Monetary Policy in Mainland China

Frictions in financial intermediation and the cost of sterilization

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Abstract

This paper implements frictions in financial intermediation into a *small open economy* DSGE model. The model is designed to recreate key aspects of the Chinese economy during the financial crisis of 2008 and the ensuing worldwide economic contraction caused by the crisis. Simulations of external foreign interest rate shocks show a significant reduction in the aggregate deviation from monetary policy targets when financial intermediation is introduced. The reduction is further enhanced when current Chinese macroprudential regulations are taken into account. The assessment of the simulations suggests that the Chinese financial sector and its relationship to the central bank could play a major role in enhancing the sustainability of the current monetary policy stance adopted by Mainland China.

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Part I
Introduction

By including frictions in financial intermediation in a model with Chinese characteristics, this paper finds that the frictions significantly lessen the impact of external foreign interest rate shocks. The overall deviation from domestic monetary policy targets is less severe when frictions in financial intermediation are present in the model simulation. Domestic monetary policy targets are chosen with the goal to reflect policy priorities of the Chinese central bank. The resilience towards foreign interest rate shocks further increases when existing Chinese banking sector regulation is implemented. This conclusion is drