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Monetary Stimulus Policy in China: the Bank Credit Channel

Min Zhang (East China Normal University)
Yahong Zhang (University of Windsor)

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Monetary Stimulus Policy in China: the Bank Credit Channel*

Min Zhang[†] Yahong Zhang [‡]

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Abstract

This paper develops a novel while plausible way to model the Chinese monetary transmission via open market operations (OMOs). In the model, monetary injections through OMOs, together with differentiated collateral regulation in the banking sector, directly affect banks' loan capacities, which then influences sectoral investments and aggregate GDP. The quantitative analysis shows that the 2009–2010 monetary expansion explains nearly 90 percent of the rise in GDP growth. Moreover, balancing credit allocation across sectors and applying unified banking regulations jointly enhance the GDP growth rate by 2.15 percentage points, with the contribution of the unified banking regulations proving more important.

Keywords: Monetary stimulus, Bank credit channel, Open market operation rule, Chinese economy

JEL classifications: E32 E44 E52

1 Introduction

In the wake of the 2007–2008 global financial crisis, the Chinese government announced a massive monetary stimulus in November 2008, in the hope of restoring the annual growth

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‡Department of Economics, University of Windsor, Windsor, Ontario, Canada N9B 3P4; E-mail: yzhang@uwindsor.ca.

rate to its previous level above-9%.[1] As the second largest economy in the world, China's massive stimulus has triggered a fast growing literature to study its impacts on the real economy. Many works, such as Chen and Zha (2018), stress the *pivotal* role played by the bank credit channel in the monetary transmission. However, many existing studies either depend on empirical approaches, such as estimating monetary policy regimes with rich Chinese features as proposed in Chen et al. (2016), or using reduced-form regressions based on large scale micro-level datasets on banks and firms, as shown in Cong et al. (2019). To the authors' knowledge, none of the existing papers has provided a structural theoretical framework in which the bank credit channel of the monetary transmission mechanism is explicitly modeled and its quantitative importance is examined. This paper tries to fill the gap. In particular, we develop a theoretical model by capturing the key institutional features of the Chinese monetary policy. We aim to connect the monetary policy and the bank lendings to quantify the impact of the monetary stimulus during 2009–2010 on the real economy.

A unique feature of the Chinese monetary policy is that it works through the bank credit channel. From 1998, the People's Bank of China (PBC), the central bank of China, pursued its purpose of accommodating short-term economic fluctuations and promoting economic growth. The PBC officially set the growth of M2 supply as the only intermediate target of monetary policy. Two sets of tools were then adopted to implement this quantity-based monetary policy. One set mainly consists of two market-based instruments, namely open market operations (OMOs) and the required reserve ratio (RRR). The other set is in nature a non-market-based instrument, mainly containing the window guidance policy and banking regulations.[2] As documented in Section 2, among these tools, the OMOs and the window guidance policy play the most significant, albeit different, roles. Specifically, the OMOs are used on a quarterly basis to target the explicit growth rate of M2. The window guidance policy is used to ensure that the growth of bank credits is in line with the growth of the M2 supply, and that the bank credits are allocated to the sectors or firms preferred by the central government. As a result, the growth rate of the M2 supply displays a strong co-movement with the bank loans in China.

During the stimulus period, the expansionary monetary policy largely operated through the OMOs in the form of central bank bills (short-term central bank bonds), and most of the monetary expansions were allocated into the state-owned banks due to the window guidance policy. As shown in Figure 6 in Section 2, the RRR for different types of commercial banks remained almost unchanged in 2009–2010. On the contrary, the PBC bought a substantial amount of central bank bills from the commercial banks, especially from the state-owned banks. Figure 7 shows that the central bank bill holdings as a

[1]Many central banks in the world implemented stimulative monetary policies with different magnitudes. See Chen, Ren and Zha (2018) for details.

[2]For example, ceiling interest rates for deposits, and flooring rates for bank lending.

share of overall assets by the commercial banks plummeted from its peak of 11.4 percent in 2009Q1 by more than half, falling to 4.6 percent in 2010Q4. In terms of ownership comparison, Figure 8 shows that the decline in the state-owned banks was much more pronounced than that in the non-state-owned banks, at 8 percentage points for the former and only 3 percentage points for the latter.

To capture the above-mentioned key features of the monetary policy in China, this paper extends a standard two-sector dynamic stochastic general equilibrium (DSGE) model along two dimensions. First, we introduce a banking sector a la Gertler and Karadi (2011) into the model. For simplicity, the banking sector, which contains the state-owned banks (SBs) and non-state-owned banks (NSBs), is assumed to be segmented. We further assume that the SBs only lend to state-owned enterprises (SOEs), and that the NSBs only lend to private enterprises (PEs).[3] The SBs and NSBs are assumed to differ in several dimensions that are closely in line with the banking regulation details and the literature on the Chinese economy. For example, in the model, the SBs issue more loans and lend at lower rates than the NSBs. Meanwhile, the SBs impose much more generous collateral requirements on the SOEs, compared to the ones offered by the NSBs to the PEs. The second and more important extension is that we develop an *alternative while plausible* method of modeling the Chinese monetary policy rule, the so-called OMO rule. In the model, the OMO rule is constructed such that the PBC systematically adjusts the banks' ability to make loans in response to GDP growth and inflation. The magnitude of the adjustment differs between the SBs and NSBs, with the SBs being more responsive.

The benefits of these two extensions come in three ways. First, unlike the reduced-form approach in the literature, the OMO rule allows us to explicitly illustrate the bank lending channel of the monetary transmission. In the model, the OMOs directly affect the balance sheet of two types of banks, which affects banks' loan capacity, and therefore, shapes the sectoral and aggregate investments and outputs.[4] Considering this, the OMO rule, closely in line with the quantity-based monetary policy, provides a more suitable framework to evaluate the effects of monetary policy in China, compared with the Taylor rule widely used in the developed economies, which feature a price-based monetary policy. Second, these extensions allow us to demonstrate two possible while important sources of credit imbalance that ultimately give rise to a misallocation problem and GDP growth drag. In our model, the OMO rule suggests that the SOEs receive more credits than the PEs in response to a credit expansion. This, together with the differentiated access to the bank loans between the SOEs and the PEs, leads to *credit imbalance.* In the presence

[3] Similar to our work, Chang et al. (2019) consider a segmented banking system. In their study, formal banks that serve SOEs and shadow banks that serve PEs co-exist. Our work focuses on the formal banking sector, and abstracts away the shadow banks.

[4] The existent studies on Chinese monetary policy typically consider demand for money by households (e.g., money in utility). In the absence of the banking sector, they cannot illustrate the credit channel of the monetary policy (See Li and Liu, 2017; Zhang, 2009).

of such a credit imbalance, a larger proportion of loans go to the less productive SOEs, even though both SOEs and PEs experience a rise in demand for bank loans. Thus, credit misallocation arises, which translates into a GDP growth drag. Third, the OMO rule, built on the segmented banking system, greatly facilitates the quantitative analysis. In particular, it enables us to quantify impacts of the credit imbalance on sector and aggregate investment and outputs along two dimensions: uneven injections across banks and differentiated banking regulations (different borrowing constraints faced by the SOEs and the PEs). Also, the OMO rule makes it possible to conduct counterfactual exercises to show their relative importance, which helps address the credit misallocation problem highlighted in the literature.

We estimate our model using quarterly data from 2000Q1–2014Q4 in China.[5] The results show that the OMO rule plays an important role in driving the business cycle properties of the Chinese economy, as well as the correlations of key macroeconomic variables. To see this, a decomposition exercise is conducted to quantify the relative contribution of the OMO shock, as opposed to the other five shocks considered in the model. At the aggregate level, around 44 percent of the fluctuations of output, and 52 percent of variations in investment are accounted for by the OMO shocks. At the sector level, the OMO shocks display *differentiated* impacts: they explain 57 percent of the variations in SOE investment, while only about 32 percent of the fluctuations in PE investment. In contrast, the banking shocks, which capture the systematic risk of the banking sector, account for about 47 percent of the fluctuations in PE investment, while only about 27 percent of the variations in SOE investment. These results suggest that SOE investment is largely policy driven, while PE investment is mainly driven by credit conditions in the banking sector. These results echo well the findings in recent studies, such as Chen and Zha (2018), that the monetary or credit expansions in China mainly boost GDP growth through SOE investment.[6]

The impulse response to the OMO shocks illustrates the credit channel of monetary transmission. In our model, uneven credit injections into the segmented banking system, as well as the different collateral constraints for bank loans faced by the SOEs and PEs, *jointly* explain the differentiated impacts of the OMO shocks on sectoral investment. During a credit expansion, the estimated OMO rule suggests that a larger portion of credit expansions go to the SBs, which significantly increases the loan capacity of the SBs compared to the NSBs. The resulting lowered lending rate greatly promotes the SOE investment. This effect is further strengthened in the SOE sector given that the SOEs are financially less constrained because of the more favorable borrowing conditions

[5]From 2000, the PBC started to frequently use OMO to affect the M2 growth rate. Thus, the sample period for the quantitative part is chosen to be 2000Q1 to 2014Q4.

[6]Chen and Zha (2018) argue that for the investment-driven economy (China), monetary policy, coupled with credit policy, played a crucial role in promoting overall economic growth through investment in the heavy sector. The heavy sector largely refers to the SOEs.

compared to the PEs. In sharp contrast, the PE investment is much less responsive to the OMO shock, due to both the smaller portion of credits received by the NSBs and much tighter borrowing constraints faced by the PEs.

Based on the estimation results, we conduct three counterfactual experiments to shed lights on the following two questions: (1) What is the effect of the 2009–2010 monetary stimulus on the GDP growth? (2) What are the relative contributions to the GDP growth of the uneven credit injections and the differentiated banking regulations? To answer the first question, we reduce the size of the OMO shock during the stimulus period (2008Q4–2010Q4) by 75 percent, which corresponds to the average OMOs observed during the post-stimulus period (2012Q4–2014Q4). As expected, removing the massive monetary stimulus gives rise to a lower GDP growth. The simulated GDP growth rate in 2009Q4 declines substantially from 10.24 percent to 8.27 percent. With the GDP growth rate in 2008Q3 being 8 percent, this result suggests that the stimulus package accounts for about 88 percent of the increase in GDP growth over the period of 2008Q3–2009Q4. This result is consistent with the finding of 85 percent in Chen et al. (2016) based on an empirical analysis.

For the second question, we find that allocating the credits to the banking sector in a more balanced way promotes the GDP growth, which can be further strengthened by a more unified banking regulations. When the NSBs are allowed to respond in the same way as the SBs to a change in overall credit expansions, the NSBs receive more credit injections than what they have in the baseline case, which ultimately raises the average GDP growth by 0.5 percentage points over the stimulus period. Further relaxing the borrowing constraints faced by the PEs (i.e., a higher loan-to-value ratio, hereafter LTV ratio) *greatly* strengthens the result; the rise in the average GDP growth reaches 2.15 percentage points over the same period. Intuitively, when new credits are injected into the banking sector in an more balanced way, although the rise in credits in the NSBs helps more PEs get loans due to lower borrowing costs (extensive margin), the fixed while low LTV ratio suggests that individual PE firms still have difficulties obtaining bank loans (intensive margin). A reform along both dimensions benefits the PEs at both extensive and intensive margins, which greatly encourages the investment in the PE sector, and translates into a higher GDP growth. The result for total factor productivity (TFP) confirms this intuition. These results deliver interesting policy implications: promoting GDP via stimulus policy requires consideration of evenly distributed credits and a unified banking regulation. Moreover, with both reforms present, particularly banking regulations, the misallocation problem associated with the credit expansions can be mitigated, and the stimulus policy could better reach its original goal.

Further analysis shows the relative importance of unifying the banking regulations. When we change the status of the SBs and NSBs in the banking sector to allow the NSBs to receive more credits than the SBs during the stimulus era. We find that without changing the differentiated LTV ratios in the banking sector, such a change deteriorates the GDP growth. Intuitively, the enlarged loan capacity for the NSBs indeed promotes the investment in the PE sector (extensive margin). However, this improvement is partially offset by the unfavorable borrowing constraints faced by the PE firms (intensive margin). Meanwhile, the reduction in loan capacity in the SBs imposes a negative pressure on the investment in the SOEs. In the end, the decrease in the SOE investment outweighs the increase in the PE sector, which leads to a lower aggregate investment. This result highlights the importance of the unfavorable borrowing condition faced by the PEs in explaining the recent economic slowdown in China.

Our paper is mostly related to the literature on Chinese monetary policy. In a pioneering study, Chen et al. (2016) identify an endogenous-switching monetary policy regimes (normal versus shortfall). However, their approach is essentially a reduced-form approach and one cannot see how monetary expansion affects the real economy through the banking sector. Chen, Ren, and Zha (2018) attribute the failure of money tightening in the post-stimulus era to the rise in shadow banking activities caused by the NSB's concern for the loan to deposit rate (LDR). Abstracted from the LDR and the shadow banks, our work focuses on the real impact of the monetary stimulus via the OMO rule and the differentiated LTV in banks. Differing from the positive question asked in this work, Chang et al. (2019) pursue the optimal reserve requirement that strikes a balance between the capital misallocation across sectors and the non-performing loans caused by the bankruptcy risk faced by the SOEs.[7] With the OMOs being the primary tool used by the PBC to achieve the monetary policy target during the stimulus period, this work abstracts from the reserve requirement (ratio), and focuses on evaluating the real effect of the 2009–2010 monetary expansions with the OMO rule.[8]

Our quantitative results also confirm the findings in the literature on misallocation in China. Several recent studies shed some light on the misallocation effect of the 2009-2010 stimulus package through different angles. Bai, Hsieh and Song (2016) point out the capital misallocation problem caused by the local governments. Cong et al. (2019) make a similar argument by the endogenous preference towards SOEs by banks caused by the bail-out expectation for the SOEs. Through close examination of the details of the quantity-based monetary policy in China, our quantitative results illustrate the importance of uneven credit injection and differentiated borrowing constraints across sectors, the two sources of credit misallocation, in improving the sectoral and aggregate output as well as the overall TFP.

The rest of the paper is organized as follows. Section 2 provides a brief background of

[7]Another difference between Chang et al. (2019) and our work is that financial frictions in Chang et al. (2019) are faced by non-financial firms, not banks. Hence, the banking sector in their paper is simply a veil. In contrast, both firms and banks in our paper face the financial frictions and the banks' balance sheets play a critical role in monetary transmission.

[8]A similar argument is made in Chen, Ren and Zha (2018), as is shown in Section 2.2.3.

monetary policy in China and the stimulus policy introduced during 2009-2010. Section 3 describes the DSGE model with the segmented banking sector. The OMO rule, in line with the essential features of the Chinese monetary policy during the stimulus era, is introduced and discussed in details. Section 4 describes the data and estimation strategy. Section 5 analyzes the model performance and describes the key mechanisms in the model. Three policy experiments are conducted in Section 6. Finally, Section 7 concludes.

2 Background

This section first provides institutional details about the unique features of the monetary policy in China. Then, we limit our attention to the stimulus period, 2009–2010, by elaborating the key features of the stimulus policy, its impact on the aggregate economy and the monetary instruments adopted by the PBC. The institutional details summarized in this section will be taken seriously in the subsequent theoretical and quantitative analysis.

2.1 Monetary policy in China

The official goal of the PBC is to stabilize macroeconomic fluctuations and to achieve economic growth. For this purpose, the PBC established a variety of intermediate targets, which evolved over time as the Chinese economy experienced a transition from a planned economy to a market economy. Before 1993, the PBC directly set bank loan quota and determined how it was allocated to the targeted sectors and firms (mainly SOEs) in the economy. In 1993, the PBC began to announce an index of the growth rate of the M1 and M2 supply. In 1996, in addition to directly controlling bank loans, the PBC started to use the monetary aggregates as the intermediate targets of the monetary policy. In 1998, the PBC officially abandoned the direct control of bank loans and *explicitly* made M2 supply as the only intermediate target. From then to 2017, China has been using this quantity-based monetary policy.

The *unique* feature of the quantity-based monetary policy is that it works through the banking credit channel. As emphasized in Chen et al. (2016), the growth rate of the M2 supply displays a strong co-movement with bank loans, which implies that the monetary policy is implemented to implicitly control the aggregate bank credits. In practice, at the end of each year, the growth rate of the M2 supply was determined by the central government. The PBC implements the monetary policy by adjusting the M2 growth rate on a quarterly basis, which ultimately shapes the bank loan capacities in the banking sector through two sets of tools. The first set of tools are marketized instruments, which mainly conclude the OMOs and the RRR. The second set of tools are non-market-based instruments from the planned economy, which mainly consist of the administrative window guidance policy on commercial bank lending, as well as the regulated interest rates for deposits and commercial bank lending.

The open market operations (OMOs), initially introduced in May 1998, are used as the main tool for the PBC to achieve the explicit target of growth rate of the M2 supply on a *regular* basis (see Chen and Zha, 2018). The bond trading in OMOs concludes spot trading, repurchase trading (repo and reverse repo), and insurance of central bank bills (short-term bonds issued by the PBC). The main participants of OMOs prior to 2015 were commercial banks, afterward extended to include the securities companies and other financial institutions, which leads to 46 participants in total. In addition, the PBC actively, but *irregularly,* uses the RRR to adjust the loan capacity of commercial banks.[9]

Non-market-based instruments, especially the window guidance policy, play a crucial role in the banking credit channel of the monetary policy. As detailed in Chen and Zha (2018), the window guidance policy is intensively and effectively used to ensure the growth of bank loans to be in line with the growth rate of M2 supply. The guidance involves the growth rate of bank loans and how the bank credits should be allocated across sectors. This non-market, non-price instrument is quite effective, especially for the SBs, for two reasons. One is that senior personnel in the SBs are appointed by the central government. Following the window guidance benefits their political career path. The other is that violating the guidance could incur fines imposed by the PBC or the China Banking Regulatory Commission (CBRC).[10]

Overall, the Chinese monetary policy is used as a policy tool to accommodate the short-run macroeconomic fluctuations. The PBC adjusts M2 growth mainly through the OMOs on a quarterly basis to influence the bank credits with the help of the window guidance policy. The institutional features of the monetary policy discussed above suggests that to properly evaluate the impact of Chinese monetary policy on the aggregate economy, especially during the stimulus period, one needs to seriously consider the quantity-based nature of monetary policy. This motivates us to deviate from the conventional Taylor rule approach by developing the OMO rule.

2.2 Stimulus policy in 2009-2010

In November 2008, the Chinese government announced a massive four trillion RMB fiscal plan in response to the plummet in GDP growth. As to be documented below, the most distinguishing features of this stimulus plan are twofold. *First,* the stimulus plan

[9] Chen, Ren and Zha (2018) point out the irregular nature of the RRR. They also document that the RRR remains almost unchanged in 2009–2010 and 2012Q2–2014Q4.

[10] Another non-market-based instrument is the regulation on deposit rate and lending rate. However, in the late 1990s, the PBC began interest rate deregulation. From 1998 to 2004, the upper bound for the retail lending rate was gradually removed. In late 2004, both the upper bound for the retail lending rate and the lower bound for the deposit rate were completely eliminated, which left window guidance as the main administrative tool to adjust monetary policy during the stimulus period.

is essentially a credit expansion. *Second*, the credit injections are *not evenly* distributed in the corporate sector: SOEs receive much credit, while PEs receive little. Moreover, regarding monetary instruments, the massive stimulus in 2009–2010 was mainly implemented through OMOs in the form of central bank bills between the PBC and the SBs. As a result, the SBs took up most of the credit injections during the stimulus period.

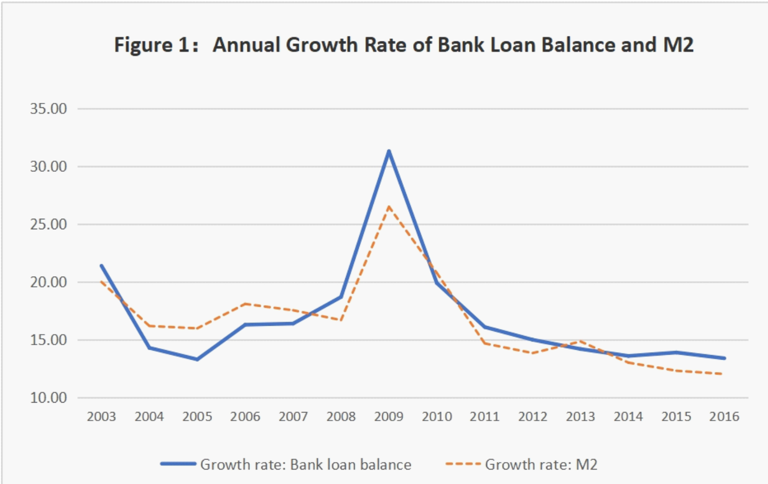
2.2.1 Key features of the stimulus policy

China's fiscal expansion is by nature a monetary and credit expansion even though the stimulus policy is largely carried out by local governments in the form of infrastructure projects. Due to the 1994 budget law, local governments cannot run budget deficits and cannot borrow themselves. To circumvent this restriction and to facilitate the stimulus package, a variety of official documents were released by the central government. The main purpose is to allow the local government to use bank loans to fund projects via the off-balance-sheet Local Government Financial Vehicles (hereafter LGFVs) (see Chen, He and Chun, 2017; Bai, Hsieh and Song, 2016). Indeed, the fiscal expansion is accompanied by a fast growth in the money supply, total social financing, and new bank loans extended by domestic commercial banks. As shown in Figure 1, from 2008 to 2009, the annual growth rate of M2 experienced a sharp rise of 10 percentage points, reaching a historically high of 26.5 percent. Likewise, the annual growth rate of bank loans jumped up by 13 percentage points over the same period. Figure 2 shows a sudden rise in new bank loans as a ratio of GDP during the stimulus period. In contrast to the average of 15 percent in normal times, this ratio rose dramatically to 26 percent in 2009, and averaged around 20 percent in 2009 and 2010, respectively.

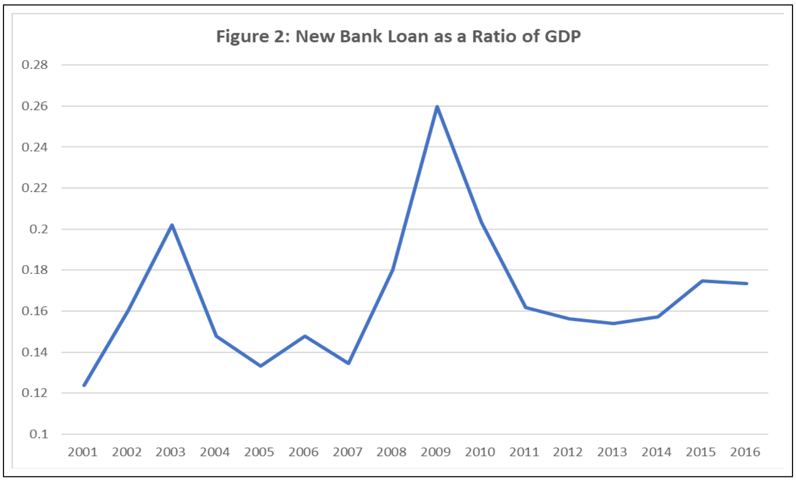
Large banks, especially the four largest national state-owned banks (so-called big-4 banks), play a dominant and important role in the rapid credit expansions.[11] Figure 3 shows that the new loans issued by the big banks (mainly the big-4 banks) as a ratio of total bank loans rises by 4 percentage points from 2008 to 2009. A similar point is also made by Deng et al. (2014). They document that in the first quarter of 2009, the big-4 banks experienced an increase in the growth rate of total loan balances by 17.49 percent (2.31 trillion RMB), substantially higher than the total increase of 1.8 trillion RMB in the entire year of 2008. In 2009, the growth rate of the total loan balances reached a historic high of about 31.03 percent (RMB 4.1 trillion), which was over twice the rate of 15.78 percent for the full year of 2008. Of note is that although the percentage rise in the total loan balance by other banks is similar to the one for the big-4 banks, the absolute

[11] The big-4 banks are Industrial and Commercial Bank of China, Bank of China, Construction Bank of China, and Agriculture Bank of China. They are state-owned commercial banks. Although corporatized and subsequentially listed, they all have a long history of state control, with the Ministry of Finance and Central Huijin Investment Ltd being the major shareholders. The big-4 banks alone account for 48.47 percent of total bank assets by the end of 2009.

amount is much smaller.



Note: The data on annual growth rates of M2 and bank loan balances come from series M0001385 and M5522882 in Wind. Both data are released by the People's Bank of China.[12]



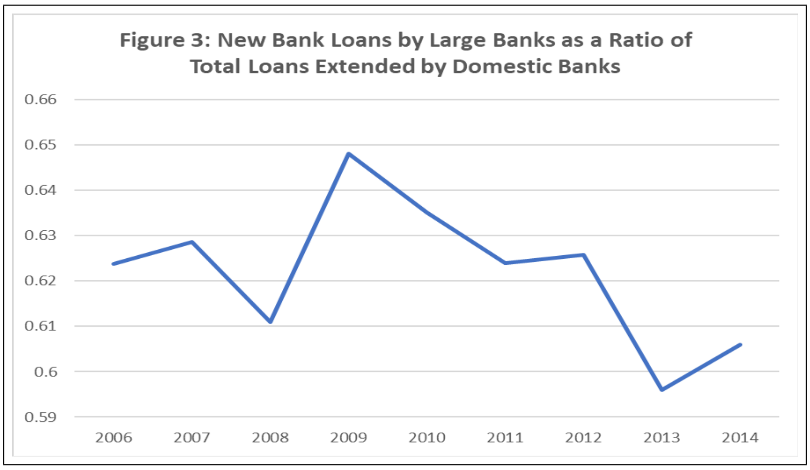
Note: The data on quarterly new bank loans and GDP come from series M0048255 and M5567876 in Wind. The time series of the new bank loan as a ratio of GDP at yearly frequency is calculated by using the quarterly data and is seasonally adjusted.

As mentioned above, the credit injections are not evenly spread in the corporate sector, with SOEs receiving the bulk of the credit.[13] For instance, Chen et al. (2016)

[12] Wind Information is the market leader in China's financial information services industry. The Wind financial database provides the most comprehensive and powerful tool for financial professionals who need the most complete information on various respects of the Chinese economy. This database is widely used in the academic research on Chinese economy. Please see more detail on Wind by visiting its official website: https://www.wind.com.cn/en/.

[13] Notably, the substantial, though uneven, credit allocation is not driven by lack of demand for bank loans by the PEs.

and Bai, Hsieh and Song (2016) argue that most new loans issued by banks, especially the big-4 banks, go to the SOEs. Focusing on LGFVs, a special form of SOEs, Chen, He, and Chun (2017) document that the LGFVs *alone* take on about 40 percent of the extra 4.7 trillion RMB bank loans (1.8 trillion RMB) during credit expansions. Similarly, Bai, Hsieh and Song (2016) find that about 90 percent of the newly increased debts of the local governments is in the form of bank loans (borrowed by the LGFVs). Based on firm-level corporate data, Cong et al. (2018) estimate the reactions of different firms to credit shocks. Their results show that the firms with a larger exposure to bank credit shocks are typically SOE firms. In particular, SOEs experience a 10 times larger increase in long-term bank loans as opposed to PEs in response to a one standard deviation increase in bank loans.



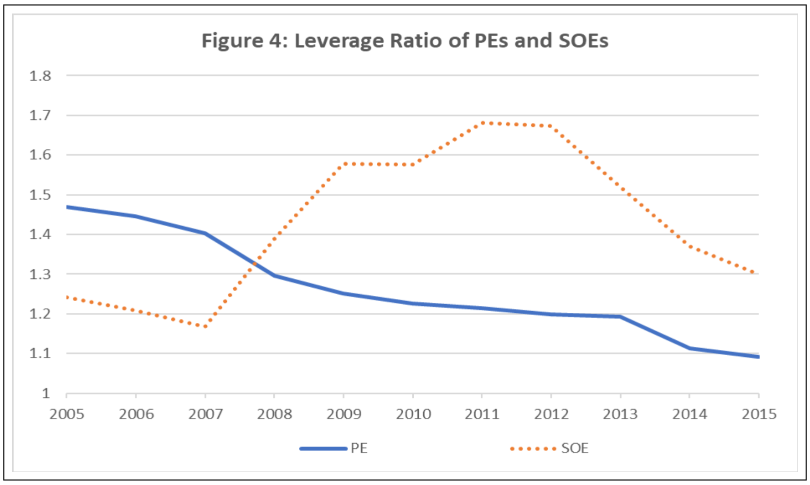
Note: The data on bank loans for 7 big banks, and 17 medium and small banks come from series M0000151 and M0000152 in Wind.[14]

As a mirror image, the massive and uneven credit injections influence China's non-financial corporate debts at both the aggregate level and sector levels. Based on the data from Chinese Academy of Social Sciences (CASS), the total non-financial corporate debt to GDP ratio experiences a rise of nearly 25 percent from 2010 to 2011, reaching a record high of 125 percent in 2011.[15] Some recent studies, based on different datasets, document even higher increase in the debt in the corporate sector, such as 145 percent in 2014 (Chivakul and Lam, 2015). At the sector level, the corporate debt displays different

[14] The big banks refer to the big-4 banks as well as Communication Bank, China Development Bank, and Postal Saving Bank of China. The medium banks include Agriculture Development Bank of China, the Export-Import Bank of China, China CITIC (China International Trust and Investment Corporation) Bank, China Everbright Bank, Huaxia Bank, China Merchants Bank, Industrial Bank, Guangdong Development Bank, Shanghai Pudong Development Bank, Evergrowing Bank, China Minsheng Bank, Bank of Beijing, Bank of Shanghai, and Pingan Bank. The small banks include Hengfeng Bank, China Zheshang Bank and China Bohai Bank.

[15] Using the definition of leverage (measured as liability to equity ratio), one sees the same increasing pattern for the corporate debts at the aggregate level.

patterns across the SOEs and PEs. Focusing on the industrial firms with annual sales revenues up to RMB 20 millions, Figure 4 shows that leverage ratios, measured as the total liability to total equity ratio, have been falling prior to 2007 for both types of firms. However, the decreasing trend started to reverse for the SOEs in 2007 and continued to rise in the subsequent years, with the leverage ratio increasing by 34.9 percent over the period of 2007 to 2010. In sharp contrast, the decreasing trend remains for its counterpart for the PEs, falling by another 12.66 percent over the same period. Similar evidence is presented in several recent papers.[16]



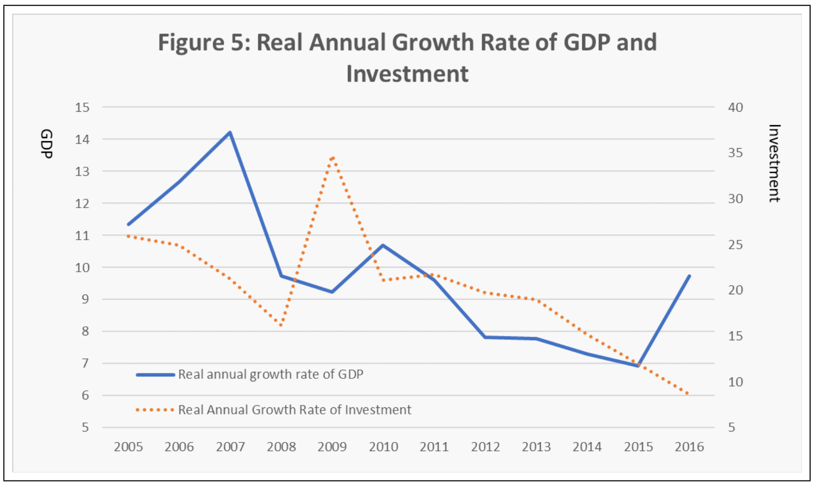
Note: Leverage is measured as a ratio of liability to equity across the firm ownership group. Data on liability of PEs and SOEs are from series M5487752 and M5487738in Wind; and data on common equity for PEs and SOEs are from series M5487347 and M5487861 in Wind. All these data are released by the National Bureau of Statistics of the People's Republic of China.

2.2.2 Impacts of stimulus policy on GDP

The stimulus plan, triggered by the plummet of GDP in 2008Q4, immediately translates into a quick recovery in GDP growth in 2010 as shown in Figure 5 (left axis). Indeed, the real GDP growth rate increases sharply to 10.70 percent in 2010. However, the recovery in GDP growth proves to be short-lived and continued to fall starting in 2010. Capital investment plays an important role in the short-lived recovery. Figure 5 (right axis) shows that the real growth rate of fixed asset investment reaches 34.7 percent in 2009,

[16] For example, using firm-level corporate data on *listed* Chinese firms, Chivakul and Lam (2015) find that the median leverage ratio for PEs falls from 125 percent in 2006 to 55 percent in 2013. On the contrary, its counterpart for SOEs has been largely remained at 110 percent since 2006, and even substantially increased for big SOEs. Similarly, using a different definition as total debts to total asset ratio, Deng et al.(2014) find that all non-financial central SOEs' leverage increased from 53.64 percent in 2007 to 63.23 percent in 2010. In contrast, the leverage for all industrial PEs decreased slightly over the sample period.

over twice the size in 2008, and contributes to about 92 percent (a historic peak) of the China's growth in 2009.



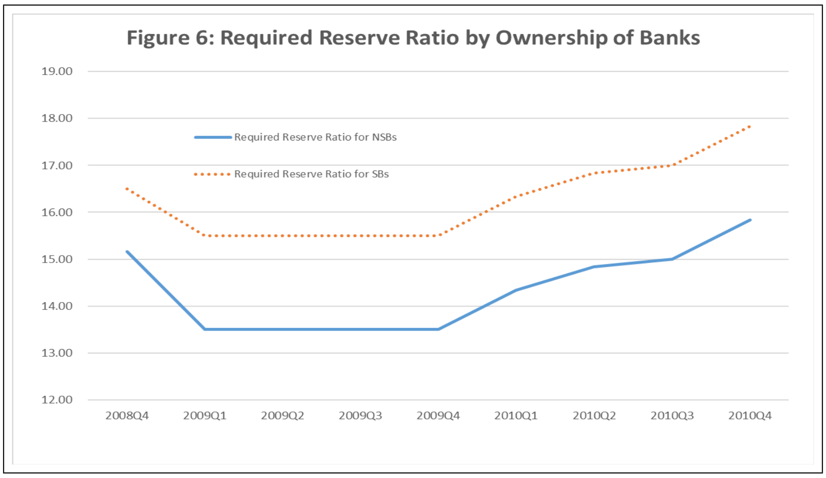
Note: The data on annual growth rate for real GDP and fixed capital investment come from series M0039354 and M5448038 in Wind, which are seasonally adjusted.

2.2.3 Implementation of monetary policy in 2009-2010

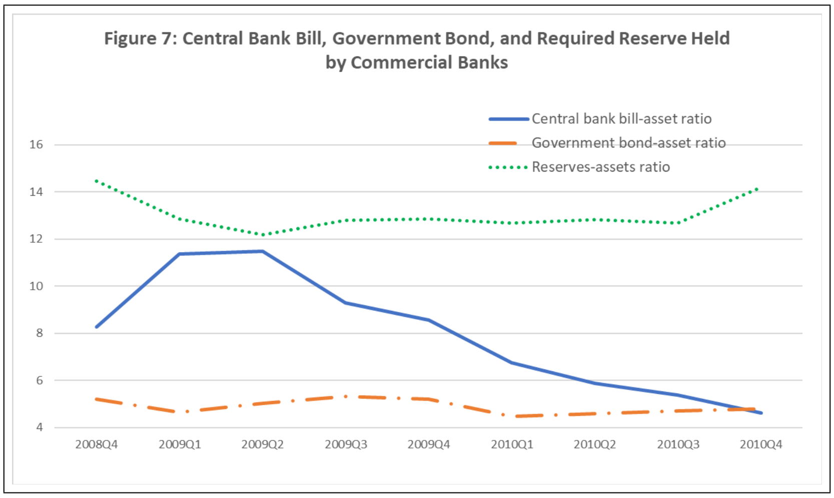
During the monetary expansion from 2008Q4 to 2009Q4, the reserve requirement remains unchanged, as shown in Figure 6. In contrast, the OMOs are used as a major tool to implement the massive monetary expansion. Particularly, the PBC bought central bank bills from commercial banks, especially from the SBs. Figure 7 plots the holdings of central bank bills, government bonds, and required reserves as a share of the total assets by commercial banks as a whole from 2008Q4 to 2010Q4.[17] Figure 7 clearly shows that over this period the respective share of government bonds and required reserves nearly stayed put, while the share of central bank bills experienced a significant decline, plummeting from a peak of 11.4 percent in 2009Q1 to 4.6 percent in 2010Q4. Figure 8 compares the central bank bill to asset ratio between the SBs and the NSBs.[18] Figure 8 shows that the central bank bills as a share of total assets declines more pronouncedly compared to the NSBs. The SBs fall by around 8 percentage points (from 14.5% to 6.5%), while the NSBs decline by about 3 percentage points (from 4.1% to 1.2%). Chen, Ren and Zha (2018) make a similar point in their work, providing empirical evidence that their estimated series of exogenous M2 growth is uncorrelated with changes in the reserve requirement, reflecting only the outcome of the OMOs.

[17]Commercial banks are the sum of 5 SBs and 14 NSBs, to be defined below.

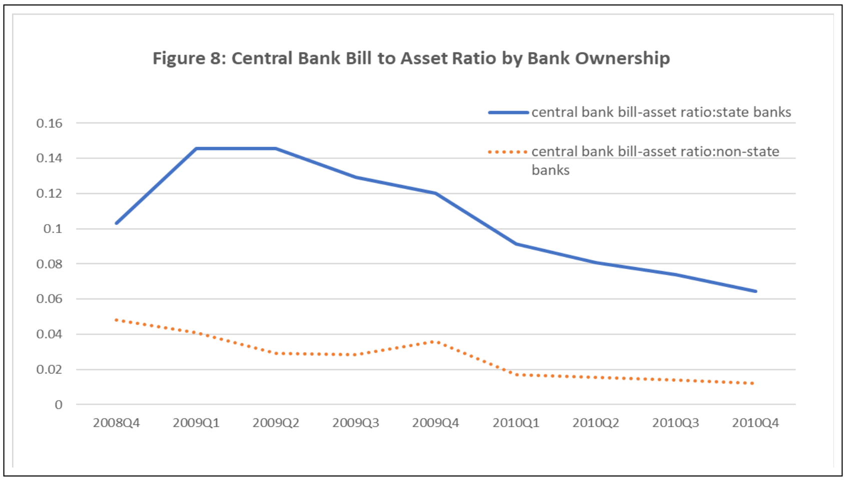
[18]SBs contain the big-4 banks and Bank of Communications. NSBs contain fourteen medium banks as explained in Footnote 14. These banks accounted for over 70 percent of the total bank assets by the end of 2009, and serve as a reasonable representative of the banking sector in China (see Deng, Morck and Wu, 2015).



Note: The data on required reserve ratio by ownership of banks are from Wind and are released by the People's Bank of China.



Note: The data on central bank bills, government bonds, and reserve requirements are released by the People's Bank of China.



Note: The data on central bank bills by ownership of banks are released by the People's Bank of China.

3 The model

In this section, we describe the model economy. Consider a discrete time, infinite horizon economy, populated by intermediate and final goods firms, producers of capital goods, banks, households, a monetary authority and a government. The final output is produced by using inputs from both SOEs and PEs. Both firms need to borrow from banks. The banking sector is also segmented into SBs and NSBs. The SBs only make loans to the SOEs and the NSBs only lend to the PEs. The monetary authority and government implement monetary and fiscal policies, respectively. The optimization problems and the market clearing conditions for these agents are described in the sections below.

3.1 Households

Households are infinitely lived with the measure being one. A representative household maximizes the following expected life-time utility

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\varepsilon_t^c \log(c_t - bc_{t-1}) - \psi \frac{h_t^{1+\eta}}{1+\eta} \right), \tag{1}$$

where c_t denotes the consumption of non-durable goods, and h_t is hours worked. We further assume

$$h_t = \left[\eta_s h_{s,t}^{\frac{1+\zeta}{\zeta}} + \eta_p h_{p,t}^{\frac{1+\zeta}{\zeta}} \right]^{\frac{\zeta}{1+\zeta}}. \tag{2}$$

That is, the household supplies specialized labour services to both SOE sector and PE sector, which are indexed by s and p, respectively. The hours worked in the two sectors are $h_{s,t}$ and $h_{p,t}$. We assume that there is a consumption demand shock ε_t^c, which obeys

$$\log \varepsilon_t^c = \rho^c \log \varepsilon_{t-1}^c + \zeta_t^c, \text{ where } \zeta_t^c \sim i.i.d\ N(0, \sigma_{\varepsilon^c}^2).$$

The household faces the following budget constraint

$$P_t c_t + D_t \leq W_{s,t} h_{s,t} + W_{p,t} h_{p,t} + R_{t-1} D_{t-1} - T_t + P_t \Pi_t, \tag{3}$$

where P_t is the price of the consumption good, and $W_{s,t}$ and $W_{p,t}$ are the nominal wage rates for the SOE and PE sectors, respectively. Households can have deposits at both SB banks and NSB banks, and both banks pay the same gross nominal return R_{t-1} from $t-1$ to t. The household pays tax T_t, and receives profits Π_t, which includes the profits from retailers, and the assets received from exiting bankers, minus the transfer to the newly entered bankers.[19]

Define $w_{s,t} = \frac{W_{s,t}}{P_t}$, $w_{p,t} = \frac{W_{p,t}}{P_t}$, $d_t = \frac{D_t}{P_t}$, and $t = \frac{T_t}{P_t}$, and the budget constraint in real

[19] The details regarding the transfers between banks and households are described in Section 3.2.2.

terms is:

$$c_t + d_t \leq w_{s,t} h_{s,t} + w_{p,t} h_{p,t} + R_{t-1} \frac{d_{t-1}}{\pi_t} - t_t + \Pi_t. \tag{4}$$

The household maximizes the life-time utility (1) subject to the budget constraint (4) by choosing c_t, d_t, $h_{s,t}$ and $h_{p,t}$. Denote λ_t as the Lagrangian multiplier associated with Equation (4), the first-order conditions are:

c_t :

$$\varepsilon_t^c \frac{1}{c_t - bc_{t-1}} - \beta b E \varepsilon_{t+1}^c \frac{1}{c_{t+1} - bc_t} - \lambda_t = 0, \tag{5}$$

d_t :

$$\lambda_t = E_t \beta R_t \frac{\lambda_{t+1}}{\pi_{t+1}}, \tag{6}$$

$h_{s,t}$:

$$\psi h_t^{\eta} \left[\eta_s h_{s,t}^{\frac{1+\zeta}{\zeta}} + \eta_p h_{p,t}^{\frac{1+\zeta}{\zeta}} \right]^{\frac{-1}{1+\zeta}} \eta_s h_{s,t}^{\frac{1}{\zeta}} - \lambda_t w_{s,t} = 0, \tag{7}$$

$h_{p,t}$:

$$\psi h_t^{\eta} \left[\eta_s h_{s,t}^{\frac{1+\zeta}{\zeta}} + \eta_p h_{p,t}^{\frac{1+\zeta}{\zeta}} \right]^{\frac{-1}{1+\zeta}} \eta_p h_{p,t}^{\frac{1}{\zeta}} - \lambda_t w_{p,t} = 0, \tag{8}$$

where $h_t = \left[\eta_s h_{s,t}^{\frac{1+\zeta}{\zeta}} + \eta_p h_{p,t}^{\frac{1+\zeta}{\zeta}} \right]^{\frac{\zeta}{1+\zeta}}$.

3.2 Banks

The banking sector is built upon Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) while augmented with key features of the Chinese banking sector. In Gertler and Karadi (2011) and Gertler and Kiyotaki (2010), the banking sector is micro-founded and the balance sheet position of the banking sector directly affects lending rates, which influence the real economy. These properties, especially the latter, help us highlight the credit channel of the Chinese monetary policy as documented in Section 2. As shown below, balance sheets of the banks are the key linkage between monetary policy and the real economy in our model. To capture the key differences between SBs and NSBs, we assume that the banking sector is segmented: the SBs only make loans to SOEs and the NSBs only lend to PEs. We further assume that compared to the NSBs, the SBs are subject to stricter banking regulations. That is, the SBs need to keep a relatively larger fraction of asset as reserves instead of loans and they are perceived as less risky.

3.2.1 Banks' balance sheet and lending constraint

As we have described in Section 2, the PBC mainly relies the bank lending channel to achieve the M2 growth target, and the main tool to influence the loanable funds of SBs and NSBs is OMOs. To model the PBC's influence, we assume that bank j in sector i is subject to a lending constraint

$$l_{j,i,t} \leq \chi_t^i a_{j,i,t},\ i \in \{sb, nsb\}, \tag{9}$$

where $l_{j,i,t}$ is the amount of loans that a bank j in sector i can make, and $a_{j,i,t}$ is the total assets for a bank j in sector i. The parameter χ_t^i, the fraction of the assets that can be lent out as loans, is a policy parameter set by the PBC. We consider Equation (9) as a reduced-form way to capture the effect of OMOs on loans. When the PBC conducts OMOs, it effectively changes χ_t^i. For example, when the PBC purchases central bank bills from the banking sector i, it effectively increases the loanable funds. That is, selling central bank bills to the PBC increases χ_t^i for banking sector i. χ_t^i is assumed to be sector-specific to capture that the PBC manages SBs and NSBs differently. We assume that the PBC adjusts χ_t^i based on inflation and GDP growth (details regarding the adjustment are described in Section 3.4).

Details of the balance sheet of bank j in banking sector i are as follows. In the beginning of period t, the net worth for bank j is $n_{j,i,t}$. The bank lends $l_{j,i,t}$ to the intermediate goods producers by using net worth $n_{j,i,t}$ and deposits $d_{j,i,t}$. The sum of the deposits in each banking sector equals the total deposits from households,

$$\sum d_{j,sb,t} + \sum d_{j,nsb,t} = d_t.$$

The flow of funds equation for each bank is

$$a_{j,i,t} = d_{j,i,t} + n_{j,i,t}. \tag{10}$$

The total assets thus consist of

$$a_{j,i,t} = l_{j,i,t} + rr_{j,i,t}, \tag{11}$$

where $rr_{j,i,t}$ refers to the required reserves and other non-loanable assets, including government bonds and central bank bills. We assume that the nominal return on $rr_{j,i,t}$ is R_t, the deposit rate. The average nominal return of the assets, $R_{i,t}^a$, thus is

$$R_{i,t}^a = R_{i,t}^l \chi_t^i + R_t(1 - \chi_t^i), \tag{12}$$

where $R_{i,t}^l$ is the nominal return on loans.

At the end of period t, the bank's net worth $n_{j,i,t+1}$ is the gross payoff from the assets that the bank funded at the beginning of the period, minus borrowing costs. In real terms, it is

$$n_{j,i,t+1} = \frac{R^a_{i,t}}{\pi_{t+1}} a_{j,i,t} - \frac{R_{i,t}}{\pi_{t+1}} d_{j,i,t},$$

which can be further expressed as

$$n_{j,i,t+1} = (\frac{R^a_{i,t}}{\pi_{t+1}} - \frac{R_{i,t}}{\pi_{t+1}}) a_{j,i,t} + \frac{R_{i,t}}{\pi_{t+1}} n_{j,i,t} \tag{13}$$

Denote $s_{i,t}$ as the spread between the lending rate $R^a_{i,t}$ and the borrowing rate $R_{i,t}$. The existence of the lending spread is because the banks face a limitation on raising deposits from households. If there were no such limitation, the spread would disappear eventually. The increase in deposits will require a rise in the deposit rate and the rise in banks' assets will generally lead to a decline in the rate of return on these assets.

3.2.2 Financial frictions in the banking sector

To motivate the banks' limited ability to raise deposits, we follow Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) to introduce a moral hazard problem. At the end of each period, a bank in sector i can choose to divert a fraction of κ_i of assets for personal use. The cost is that the bank can be forced into bankruptcy at the beginning of the subsequent period. In this environment, for households to be willing to lend to the bank, the following incentive constraint must be satisfied:

$$V_{j,i,t} \geq \varepsilon^\kappa_t \kappa_i a_{j,i,t}. \tag{14}$$

ε^κ_t is a shock to the fraction of assets that can be diverted, which can be thought of as a disturbance that affects the perceived riskiness of the banking sector. It follows

$$\log \varepsilon^\kappa_t = \rho^\kappa \log \varepsilon^\kappa_{t-1} + \zeta^\kappa_t,\ \zeta^\kappa_t \sim i.i.d\ N(0, \sigma^2_{\varepsilon^\kappa}).$$

Equation (14) states that the present value of payout from operating the bank, $V_{j,i,t}$, must exceed the gain of diverting assets, $\varepsilon^\kappa_t \kappa_i a_{j,i,t}$. There is a threshold level of deposits such that if deposits received by the bank are more than the threshold, the bank would have the incentive to default. The households would not expand their deposits beyond the threshold. As a result, there is an interest rate spread between the lending and borrowing rates. To capture the fact that perceived riskiness for the SBs is lower than the NSBs, we assume that $\kappa_{sb} < \kappa_{nsb}$.

Given the financial frictions, banks have the incentive to accumulate retained earnings in order to eventually only use internal funds. To limit this possibility, we assume that each bank has a finite lifetime. In each period, the banks are subject to an $i.i.d$ probability σ^i of surviving, and a probability of $1-\sigma^i$ of exiting. The banks pay dividends only when they exit. Define $\Lambda_{t,t+1} = \lambda_{t+1}/\lambda_t$.[20] Bank j's objective is to maximize the expected present value of future dividends,

$$V_{j,i,t} = E_t \sum_{s=1}^{\infty} [(\beta)^s \Lambda_{t,t+s}(1-\sigma^i)(\sigma^i)^{s-1} n_{j,i,t+s}],$$

which can be expressed recursively as

$$V_{j,i,t} = E_t[\beta \Lambda_{t,t+1}(1-\sigma^i) n_{j,i,t+1} + \beta \Lambda_{t,t+1} \sigma^i V_{j,i,t+1}]. \tag{15}$$

The problem of bank j in sector i thus is as follows. The bank maximizes the expected present value of future dividends (15) by choosing $a_{j,i,t}$, subject to the flow of funds constraint (10), the total assets equation (11), the average nominal return on assets equation (12), the law of motion for net worth (13) and the incentive constraint (14). $V_{j,i,t}$ can be further expressed as a linear function as follows,

$$V_{j,i,t} = \mu_{i,t} a_{j,i,t} + \upsilon_{i,t} n_{j,i,t}, \tag{16}$$

with

$$\mu_{i,t} = \beta E_t[(1-\sigma^i)\Lambda_{t,t+1}(\frac{R^a_{i,t}}{\pi_{t+1}} - \frac{R_t}{\pi_{t+1}}) + \sigma^i \Lambda_{t,t+1} x_{i,t} \mu_{i,t+1}], \tag{17}$$

and

$$\upsilon_{i,t} = E[(1-\sigma^i) + \beta \sigma^i \Lambda_{t,t+1} z_{i,t+1} \upsilon_{i,t}]. \tag{18}$$

$\mu_{i,t}$ is the marginal gain of expanding assets by one unit, and $\upsilon_{i,t}$ is the marginal gain of having one more unit of net worth. Moreover, $x_{i,t} = \frac{a_{j,i,t+1}}{a_{j,i,t}}$, and $z_{i,t+1} = \frac{n_{j,i,t+1}}{n_{j,i,t}}$.[21] Using Equations (17) and (18), the incentive constraint (14) can be written as

$$\varepsilon^\kappa_t \kappa_i a_{j,i,t} \leq \mu_{i,t} a_{j,i,t} + \upsilon_{i,t} n_{j,i,t}. \tag{19}$$

When

$$0 < \mu_{i,t} < \varepsilon^\kappa_t \kappa_i, \tag{20}$$

that is, the excess marginal value from continuing to manage assets, $\mu_{i,t}$, is positive but less than the marginal benefit from diverting funds, the incentive constraint is binding:

$$\varepsilon^\kappa_t \kappa_i a_{j,i,t} = \mu_{i,t} a_{j,i,t} + \upsilon_{i,t} n_{j,i,t}. \tag{21}$$

[20] Since households own the banks, we assume that the banks discount the future as the same rate as the households. The calculation of $\Lambda_{t,t+1}$ is based on the households' marginal utility.

[21] $x_{i,t}$ and $z_{i,t+1}$ do not depend on bank-specific factors. See Gertler and Karadi (2011) for details.

Let $\phi_{i,t}$ denote the maximum asset-to-net worth ratio (leverage), $\frac{a_{j,i,t}}{n_{j,i,t}}$, and we have

$$\phi_{i,t} = \frac{\upsilon_{i,t}}{\varepsilon_t^{\kappa}\kappa_i - \mu_{i,t}}. \tag{22}$$

Equation (22) shows that for each banking sector, the leverage is endogenously determined. Furthermore, $\phi_{i,t}$ does not depends on bank-specific factors. A higher $\varepsilon_t^{\kappa}\kappa_i$ reduces leverage. Since $\kappa_{sb} < \kappa_{nsb}$, the lending ability of the NSB sector is reduced more when a negative banking shock ε_t^{κ} hits the economy.

Let $A_{i,t} = \int a_{j,i,t+1}dj$ be the total assets across banks in sector i. Households receive the assets of the exiting banks, $(1-\sigma^i)A_{i,t}$, at the end of period t, and they transfer a fraction $\omega/(1-\sigma^i)$ of the receiving funds to the newly entered bankers in the beginning of the next period. Thus, the total net worth in sector i, $N_{i,t+1} = \int n_{j,i,t+1}dj$, is the sum of the net worth of the existing banks and new banks.

$$N_{i,t+1} = \sigma^i[(\frac{R_{i,t}^a}{\pi_{t+1}} - \frac{R_{i,t}}{\pi_{t+1}})\phi_{i,t} + \frac{R_{i,t}}{\pi_{t+1}}]N_{i,t} + \omega A_{i,t}. \tag{23}$$

3.3 Goods producers

3.3.1 Intermediate goods sector

Intermediate goods producers carry out wholesale production and sell goods as inputs to retailers. To produce, firms use the following constant-returns-to scale technology

$$y_{i,t} = z_{i,t}k_{i,t-1}^{\alpha^i}h_{i,t}^{1-\alpha^i}, i \in \{s,p\} \tag{24}$$

where s represents the SOE sector, and p represents the PE sector. $z_{i,t}$ is a shock to technology, which follows

$$\log z_{i,t} = (1-\rho^z)\log z_{i,ss} + \rho^z \log z_{i,t-1} + \zeta_t^z, \zeta_t^z \sim i.i.d.N(0,\sigma_z^2).$$

We assume that average productivity is higher for PEs: $z_{p,ss} > z_{s,ss}$.

The intermediate firms need to purchase capital from capital producers at the end of period $t-1$. To finance the purchase of capital goods, $k_{i,t-1}$, they borrow nominal loans from banks at the rate $R_{i,t-1}^l$. In period t, the firms produce wholesale goods using capital $k_{i,t-1}$ and labour $h_{i,t}$. At the end of period t, the firms sell the undepreciated capital $(1-\delta_i)k_{i,t-1}$ at price $Q_{i,t}$, pay labour costs $W_{i,t}h_{i,t}$ and pay back loans $L_{i,t-1}R_{i,t-1}^l$ to the banks. The firms also need to decide how much capital $k_{i,t}$ to acquire for the next period, and how many new loans $L_{i,t}$ they need for capital purchases. Denote $P_{i,t}^w$ as the wholesale goods price. The firms' budget constraint in nominal terms is

$$P_{i,t}^w y_{i,t} + L_{i,t} + (1-\delta_i)Q_{i,t}k_{i,t-1} = W_{i,t}h_{i,t} + Q_{i,t}k_{i,t} + P_t c_{i,t}^f + L_{i,t-1}R_{i,t-1}^l,$$

where $c^f_{i,t}$ is the consumption of wholesale goods producers. Define $p^w_{i,t} = \frac{P^w_{i,t}}{P_t}$, $l_{i,t} = \frac{L_{i,t}}{P_t}$, and $q_{i,t} = \frac{Q_{i,t}}{P_t}$. The firms' budget constraint in real terms is

$$p^w_{i,t} y_{i,t} + l_{i,t} + (1 - \delta_i) q_{i,t} k_{i,t-1} = w_{i,t} h_{i,t} + q_{i,t} k_{i,t} + c^f_{i,t} + \frac{l_{i,t-1} R^l_{i,t-1}}{\pi_t}, \tag{25}$$

Following Jermann and Quadrini (2012), we assume that when borrowing, these producers face a collateral constraint:

$$l_{i,t} \leq \frac{\theta_i E_t q_{i,t+1} (1 - \delta_i) k_{i,t}}{R^l_{i,t} / \pi_{t+1}}, \tag{26}$$

where θ_i is the loan to value (LTV) ratio, the fraction of the capital good value that can be used as a collateral. We assume that $\theta_{soe} > \theta_{pe}$, which is consistent with the empirical evidence that PEs typically face a stricter borrowing standard.

Each period, wholesale good producers choose $k_{i,t}$, $l_{i,t}$ and $h_{i,t}$ to maximize their lifetime consumption,

$$E_0 \sum_{t=0}^{\infty} (\beta^f)^t (\ln c^f_{i,t}), \tag{27}$$

subject to the collateral constraint (26) and budget constraint (25). β^f is the discount factor for firms. To motivate that firms have an incentive to borrow, we assume that $\beta^f < \beta$. For simplicity, we assume that the SOEs and PEs have the same discount factor.

3.3.2 Capital producers

Capital producers operate in a competitive market and produce capital for both SOEs and PEs. Capital producers purchase the final sector goods from retailers and produce efficient investment goods. Following Christiano, Eichenbaum and Evans (2005), we assume that capital producers face investment adjustment costs $S(\frac{i_{i,t}}{i_{i,t-1}})$, such that in the steady state $S = S' = 0$ and $S'' = \tau_i > 0$, where $\tau_i > 0$ is an investment adjustment cost parameter. The production function of capital goods is

$$f(.) = i_{i,t} - S(\frac{i_{i,t}}{i_{i,t-1}}) i_{i,t}.$$

We assume that the capital producers have the same discount factor as households, and they solve for $i_{i,t}$ to maximize

$$\max E_t \sum_{s=0} \beta^s \Lambda_{t,t+1} \{ q_{i,t} [1 - S(\frac{i_{i,t}}{i_{i,t-1}})] i_{i,t} - i_{i,t} \}.$$

Let functional form for $S(\frac{i_{i,t}}{i_{t-1}})$ be

$$S(i_{i,t}, i_{i,t-1}) = 0.5\tau_i(\frac{i_{i,t}}{i_{i,t-1}} - 1)^2.$$

The aggregate stock of capital evolves as follows:

$$k_{i,t} = (1 - \delta_i)k_{i,t-1} + i_{i,t}. \tag{28}$$

3.3.3 Retailers

In each production sector, there are continuum of retailers of mass 1, indexed by j. They buy intermediate goods from wholesale goods producers at $P^w_{i,t}$ in a competitive market and differentiate the goods at no costs into final goods $y_{i,t}(j)$, selling $y_{i,t}(j)$ at the price $P_{i,t}(j)$.

The sectoral final goods $y_{i,t}$ is the composite of individual variety,

$$y_{i,t} = \left[\int_0^1 y_{i,t}(j)^{\frac{\vartheta-1}{\vartheta}} dj\right]^{\frac{\vartheta}{\vartheta-1}},$$

where ϑ is the elasticity of substitution. The price index that minimizes the final producers' cost function is

$$P_{i,t} = \left[\int_0^1 P_{i,t}(j)^{1-\vartheta} dj\right]^{\frac{1}{1-\vartheta}}.$$

The demand function faced by each type of retailer is given by

$$y_{i,t}(j) = \left(\frac{P_{i,t}(j)}{P_{i,t}}\right)^{-\vartheta} y_{i,t}. \tag{29}$$

Following Calvo (1983), in each period, only a fraction $1 - \nu^i$ of retailers reset their prices, while the remaining retailers keep their prices unchanged. The retailer j chooses $P_{i,t}(j)$ to maximize its expected total profits over the periods during which its prices remain fixed:

$$E_t\Sigma_{s=0}^{\infty}\nu^{i,s}\Delta_{i,t+s}\left[P_{i,t}(j)y_{i,t+s}(j) - P^w_{i,t+s}y_{i,t+s}(i)\right],$$

where $\Delta_{t,t+s} = \beta^s\Lambda_{t,t+s}$ is the stochastic discount factor for nominal payoffs. Note that the retailers use the same discount factor as households. Let $\tilde{P}_{i,t}$ be the optimal price chosen by all firms adjusting at time t. The aggregate price for final goods at the sectorial level evolves according to:

$$P_{i,t} = [\nu^i P^{1-\vartheta}_{i,t-1} + (1 - \nu^i)(\tilde{P}_{i,t})^{1-\vartheta}]^{\frac{1}{1-\vartheta}}.$$

3.3.4 Final goods producers

A representative firm acts in a perfectly competitive market and uses goods produced by SOE and PE firms in the retail sector to produce final consumption goods, y_t, according to the following CES technology:

$$y_t = \left[(\omega_s)^{\frac{1}{\nu^f}} (y_{s,t})^{\frac{\nu^f - 1}{\nu^f}} + (\omega_p)^{\frac{1}{\nu^f}} (y_{p,t})^{\frac{\nu^f - 1}{\nu^f}} \right]^{\frac{\nu^f}{\nu^f - 1}},$$

where ω_s and ω_p denote the sectoral shares in the final goods, with $\omega_s + \omega_p = 1$, and $\nu^f > 0$ is the elasticity of substitution between sectoral goods. The demands for goods in the SOE and PE sectors are $y_{s,t} = \omega_s y_t \left(\frac{p_{s,t}}{p_t}\right)^{-\nu^f}$, and $y_{p,t} = \omega_p y_t \left(\frac{p_{p,t}}{p_t}\right)^{-\nu^f}$. The aggregate price index is

$$p_t = \left[\omega_s p_{s,t}^{1-\nu^f} + \omega_p p_{p,t}^{1-\nu^f} \right]^{\frac{1}{1-\nu^f}}.$$

3.4 Monetary authority

In the DSGE literature, monetary policy has long been modeled by an interest rate rule, which assumes that the central bank adjusts the nominal interest rate in response to changes in inflation and output. It is suitable for developed economies, such as the United States, the EU region and Canada. The interest rate rule is less useful for the Chinese economy due to its unique nature documented in Section 2. Some recent studies (Zhang, 2009; Li and Liu, 2017) adopt a money growth rule, capturing the fact that monetary policy in China is mainly quantity-based. However, the absence of the banking sector makes it difficult for these papers to study how changes in money supply transmit into the real economy through the bank credit channel.

