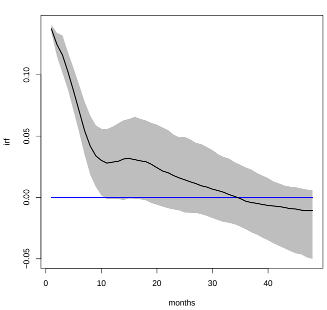

(a) Industrial Production



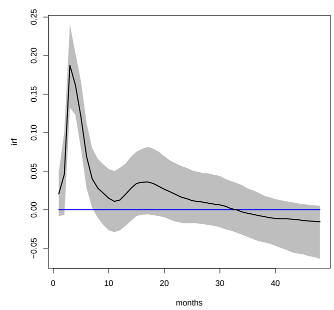

(b) CPI



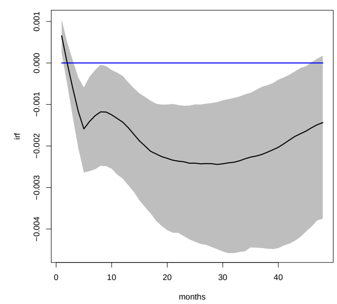

(c) House sales



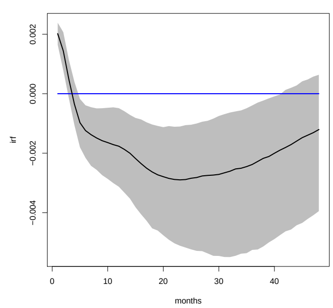

(d) Benchmark rate




(e) Repo rate

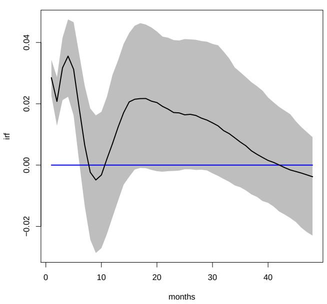



(f) M2

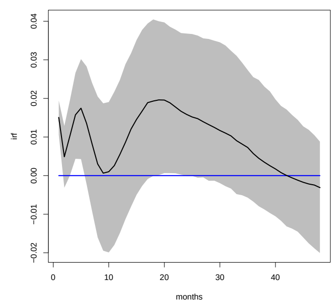



(g) Loans

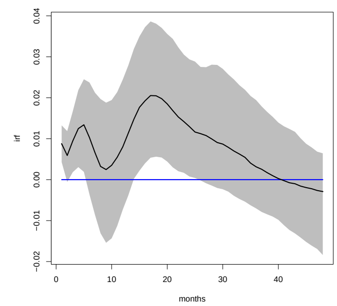
Figure 7: Impact of the authority based shock (benchmark rate) on the macroeconomy



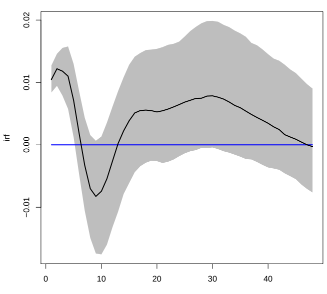

(a) IB, 1 year



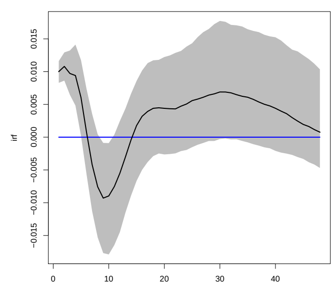

(b) IB, 3 year



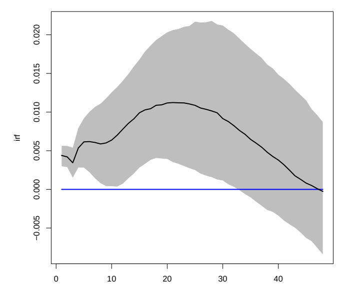

(c) IB, 10 year




(d) EX, 1 year




(e) EX, 3 year




(f) EX, 10 year

Figure 8: Impact of the authority based shock (benchmark rate) on the yield curve

# 5 Conclusions

Our results highlight, that China's monetary system is still very different from its Western equivalents, despite many reforms happening over the last few decades. There is clear evidence, that there are currently two distinct and mostly orthogonal monetary policy shocks: A "Western type" market based shock, that is enacted through open market operations on the interbank market, and an "authority based" shock, that is relying on the traditional compliance of the big state owned banks with the PBoC's wishes. While the transmission of the market based shocks goes from the financial sector (or rather one part of it, namely the interbank market) into the real economy and lastly back into the financial sector, the authority based shocks, goes through regulation driven loans, into the real economy and only then feeds back into the financial market.

The existence of separate tools for the different objectives of the PBoC – such as stabilizing consumer price inflation and avoiding an overheating real estate sector – is not necessarily detrimental, and indeed – and contrary to the Fed's and the ECB's policy - in line with the Tinbergen rule, which suggests one instrument per objective. However, those complexities need to be kept in mind, when assessing Chinese monetary policy.

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