Our paper proposes an alternative way to model Chinese monetary policy, the so called OMO rule. By Equations (9) and (11), we see that χ_t^i plays an important role in linking monetary policy and banks' capacity to make loans through OMOs. When the PBC performs OMOs, it is equivalent to adjusting χ_t^i. Specifically, the PBC's action of buying government bonds and central bank bills from banks leads to an increase in χ_t^i; while the PBC's action of selling government bonds and central bank bills to banks results in a decrease in χ_t^i. To explicitly model the OMO channel, largely observed during the stimulus era, we assume that the PBC follows a simple Taylor- type rule. Specifically, χ_t^i is assumed to respond to the deviation of its previous value χ_{t-1}^i from its steady-state value χ_{ss}^i, the deviation of the previous quarter inflation π_{t-1} from its steady-state value π_{ss}, and the deviation of the year-over-year output growth rate $y_{t-1}^g = \frac{y_{t-1}}{y_{t-5}}$ from its steady-state value y_{ss}^g. We further assume that χ_t^i responds negatively to both inflation and output growth, reflecting the idea that the money supply increases if inflation and output growth in the previous quarter is lower than the steady-state inflation and output growth rate. Lastly, to capture the fact that the PBC's OMOs affect *mostly* the SB banks, we assume that the PBC applies the rule to the SBs and NSBs differently. That is, the PBC adjusts χ_t^{sb} directly according the following rule,

$$\frac{\chi_t^{sb}}{\chi_{ss}^{sb}} = \left(\frac{\chi_{t-1}^{sb}}{\chi_{ss}^{sb}}\right)^{\rho_{omo}} \left(\left(\frac{\pi_{t-1}}{\pi_{ss}}\right)^{-\rho_{\pi,omo}} \left(\frac{y_{t-1}^g}{y_{ss}^g}\right)^{-\rho_{y,omo}}\right)^{1-\rho_{omo}} e^{\zeta_t^{omo}}, \tag{30}$$

where ζ_t^{omo} is an OMO policy shock which follows

$$\zeta_t^{omo} \sim i.i.d.\, N(0, \sigma_{omo}^2).$$

ρ_{omo}, $\rho_{y,omo}$ and $\rho_{\pi,omo}$ are policy coefficients chosen by the PBC. For NSBs, we assume that OMOs have less effects on χ_t^{nsb}. The fraction of loanable funds in the NBS is assumed to follow

$$\frac{\chi_t^{nsb}}{\chi_{ss}^{nsb}} = \left(\frac{\chi_t^{sb}}{\chi_{ss}^{sb}}\right)^{d_{omo}}, \tag{31}$$

where $d_{omo} \in [0, 1]$, and it governs the degree of the adjustments of χ_t^{nsb} in the NSBs relative to that of the SBs. To show that the SBs are subject to stricter banking regulations from the PBC and must keep a larger fraction of assets as non-loanable funds, we assume that $\chi_{ss}^{sb} < \chi_{ss}^{nsb}$.

Note that parameter d_{omo} is important in that it determines how credit injections are allocated across the SBs and NSBs. When $d_{omo} = 0$, Equation (31) suggests that χ_t^{nsb} remains at its steady state value and experiences no increase at all. When $d_{omo} = 1$, Equation (31) suggests that the NSBs respond to the credit injections in the same way as the SBs. That is, χ_t^{nsb} deviates from its steady state value by the same percentage change as χ_t^{sb} for the SBs. Lastly, when d_{omo} takes a value between 0 and 1, the percentage change in χ_t^{nsb} is lower than that for χ_t^{sb}, implying that the increase in the loan capacity of the NSBs is smaller than that for the SBs.

Given that China's monetary policy has started to transition from a quantity-based to a price-based framework in recent years, we also consider an interest rate rule: the PBC adjusts the nominal interest rate in response to its past value R_{t-1}, deviations of inflation, π_{t-1}, from its steady-state value, π_{ss}, and output growth (at annual frequency), y_{t-1}^g, from its steady-state level,

$$\frac{R_t}{R_{ss}} = \left(\frac{R_{t-1}}{R_{ss}}\right)^{\rho_r} \left(\left(\frac{\pi_{t-1}}{\pi_{ss}}\right)^{\rho_\pi} \left(\frac{y_{t-1}^g}{y_{ss}^g}\right)^{\rho_y}\right)^{1-\rho_r} e^{\zeta_t^r},$$

where ρ_m, ρ_y and ρ_π are policy coefficients chosen by the PBC. R_{ss} is the steady-state values of R_t and ζ_t^r is an interest rate shock which follows

$$\zeta_t^r \sim i.i.d.\, N(0, \sigma_r).$$

Finally, to capture the idea that the PBC mainly relies on the bank lending channel to adjust the M2 growth rate, we define the growth rate of M2 as the growth rate of total loans held by banks,

$$\frac{M2_t}{M2_{t-1}} = \frac{L_{soe,t} + L_{pe,t}}{L_{soe,t-1} + L_{pe,t-1}}.$$

3.5 Government and resource constraint

One noticeable feature in the post-crisis stimulus package is that governments were allowed to create local government financial vehicles (LGFVs) to stimulate the economy.[22] These newly created LGFVs are mainly financed by bank loans. Given that our focus in this paper is monetary policy and its transmission mechanism, we do not model LGFVs in details. Instead, we consider LGFVs as a special form of SOEs and the investments made by LGFVs are considered as SOE investments. The government's behavior and budget constraint are fairly simple: government expenditures only include government consumption, g_t, and are financed by lump sum tax, t_t,

$$g_t = t_t.$$

g_t follows an AR(1) process,

$$\log g_t = (1 - \rho_g) \log g_{ss} + \rho_g \log g_{t-1} + \zeta_t^g, \;\; \zeta_t^g \sim i.i.d.N(0, \sigma_g^2),$$

where g_{ss} is the steady-state government consumption.

Finally, the resource constraint for the model economy is:

$$c_t + c_{s,t}^f + c_{p,t}^f + g_t + i_{s,t} + i_{p,t} + 0.5\tau_p(\frac{i_{p,t}}{i_{p.t-1}} - 1)^2 + 0.5\tau_s(\frac{i_{s,t}}{i_{s.t-1}} - 1)^2 = y_t. \tag{32}$$

4 Model estimation

We estimate the model to the Chinese economy over the period 2000Q1-2014Q4. Following the common practice in the DSGE literature, most of the model parameters are calibrated to match the key features of the Chinese economy in the long run. The stochastic shocks processes and some of the behavior parameters are estimated using the Bayesian approach.

[22]For example, the Beijing Capital Group is a LGFV. It is owned by Beijing's local government. This company owns a subway and two toll high-ways.

4.1 Calibrated parameters

The model period is set to be one quarter. Table 1 lists the calibrated parameter values in our baseline model. The discount factor for households β is set to 0.9933 to match the average annual deposit rate of 1.027 over the sample period of 2009-2015 as documented in Chen et al. (2016).[23] We set the discount factor β^f for both SOEs and PEs to 0.98, which is smaller than β so that firms are borrowers in the equilibrium. Relative utility weight of labour ψ is set to 28.3 so that the aggregate labour hours equals to 1/3. We set η, the inverse of the Frisch elasticity of labor supply, to 1, which is close to the value in Chang et al. (2019). The labour supply parameters for the SOE sector η_s and the PE sector η_p are set to 0.7 and 0.3, respectively, implying that about 30 percent of the total employment is in the SOE sector and about 70 percent in the PE sector. These fractions are in line with what suggested in Song, Storesletten and Zilibotti (2011) and Brant and Zhu (2010).[24] The elasticity of substitution of the labour supply between SOE and PE ζ is set to 1.

Due to the data availability, the parameters in the production function for the SOE and PE firms are determined by using the Chinese industrial firm data set, which is widely used in the literature on the Chinese economy.[25] The data set for Chinese industrial firms, mainly containing industries such as manufacturing, construction, and mining, provides a wide variety of information on both SOE and PE firms. The output shares of the SOE and PE sectors, ω_s and ω_p, are set to be 0.35 and 0.65, respectively, which is the average output shares of these two sectors over the period from 2006 to 2011. The elasticity of substitution between the SOE and PE sectors ν^f is set to 3, the same as in Chang et al. (2019). The capital depreciation rate of the SOE sector δ^s is set to 0.05 and the PE sector δ^p is set to 0.035, which is close to the values used in Li and Liu (2017). We set the capital shares for the SOE and PE sectors α^s and α^p to be 0.6 and 0.4 respectively, reflecting that the SOE sector is more capital intensive and, thus, has a higher capital share. Note that the values of δ^s, δ^p, α^s and α^p in our baseline model are higher than the values usually used for developed economies, implying a higher investment-to-GDP ratio for the Chinese economy. The elasticity of demand for intermediate goods ϑ is set to 11, implying that the steady-state mark-up ratio is about 10 percent, which is quite close to the value used in Chang et al. (2019). The loan-to-value ratio is set to 0.7 for the SOE sector and 0.3 for the PE sector respectively, implying that 56 percent of the

[23] Our choice is close to that calculated from the data in Wind; the average annual deposit rate measured as the one-year regulated deposit rate is 1.028 by using data in Wind over the same period. Song, Storesletten and Zilibotti (2011) report a slightly lower value of 1.0175 when they focus on the period from 1998-2005.

[24] Our calculation is based on the data for the Chinese industrial firms that contain three industries: manufacturing, construction, and mining. Song, Storesletten and Zilibotti (2011), focusing only on the manufacturing sector, report a 56 percent of the employment share in PE in 2007. Brandt and Zhu (2010) document the employment share in PE at around 62 percent in 2007.

[25] The data for the PE firms are scarce in China, especially in the agriculture and service sectors.

total loans are extended to the SOE sector, while 44 percent to the PE sector, which are close to their empirical counterparts.

For financial intermediaries, the fraction of the funds that can be diverted, κ^{sb}, and the survival rate for the SBs, σ^{sb}, are set to 0.68 and 0.97, respectively, while for the NSBs, κ^{nsb} and σ^{nsb} are set to 0.70 and 0.95, respectively. Note that for the NSBs, the diversion rate is higher and survival rate is lower compared to the SBs, reflecting the fact that NSBs face higher risks. These values imply an annual spread of 266 basis points in the SOE sector over the period of 2009-2014. The spread refers to the gap between the actual average lending rate of the leading five SBs and the government bond yield.[26] The counterpart for the PE sector is 282 basis points, which is close to the annual spread of 288 basis points over the same period, the spread between the actual average lending rate of the NSBs and the government bond yield.[27] The fraction of loanable assets for SBs, χ_{ss}^{sb}, is set to 0.75, and the value for NSBs, χ_{ss}^{nsb}, is set to 0.85, reflecting that regulations for the SBs are stricter than for NSBs.

Table 2 compares the simulated results for steady-state endogenous variables and their empirical counterparts. The comparison shows that the calibrated model can reproduce the key features of the Chinese economy at both the aggregate and sector levels. For example, at the aggregate level, the model predicted that the investment to output ratio and consumption to output ratios are 0.34 and 0.50 respectively, close to their empirical counterparts 0.37 and 0.47 from 2000-2014. At the sector level, the shares of investment by SOE and PE firms predicted from the baseline model are 0.44 and 0.56, respectively, close to their empirical counterparts of 0.32 and 0.68. The model also predicts higher TFP for PE firms. The ratio of PEs' productivity to SOEs' is 1.27, which is close to its empirical counterpart of 1.42 over the period 2006-2011.[28]

For the banking sector, our model generates a loan distribution across SBs and NSBs that is close to the data. The loans from the SBs accounts for about 56% of the total loan, while the loans from NSBs are about 44% of the total loan. The model predicted lending rates also square well with the data. Regarding the asset ratio in SBs and NSBs, the model's predicted value is 1.42, lower than its empirical counterpart, 2.7.

[26] The leading five SBs refer to the Industrial and Commercial Bank of China, Bank of China, Construction Bank of China, Agriculture Bank of China and the Communication Bank. These five banks are typically state-owned and heavily influenced by the central government.

The actual lending interest rate for the state-owned banks is calculated to be 5.39 percent over the period of 2009-2014, based on the quarterly data in Wind on the weighted average of the interest rate from extending RMB loans to non-financial firms.

[27] The NSBs refer to the 14 medium banks explained in Footnote 9. The actual lending interest rate is calculated to be 5.51 percent by using the same method as that for the SBs.

[28] The TFP is measured by using Cobb-Douglas production function with labor share being 0.5 and annual data on employment, fixed assets, nominal sale revenues, and producer price index (PPI) from Wind.

Table 1: Calibrated Parameters

Household		
Discount rate for households	β	0.9933
Discount rate for firms	β^f	0.98
Relative utility weight of labour	ψ	28.3
Inverse Frisch elasticity of labour supply	η	1
Labour supply parameter for SOEs	η_s	0.7
Labour supply parameter for PEs	η_p	0.3
Elasticity of substitution of labour supply between SOEs and PEs	ζ	1
Good producers		
Share of SOE in aggregate production function	ω_s	0.35
Share of PE in aggregate production function	ω_p	0.65
Elasticity of substitution parameter between SOEs and PEs	ν^f	3
Capital share parameter, SOEs	α^s	0.6
Capital share parameter, PEs	α^p	0.4
Capital depreciation rate for SOEs	δ^s	0.05
Capital depreciation rate for PEs	δ^p	0.035
Elasticity of substitution parameter in retailers production	ϑ	11
Loan to value ratio for SOEs	$\theta_{s,t}$	0.7
Loan to value ratio for PEs	$\theta_{p,t}$	0.3
Financial intermediaries		
Fraction of assets can be diverted: SBs	κ^{sb}	0.68
Fraction of assets can be diverted: NSBs	κ^{nsb}	0.70
Fraction of loanable assets: SBs	χ^{sb}	0.75
Fraction of loanable assets: NSBs	χ^{nsb}	0.85
Survival rate of the SBs	σ^{sb}	0.97
Survival rate of the NSBs	σ^{nsb}	0.95

Table 2: Steady-State Properties: Model vs. Data

	Model	Data
Aggregate Variables		
Consumption/output	0.50	0.47
Investment/output	0.34	0.37
Government spending/output	0.16	0.16*
Firms: SOE and PE		
SOE output / total output	0.35	0.35*
PE output / total output	0.65	0.65*
SOE empl. / PE empl	0.44	0.45
SOE Inv. / total Inv	0.44	0.32
PE Inv. / total Inv	0.56	0.68
PE productivity / SOE productivity	1.27	1.42
Banks: SB and NSB		
SB loan / total loan	0.56	0.60
NSB loan/total loan	0.44	0.40
SB risk premium	266	277
NSB risk premium	282	288
SB annual loan rate	5.36%	5.39%
NSB annual loan rate	5.52%	5.51%
SB assets / NSB assets	1.42	2.7

NOTE: some of the moments are used as targets, and they are marked with an asterisk.

4.2 Data

This section describes the time series used in estimation. We estimate the following parameters: the ones governing the OMO rule and interest rate rule; the ones determining the price stickiness and capital adjustment costs, and the ones determining the persistence and standard deviations for the six exogenous shocks. Note that none of the parameters being estimated affects the model's steady-state.

We use six quarterly time series as observables: (1) GDP, (2) consumption, (3) M2, (4) government consumption, (5) the inflation rate, and (6) the nominal interest rate. The data are taken from China's Macroeconomy: Time Series Data, Federal Reserve Bank of Atlanta. The time span for the baseline estimation is 2000Q1–2014Q4 since only from 2000 has the PBC started to frequently use OMO to affect the M2 growth rate. Consumption is households consumption. Government spending refers to government consumption. Inflation is constructed by using GDP deflator. We use 1-day Repo rate as the nominal interest rate. Since the original data series for GDP, consumption, private sector investment and government spending are in nominal terms, we convert them into real terms using the GDP deflator. Real M2 is also constructed by using nominal M2 divided by the GDP deflator. For real GDP, real consumption, real government spending, and real M2, we take logs and generate the first differences of each of the series. We further remove the mean from each of the first-differenced time series.[29] For inflation and nominal interest rate, we simply remove the means from the data. Figure 9 describes the raw data used in the estimation.

4.3 Priors

The priors are displayed in Table 3. We set the priors as loose as possible and most of them are quite standard. We assume that ρ_π, the parameter governing the interest rate rule reaction to inflation, follows a gamma distribution with a mean of 1.5 and standard deviation of 0.25; ρ_y, the parameter governing the reaction to output, follows a normal distribution with a mean of 0.25 and standard deviation of 0.15; and ρ_r, the inertia parameter, follows a beta distribution with a mean of 0.8 and standard deviation of 0.15. Since there is not much guidance in the literature regarding the priors for the OMO rule, we modify the priors used for the interest rate rule and use them for the OMO rule. We assume that $\rho_{\pi,omo}$, the parameter governing the OMO rule reaction to inflation, follows a gamma distribution with of mean 1.5 and standard deviation of 0.25, the same as in the interest rate rule; Since the PBC's adjustment of M2 is heavily influenced by GDP growth, we assume a higher value for the mean of the prior distribution for $\rho_{y,omo}$, the parameter governing the OMO rule reaction to output. That is, we assume that $\rho_{y,omo}$

[29] The trend growth rate of the endogenous variables in the model is zero. Removing the means allows us to obtain the appropriate measurement equations.

follows a normal distribution with a mean of 1.5 and standard deviation of 0.15. We assume that ρ_{omo}, the inertia parameter, follows a beta distribution with a mean of 0.8 and standard deviation of 0.15. The parameter, d_{omo}, capturing that the OMO rule targets the SBs to a larger degree compared to NSBs, is our key parameter. We set d_{omo} to follow a beta distribution with a mean of 0.5 and standard deviation of 0.2.

The priors on the adjustment cost parameter for business investment τ^s and τ^p are set to follow a gamma distribution with a mean of 6 and standard deviation 1.5. For Calvo pricing parameters υ^s and υ^p, we assume that they follow a beta distribution with a mean of 0.5 and standard deviation 0.1. The standard deviations of the innovations are assumed to follow an inverse-gamma (IG) distribution with a mean of 0.001 and two degrees of freedom except for the banking sector shocks. The persistence of most of the AR(1) processes is beta distributed with a mean of 0.85 and standard deviation of 0.1 except that the persistence for the banking sector shock is set to a beta distribution with a mean of 0.5 and standard deviation of 0.1.

5 Estimation results and model mechanism

5.1 Estimation results

5.1.1 Posterior modes

The estimated modes are presented in the last column of Table 3. The estimated OMO rule parameters $\rho_{\pi,omo}, \rho_{y,omo}$ and $\rho_{r,omo}$ are $1.55, 1.53$ and 0.91, respectively, suggesting that the PBC increases the money supply in response to a decrease in price levels or output growth. This is consistent with the notion that in China, the money supply is pro-growth. The parameter d_{omo} is estimated at 0.30. This suggests that compared to SBs, the degree of the OMO influence is much smaller for NSBs: an OMO shock leading to a one percent increase in χ_t^{sb} only increases χ_t^{nsb} by 0.3 percent. The estimated interest rate policy parameters ρ_π, ρ_y and ρ_r are 1.55, -0.01 and 0.94, respectively, suggesting that there is a high degree of persistence in policy rate adjustments, and the interest rate responds little to output. The Calvo price parameters υ^s and υ^p are estimated at 0.64 and 0.66. The investment adjustment cost parameters τ^s and τ^p are estimated at 2.45 and 6.47, suggesting that it is more costly for PE firms to adjust investment. For the estimated shock processes, the size of OMO shock, $\sigma_{omo} = 0.047$, is much larger than that of the interest rate shock, $\sigma_r = 0.011$. Among all the shocks, the banking shock is the least persistent with $\rho^\kappa = 0.28$.

Table 3: Estimation Results

Coef.	Description	Density	Prior Mean	Std.	Posterior Mode
ϱ_π	Taylor rule inflation	Gamma	1.5	0.25	1.55
ϱ_y	Taylor rule output	Normal	0.25	0.15	-0.01
ϱ_r	Taylor rule smoothing	Beta	0.8	0.15	0.94
$\varrho_{\pi,omo}$	OMO rule inflation	Gamma	1.5	0.25	1.55
$\varrho_{y,omo}$	OMO rule output	Normal	1.5	0.15	1.53
ϱ_{omo}	OMO rule smoothing	Beta	0.8	0.15	0.91
d_{omo}	OMO rule difference	Beta	0.5	0.2	0.30
τ^s	Inv. adj. cost parameter, SOE	Gamma	6.00	1.50	2.45
τ^p	Inv. adj. cost parameter, PE	Gamma	6.00	1.50	6.47
υ^s	Calvo price parameter	Beta	0.5	0.10	0.64
υ^p	Calvo price parameter	Beta	0.5	0.10	0.66
ρ^z	Technology	Beta	0.80	0.10	0.90
ρ^c	Demand	Beta	0.85	0.10	0.72
ρ^κ	Banking	Beta	0.5	0.10	0.28
ρ^g	Government spending	Beta	0.85	0.10	0.86
σ_z	Technology	IG	0.1	2.00	0.011
σ_r	Interest rate	IG	0.1	2.00	0.011
σ_c	Demand	IG	0.1	2.00	0.053
σ_κ	Banking	IG	0.2	2.00	0.026
σ_g	Government spending	IG	0.1	2.00	0.029
σ_{omo}	OMO	IG	0.1	2.00	0.047
	log data density			1107.49	

5.1.2 Business cycle properties: model versus data

To see whether the model can generate reasonable business cycle properties, we compare the model predictions with the data in terms of standard deviations and correlations of the key variables.

Table 4: Business Cycle Properties: Model vs Data (in %)

	Data	Model
Output	0.55	1.68
Consumption	0.81	0.93
Investment	3.01	4.74
M2	1.51	1.99
Inflation	0.95	2.15
Interest rate	0.17	0.40
SOE inv.	3.86	7.85
PE inv.	3.14	2.74

Table 4 compares the volatilities of the key variables in the data and the implied counterparts of the model based on the posterior modes. The results show that the estimated model does a decent job in terms of matching the data, except that the standard deviations of output and SOE sector investment predicted by the model are much larger than what is seen in the data.[30] For instance, the predicted moments for aggregate consumption are quite close between the model and the data. The model also captures the fact that the investment in SOE sector is more volatile than that in the PE sector. For nominal variables, the model captures that both M2 and inflation are more volatile than the interest rate, although the model overestimates the volatilities in those variables.

Table 5: Correlations: Model vs Data

	Data	Model
Output, consumption	0.28	0.15
Output, SOE inv.	0.13	0.86
Output, PE inv.	0.36	0.91
Output, M2	0.17	0.34
Output, int. rate	-0.44	-0.25
M2, SOE inv.	0.51	0.42
M2, PE inv.	0.18	0.30

Table 5 assesses the correlations of the key variables between the data and model. The estimated model does a good job in capturing the positive correlation between con-

[30] One possible reason for the gap could lie in net exports. In the data, net exports smooth the dynamics of GDP over the business cycle. However, it is absent in the model given that the model is a closed economy. When net exports are removed from the data on GDP, the predicted second moment for GDP indeed moves closer to the data.

sumption and GDP. The model predicts a positive relationship between M2 and GDP, and a negative one between the interest rate and GDP. The features are close to what is suggested in the data. The model also shows that SOE investment has a much stronger correlation with M2 than PE investment (0.51 versus 0.18 in the data; and 0.42 versus 0.30 in the model). Consistent with the data, the model predicts a stronger positive correlation between output and investment in the PE sector (0.91) than in the SOE sector (0.86), although the magnitudes of the correlations are larger than those seen in the data.

5.1.3 Variance decomposition: importance of OMO shock

Figure 10 presents the estimated shocks. What worth mentioning is the large rise in the value of the OMO shock in the stimulus period 2008Q4 to 2010Q4 (the shaded area). Indeed, the average size of the OMO shocks during 2009Q1 to 2010Q4 is about four times as large as that in the post-stimulus period.

To examine the importance of each shock in explaining the variations in the main macroeconomic variables at the business cycle frequency, we conduct variance decomposition in Table 6. Overall, the OMO shock turns out to be the most important shock in explaining the business cycle fluctuations in China (except that the demand shock accounts for about 90 percent of the fluctuations in consumption). The banking shock comes as the second. The OMO shocks play a crucial role in explaining the variations in output and investment (see the last column): 44.4 percent of the fluctuations in output and 52.44 percent of variations in total investment are accounted for by the OMO shocks. At the sector level, the OMO shock displays differentiated effects on investment. The OMO shock plays a larger role in explaining 57.14 percent of the variations in investment in the SOE sector, while only accounting for 31.85 percent of the fluctuations in the PE sector. In contrast, the banking shock accounts for about 46.72 percent of the fluctuations in PE investment while it accounts for only about 27.15 percent of the variations in SOE investment. This suggests that the SOE investment is largely policy driven, whereas PE investment is mainly driven by credit conditions in the banking sector. The OMO shock and the banking shock also play an important role in explaining the fluctuations in the nominal variables, including M2, inflation and the policy rate.

Note that compared to the OMO shocks, the interest rate shocks play a minor role in determining the business cycle fluctuations in the Chinese economy (see the third column). This suggests that although the PBC has been gradually moving from using M2 growth as the main target to using the interest rate rule, the OMO rule remains much more effective than the interest rate rule.

Table 6: Variance Decomposition at Business Cycle Frequency (in %)

	Banking	Demand	Int. rate	Technology	Government	OMO
Output	30.85	3.64	4.06	8.92	8.09	44.44
Consumption	0.66	88.96	0.2	7.62	0.74	1.81
Investment Total	35.63	0.74	4.37	6.59	0.23	52.44
Investment SOE	27.15	1.97	1.6	11.46	0.68	57.14
Investment PE	46.72	2.37	15.01	2.85	1.2	31.85
M2	73.81	1.69	2.67	12.43	2.12	7.28
Inflation	30.85	2.9	15.33	6.79	2.01	42.11
Policy rate	13.94	13.25	12.73	21.41	3.8	34.88

5.2 Model mechanism

Given the importance of the OMO and banking shocks, in this section we present the model dynamics after these two shocks.

5.2.1 OMO shocks

Figure 11 shows how the model economy responds to an OMO shock in the baseline case. The shock increases χ_t, the upper limit for the fraction of assets that can be lent out as loans, in both SBs and NSBs. Recall that at the steady state, the SBs can lend out 75 percent of their assets as loans and the NSBs can lend out 85 percent of their assets as loans. The first panel of Figure 11 shows that for the SBs, χ_t^{sb} increases upon its steady state value by 4.6 percent (from 75% to 78.5%) after the shock. The NSBs also benefit from the shock; however, with d_{omo} being 0.30, the increase in χ_t^{nsb} in the NSB sector is much smaller compared to SBs. The increase in χ_t^{nsb} is only 1.3 percent (from 85% to 86.2%). The increased capacity of making loans relaxes the SBs' incentive constraint, leading to a decline in the risk premium and lending rate in the SB sector. Since the SBs only lend to SOEs, the firms in the SOE sector increase borrowing due to the lower rate and the SB banks' leverage increases. Investment in the SOE sector rises, driving up the asset prices in the SOE sector (this would further relax the collateral constraint that the SOE firms face). Labour supply rises as well due to the rise in wages (not shown in the figure), leading output in the SOE sector to rise.

The supply of loanable funds in the NSB sector also increases after the shock although the magnitude is smaller. This should lead to a decline in the risk premium and lending rate. However, Figure 11 shows a *slight* increase in both the risk premium and lending rate. To understand this, we need to look at what happens in the demand side. Since goods from the two sectors are complementary, the increase in the demand for SOE goods also drives up the demand for PE goods. The output in the PE sector rises. Investment in the PE sector and demand for loans rises, driving an increase in the risk premium and lending rate. In the equilibrium, the demand effect dominates the supply side. As a result, both the risk premium and lending rate increase after the OMO shock.

5.2.2 Banking shocks

The banking sector shock is the second most important shock determining output dynamics. Figure 12 shows how the model variables respond to a shock to the banking sector. The shock increases the diversion fraction, which can be interpreted as the received riskiness related to the banking sector. Note that the banking shocks are symmetric across SBs and NSBs. The increase in riskiness leads to a rise in the risk premium for both SBs and NSBs, leading to an increase in the lending rates in both sectors. This causes both labor demand and capital demand to decline in SOE and PE firms, leading to a decline of the aggregate output.

6 Policy experiments

As described in Section 2.2, two key features of the stimulus policy implemented by the Chinese government in 2009–2010 are that: (1) it is essentially a monetary and credit expansion, (2) the credit expansion is implemented in a way that favors the SBs and SOEs instead of the NSBs and PEs. These empirical facts pose interesting questions regarding the role of the credit channel of the monetary transmission mechanism during the stimulus period. Of particular interest is the extent to which the economic recovery is driven by the extra monetary stimulus (through the credit channel). Another issue for examination is how a more balanced distribution of the credit expansion across the state and non-state sectors would affect the economic recovery. In what follows, we answer these questions by conducting counterfactual exercises.

6.1 Policy experiment 1: removing stimulus package

As shown in Figure 10, the OMO shocks from 2008Q4 to 2010Q4 (stimulus period) are much larger than the shocks over the period of 2012Q4–2014Q4 (the post-stimulus period focused in this subsection). More specifically, the average size of the OMO shocks during the stimulus period is 0.014, about four times as large as its counterpart in the post-stimulus period (about 0.003)[31]. Using this difference, the strategy used to remove the substantial credit injections is to replace the size of the OMO shocks during the stimulus period by the level observed in the post-stimulus period. That is, we reduce the size of OMO shocks in 2008Q4–2010Q4 by 75 percent, while keeping the size of the subsequent

[31] The value of 0.014 means that the average size of the OMO shock is 1.4 percent above its steady state. A similar interpretation applies to the value of 0.003.

Note that we consider the large negative shock in 2014Q2 (-0.04) as a outlier, and do not include it when calculating the average size of the OMO shocks for the post-stimulus period.

OMO shocks and the other shocks intact. We then simulate the GDP growth path and compare the result with its empirical counterpart.

Figure 13 reports the results. The gap between the actual and counterfactual paths measures the impact of the monetary stimulus. Clearly, eliminating the extra credit injections greatly lowers the economic recovery. For instance, in the absence of the stimulus policy, the predicted GDP growth rate in 2009Q4 is 8.27 percent, much lower than its empirical counterpart, 10.24 percent. Given that the GDP growth rate in data in 2008Q3 is 8 percent, the counterfactual exercise predicts a rise of 0.27 percentage points in the GDP growth rate from 2008Q3 to 2009Q4, which is about 12 percent of the actual increase in the GDP growth rate (2.24 percentage points in the data). This suggests that the stimulus policy accounts for around 88 percent of the overall response of the GDP growth.

Our result is similar to the finding in Chen et al. (2016). Their study develops an endogenous-switching monetary policy, and uses an empirical approach to pursue the same question as our work. By shutting down the more aggressive monetary policy regime in 2009Q1-2009Q3, they find that the monetary stimulus accounts for about 85 percent of the changes in GDP growth over the same sample period.

6.2 Policy experiment 2: a more balanced credit injections

The uneven distribution of the credit across the state and non-state sectors during 2009-2010 is caused by two factors. The first one is how the credit expansions are injected into the banking sector. Since stimulus policy favors the SBs, most of the monetary stimulus went to the SBs during the stimulus period. As a result, the SBs could make more loans compared to the NSBs. In our model, this difference is captured by the movements in χ_t^{sb} and χ_t^{nsb}. Specifically, the percentage change in χ_t^{sb} rises more than χ_t^{nsb} upon their respective steady state value during the stimulus period. The second one is the banking regulation difference between the SBs and NSBs, which further amplifies the impact of the monetary stimulus. One aspect of such differences, captured in our model, is that the SOEs and the PEs face different loan-to-value ratio (LTV) requirements imposed by banks.

This subsection examines the relative importance of these two factors in shaping the impact of monetary policy on the aggregate economy. More specifically, we aim to understand what would happen to the GDP growth and TFP if the credit expansions were injected into the economy in a more balanced way. In what follows, two counterfactual exercises are conducted to address this issue. In counterfactual 1, we increase the monetary stimulus to the NSB sector; in counterfactual 2, we further relax the unfavorable LTV ratio faced by the PEs.

6.2.1 Increasing monetary stimulus to NSBs

As discussed in Section 3.4, the parameter d_{omo} determines how money injections are allocated across the SBs and NSBs. In the baseline model, $d_{omo} = 0.3$, which suggests that if the PBC's monetary stimulus leads to a one-percentage point increase in χ_t^{sb} (the fraction of the total assets that can be lent out as loans) in the SBs, the increase in χ_t^{nsb} is only 0.3 percentage point.[32] In counterfactual 1, we consider a more balanced allocation of credit injections where d_{omo} is set to 1 during the stimulus period. With $d_{omo} = 1$, the rise in χ_t in terms of percentage change is the same for both banking sectors.

Figure 14 illustrates the mechanism behind increasing d_{omo} to one. Faced with the same OMO shocks, it compares the model dynamics between the baseline model and the counterfactual exercise. When $d_{omo} = 1$, χ_t^{nsb} responds to the credit injections more actively, increasing from 0.86 in the baseline case to 0.89 in the counterfactual case. As a result, a higher fraction of the asset of the NSB banks can be lent out, and the NSB banks are, thus, less incentive constrained. This makes the risk premium and the lending rate decline. Investment and output in the PE sector increase more compared to the baseline case. It follows that the aggregate output and TFP are higher in the counterfactual case.[33]

To study the overall effect of increasing d_{omo} on the aggregate economy, we conduct another experiment, in which we allow all the six shocks to be active. We simulate the GDP growth path and TFP. For GDP, we compare the simulated path with the data (or equivalently, the baseline results).[34] Figure 15 shows that the effect of the stimulus policy on GDP growth becomes larger as opposed to the data. In particular, the result shows that over the period of 2009Q2 to 2010Q1, allowing the NSB banks to receive more credits (about 3 percent of the assets by the NSBs) raises the GDP growth rate. Average GDP growth goes up to 10.17 percent in Counterfactual 1, about 0.5 percentage points higher than what is observed in the data (9.69 percent) over this period.

The increase in GDP growth rate is accompanied by the improvement in aggregate TFP. During most of stimulus period, there is a rise in aggregate TFP when $d_{omo} = 1$ relative to the baseline model where $d_{omo} = 0.3$, and the average rise in TFP is about 0.02 percent of its steady state level.

[32] By Equation (31), one-percentage point increase in χ_t^{sb} means χ_t^{sb} increases by one-percentage of its steady state value χ_{ss}^{sb}. Similarly, 0.3-percentage point increase in χ_t^{nsb} means χ_t^{nsb} increases by 0.3-percentage of its steady state value χ_{ss}^{nsb}.

Note that the size of the loan supply in each sector not only depends on χ_t^{sb} and χ_t^{nsb}, but also the total assets held by each of them.

[33] The total productivity is the weighted average of the SOE sector TFP and the PE sector TFP. The rise in total productivity is simply because more output is produced by the PEs.

[34] Note that since GDP is one of the observables used in estimation, the simulated path in the baseline model coincides with the data.

6.2.2 Relaxing the borrowing constraint faced by PEs

In our baseline model, the PEs are more financially constrained in that the LTV ratio faced by the PEs is lower than the one for the SOEs. In the baseline model, the LTV ratio is constant with $\theta_{pe} = 0.3$ and $\theta_{soe} = 0.7$. In this subsection, keeping $d_{omo} = 1$, we further allow θ_{pe} to be time-varying with the credit injections during the stimulus period. That is, when the NSBs receive more stimulus, they are allowed to increase the LTV ratio accordingly. To achieve this, we assume that during the stimulus period, the LTV ratio faced by the PEs, $\theta_{pe,t}$, follows

$$\theta_{pe,t} = \theta_{pe} \left(\frac{\chi_t^{NSB}}{\chi_{ss}^{NSB}} \right)^{\varpi}, \tag{33}$$

where $\theta_{pe} = 0.3$, the value used in the baseline model. We further assume that $\varpi > 0$, implying that when there is an increase in χ_t^{nsb} compared to its steady-state value χ_{ss}^{nsb}, there is an increase in $\theta_{pe,t}$. The magnitude of the adjustment in $\theta_{pe,t}$ depends on ϖ.[35] In the following experiment, we set $\varpi = 0.35$ so that the LTV ratio faced by the PEs rises from 0.3 to about 0.35 in response to the same OMO shock as that in Section 6.2.1.[36]

The purple dotted line (Counterfactual 2) in Figure 14 displays the impulse response functions of the key variables in this experiment, with $d_{omo} = 1$ and $\varpi = 0.35$. Compared to the red dotted line (Counterfactual 1), the main changes occur in the PE sector. Due to the slightly relaxed borrowing conditions, the PEs absorb more of the credits which are available due to the monetary stimulus. Compared to Counterfactual 1, the rise in investment in the PE sector almost doubles in Counterfactual 2, leading to a higher GDP growth and total productivity.

Similarly, we simulate the economy under all six shocks with the new rule. The purple line in Figure 15 shows the GDP growth path in the new economy. Compared to the red line (constant θ_{pe}), the stimulus effect is much more pronounced when $\theta_{pe,t}$ rises with d_{omo}. A slightly loosened borrowing constraint gives the PEs a better position to take advantage of a higher d_{omo}. The average GDP growth from 2009Q2 to 2010Q1 in Counterfactual 2 reaches 11.85 percent, about 2.15 percentage points higher than what is observed in the data.[37]

The sizable results obtained in Counterfactual 2 reflect the effect on the non-state sector along both extensive and intensive margins of simultaneously balancing the credit injections between the two banking sectors and mitigating the unfavorable borrowing conditions faced by the PEs. Intuitively, in Counterfactual 1, although increasing the

[35] Note that in this way, the fraction of the loan held by the SBs and NSBs at the steady state remains the same between the baseline model and the counterfactual economy.

[36] By setting $\varpi = 0.35$, we consider a moderate rise in the LTV ratio faced by the PEs. Our robustness check shows that the predicted average GDP growth rate increases with the value of ϖ.

[37] Altering the order of these two changes gives similar results. That is, the increasing the LTVs faced by the PEs *alone* generates a much smaller rise in GDP growth rate than implementing both changes.

credits in the NSBs ($d_{omo} = 1$) helps more PEs get funds due to the lower borrowing costs (extensive margin), the fixed LTV ratio suggests that for an individual PE firm, it is still difficult to obtain bank loans (intensive margin). A reform along both dimensions benefits the PEs at the extensive and intensive margins, which pronouncedly encourages the investment in the PE sector, and translates into a higher overall investment and GDP growth in the economy. Indeed, the results regarding the TFP confirm the intuition; the rise in TFP over the period of 2009Q2 to 2010Q1 averages about 0.07 percent of its steady state level.

6.3 Policy experiment 3: switching OMO rule between SBs and NSBs

In the pervious section, we consider the cases where the credits are distributed in a more balanced way. In this section, we consider an alternative: we assume that the PBC implements the monetary stimulus mainly though the NSBs instead of the SBs. Specifically, we replace the OMO rule defined in Section 3.4 with the new rule:

$$\frac{\chi_t^{nsb}}{\chi_{ss}^{nsb}} = \left(\frac{\chi_{t-1}^{nsb}}{\chi_{ss}^{nsb}}\right)^{\rho_{omo}} \left(\left(\frac{\pi_{t-1}}{\pi_{ss}}\right)^{-\rho_{\pi,omo}} \left(\frac{y_{t-1}^{g}}{y_{ss}^{g}}\right)^{-\rho_{y,omo}}\right)^{1-\rho_{omo}} e^{\zeta_t^{omo}},$$

where ζ_t^{omo} is a OMO policy shock which follows

$$\zeta_t^{omo} \sim i.i.d.\, N(0, \sigma_{omo}^2).$$

The size of the adjustment for the SBs follows

$$\frac{\chi_t^{sb}}{\chi_{ss}^{sb}} = \left(\frac{\chi_t^{nsb}}{\chi_{ss}^{nsb}}\right)^{d_{omo}}.$$

In this counterfactual exercise, the parameters governing the PBC's responses to inflation and output growth remain the same as in the baseline case; however, the NSBs are the main recipients of the credit injections through the above-modified OMO rule. In addition, the value of d_{omo} remains at 0.3, which suggests that if there is one percentage increase in χ_t^{nsb}, there is only 0.3 percentage point increase in χ_t^{sb}.

The red dotted line in Figure 16 represents the dynamics of the key macro variables to the OMO shock under this alternative OMO rule (Counterfactual 1). Compared to the baseline case, the PE sector invests more, while the SOE sector invests less. However, the aggregate output rises by less than the one in the baseline model. The reason for this result is that in Counterfactual 1, the LTV ratio faced by the PEs remains lower than that faced by the SOEs, the same as in the baseline model. Although there are more credits available for lending out in the NSBs, the lower LTV ratio in the PE sector dampens the rise in investment. On the other hand, the credit available in the SBs rises less than the one in the baseline case, which hurts the SOE investment. As a result, at the aggregate level, the rise in investment in the PE sector is not enough to compensate for the decline in the SOE sector, which gives rise to a lower aggregate investment, and consequently, aggregate output. Similarly, we simulate the GDP growth path under all six shocks using the new OMO rule. As shown by the red line in Figure 17, the GDP growth rate averages 8.47 percent for the period of 2009Q2 to 2010Q1 in Counterfactual 1, lower than what one observes in the data (9.69 percent), confirming the mechanism described in Figure 16.

In Counterfactual 2, we further allow the LTV restriction faced by the PEs to be time varying. Particularly, we follow the strategy used in Section 6.2.2 and set $\varpi = 0.35$. The purple dotted line in Figure 16 represents the impulse responses of the key variables to the OMO shock in the case where the economy is under the new OMO rule and a time-varying LTV ratio for the PE sector. It shows that increasing the lending capacity of the NSBs and loosening the PEs' borrowing constraint jointly lead to a higher aggregate output than in the baseline model. The overall effect on the GDP growth rate is shown in Figure 17. In sharp contrast with the result in Counterfactual 1, the consideration of a higher LTV ratio in Counterfactual 2 leads the average GDP growth rate to be about 0.6 percentage points higher than what is observed in data over the period of 2009Q2 to 2010Q1.

7 Conclusions

Deviating from the standard reduced-form approach (e.g., Taylor type interest rate or money growth rules) used in the existing literature, this paper considers the key institutional features of the monetary policy in China, and develops an alternative way to model Chinese monetary policy through open market operations (OMOs).

We construct the OMO rule in a two-sector dynamic stochastic general equilibrium (DSGE) model with a segmented banking sector, capturing the feature that the Chinese monetary policy mainly operates through the bank credit channel. In face of credit expansions, the size of credits obtained by the state-owned banks (SBs) and non-state-owned banks (NSBs) is determined by the OMO rule through the bank balance sheet. In particular, the OMO rule allows the loan capacity of the SBs to increase more pronouncedly compared to the NSBs. This leads to a credit misallocation problem: the less productive SOEs receive more bank loans at lower costs (the extensive margin). This credit misallocation is further aggravated in that the PEs face less favorable borrowing conditions (lower LTV ratio, the intensive margin). To our knowledge, this contribution is the first attempt to explicitly model the credit channel through which the OMO propagates into the real economy along both the extensive and intensive margins.

With the presence of the OMO rule, we conduct a variety of counterfactual exercises. Our results show that the stimulus policy accounts for nearly 90 percent of the rise in GDP growth over the period 2008Q3-2009Q4, close to the result established in the recent literature. Second, we explore the relative importance of uneven distribution of credits across the SBs and NSBs, as well as different borrowing conditions in shaping the impacts of the stimulus package on aggregate output. We find that a more balanced credit distribution proves to be quantitatively significant but *moderate*. However, a reform that involves both a balanced distribution and unified banking regulations generates a much stronger effect on GDP growth. Intuitively, with both reforms present, the misallocation problem is greatly mitigated along both the extensive and intensive margins. Mitigation of credit imbalances therefore encourages investment in both sectors, particularly in the PEs, which is the more productive sector. In addition, we find that without unifying the banking regulations for the LTV ratios, a reform that simply switches the status of the NSBs and SBs would even lower the aggregate investment, and then, hurt the GDP growth. These results suggest that a unified banking regulation should receive *more* attention by policymakers to enhance the effectiveness of the monetary policy.

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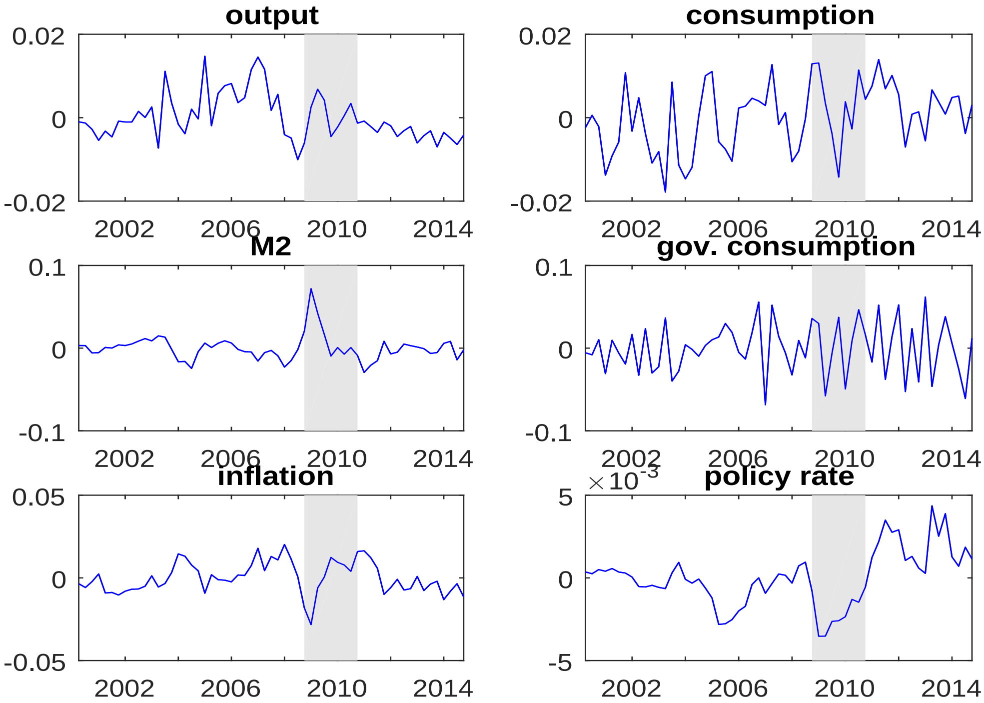
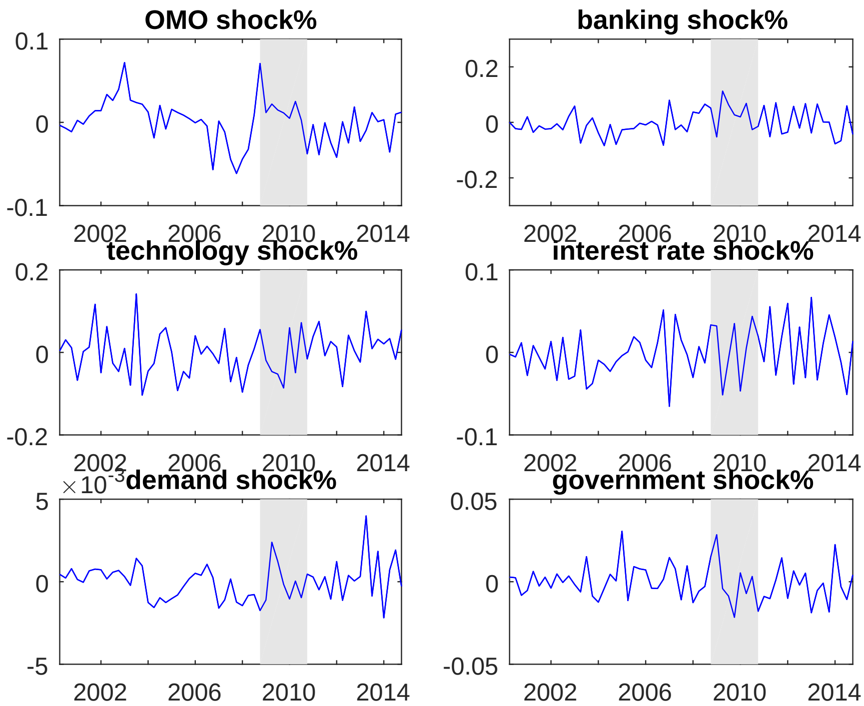
Figure 9: Raw Data Used in Estimation



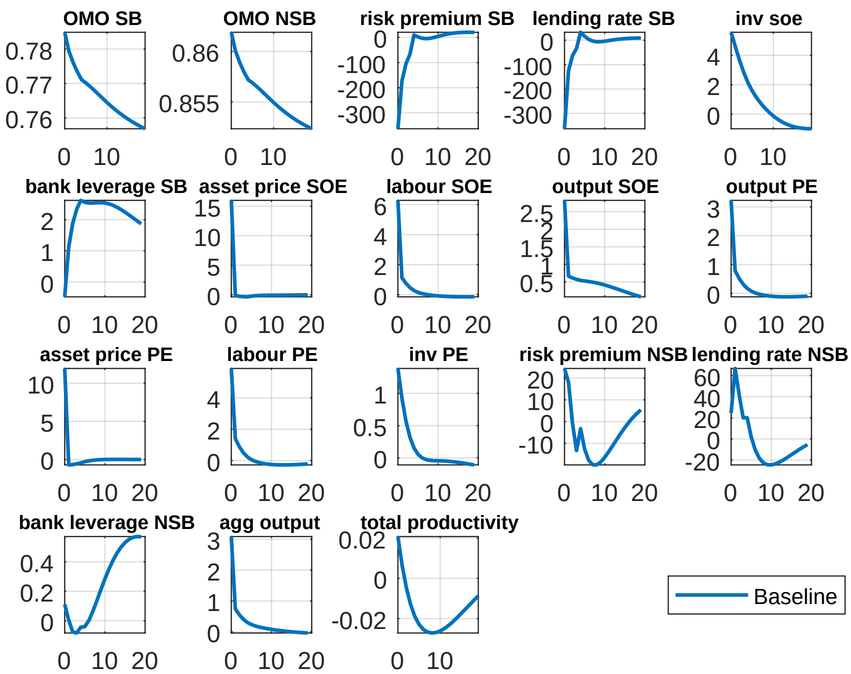
Notes: The shaded bars indicate the stimulus period: 2008Q4 to 2010Q4.

Figure 10: Estimated Shocks



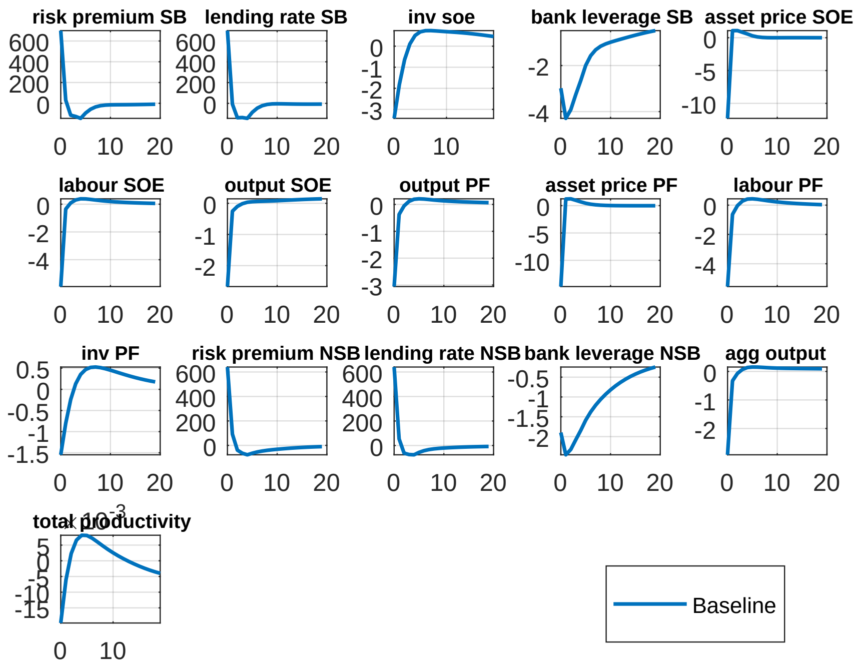
Notes: The shaded bars indicate the stimulus period: 2008Q4 to 2010Q4.

Figure 11: The Effect of OMO Shock: Baseline



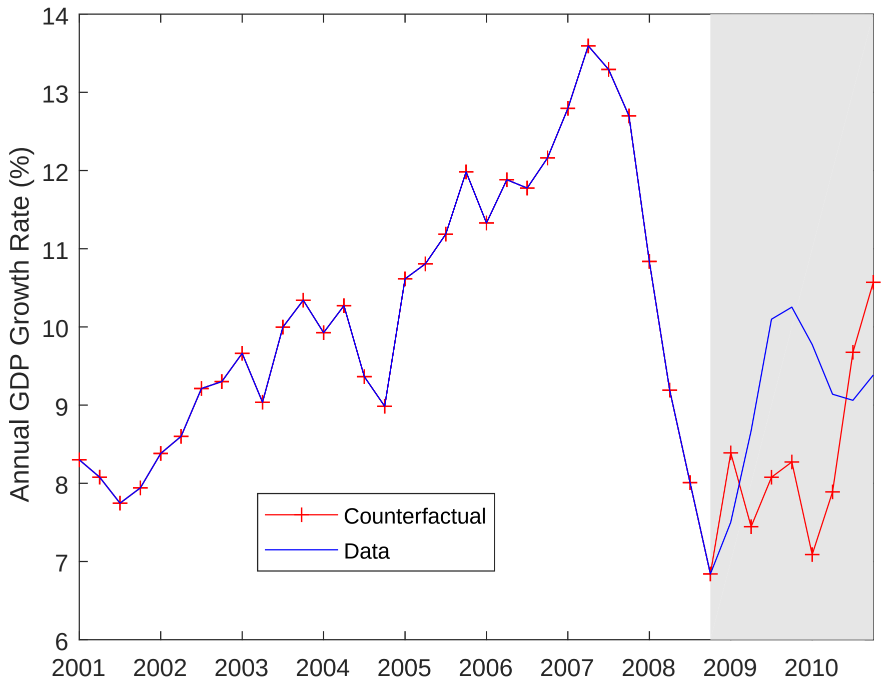
Notes: Both OMO SB and OMO NSB are expressed in absolute values: the value of the fraction of assets that can be lent out as loans. The risk premium and lending rates are in basis points. All of the remaining variables are in percentage deviations from their steady-state values.

Figure 12: Effect of Banking Sector Shock: Baseline



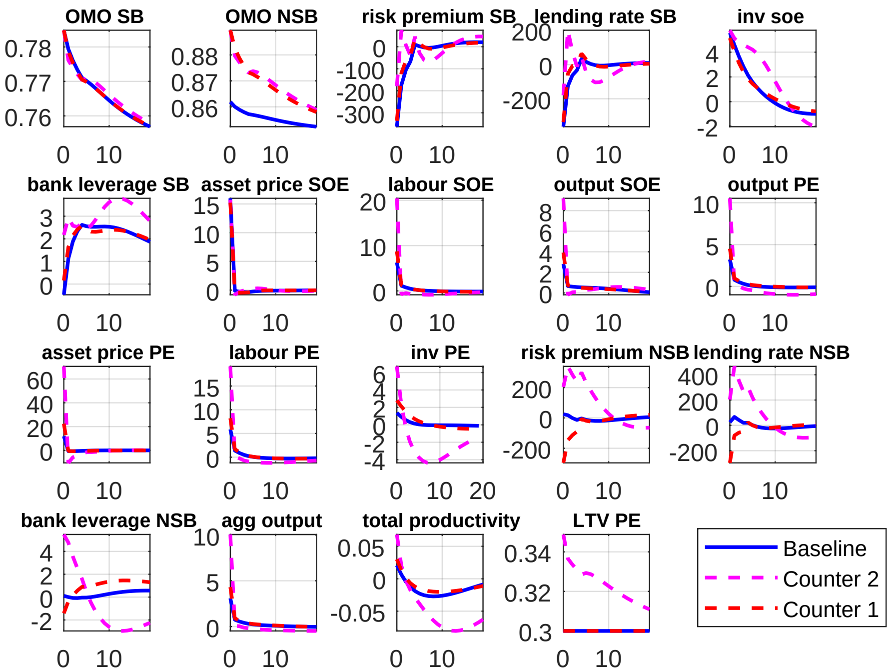
Notes: The risk premium and lending rates are in basis points. All of the remaining variables are in percentage deviations from their steady-state values.

Figure 13: Policy 1 – Reducing OMO Shocks during Stimulus Period



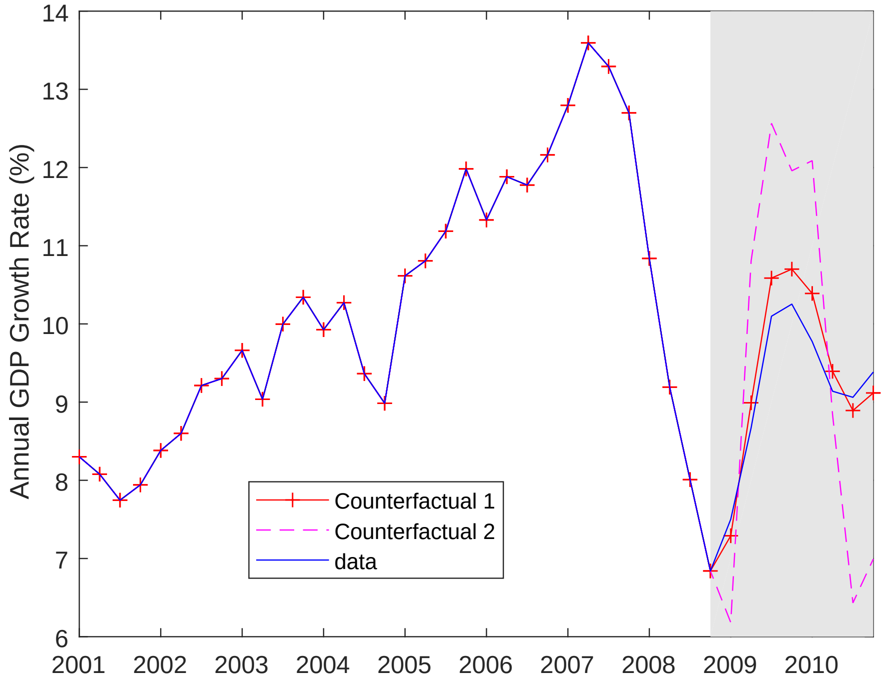
Notes: The vertical axis is the annual GDP growth rate (in percent), calculated using year over year GDP growth. Counterfactual refers to the case where the size of the OMO shocks during the stimulus period is reduced to one quarter of that of the estimated OMO shock. The shaded area indicates the stimulus period: 2008Q4 to 2010Q4.

Figure 14: Policy 2 – Increasing Credit Injections to NSBs: Effect after an OMO Shock



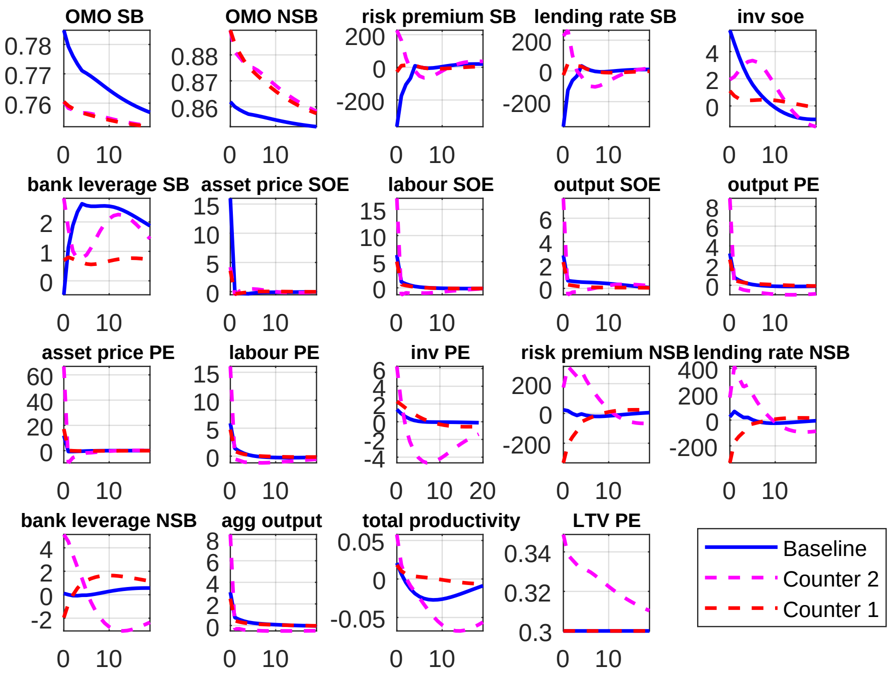
Notes: The figure shows the effect of increasing credit injections to NSBs. Counterfactual 1 (Counter 1) refers to the case where d_{omo} increases from 0.3 (baseline) to 1. Counterfactual 2 (Counter 2) refers to the case in which we set $d_{omo} = 1$ and allow the LTV of the PE sector to be time-varying. Both OMO SB and OMO NSB are expressed in absolute values and they are the value of the fraction of assets that can be lent out as loans. LTV PE is also expressed in absolute values. The risk premium and lending rates are in basis points. All of the remaining variables are in percentage deviations from their steady-state values.

Figure 15: Policy 2 – Increasing Credit Injections to NSBs: Effect on GDP Growth



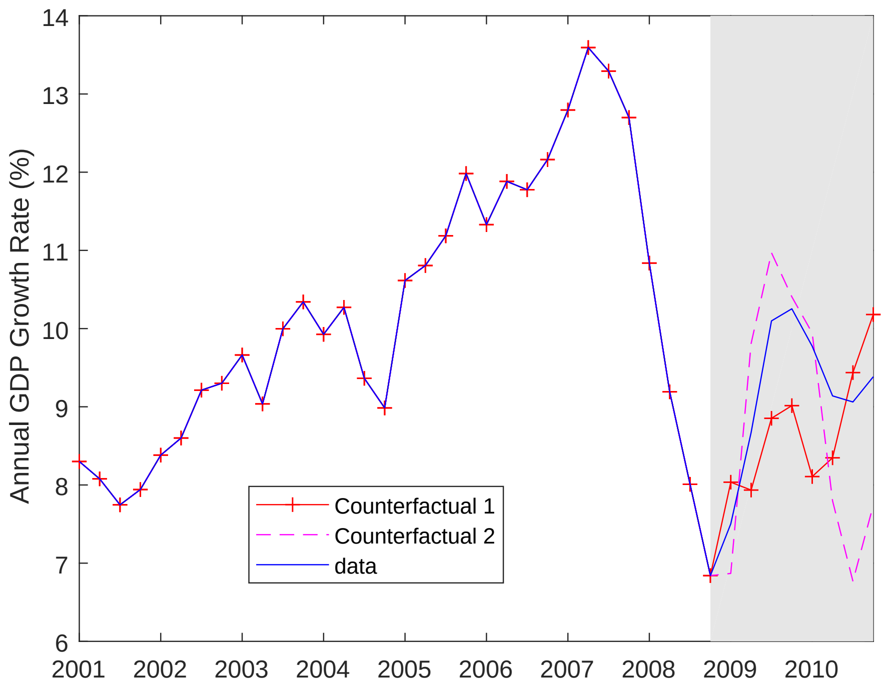
Notes: The vertical axis is the year over year GDP growth rate (in percent). Counterfactual 1 refers to the case where $d_{omo} = 1$. Counterfactual 2 refers to the case where $d_{omo} = 1$ and the LTV of the PE sector is time-varying. The shaded area indicates the stimulus period: 2008Q4 to 2010Q4.

Figure 16: Policy 3 – Switching OMO Rule between SBs and NSBs



Notes: The figure shows the effect of the switching OMO rule between SBs and NSBs after an OMO shock. Counterfactual 1 (Counter 1) refers to the case in which we allow OMO parameters to switch between SBs and NSBs. Counterfactual 2 (Counter 2) further allows the LTV of the PE sector to be time-varying. Both OMO SB and OMO NSB are expressed in absolute values and they are the value of the fraction of assets that can be lent out as loans. LTV PE is also expressed in absolute values. The risk premium and lending rates are in basis points. All of the remaining variables are in percentage deviations from their steady-state values.

Figure 17: Policy 3 – Switching OMO Rule between SBs and NSBs: Effect on GDP Growth



Notes: The vertical axis is the year over year GDP growth rate (in percent). Counterfactual 1 refers to the case in which we allow OMO parameters to switch. Counterfactual 2 further allows the LTV of the PE sector to be time-varying. The shaded area indicates the stimulus period: 2008Q4 to 2010Q4.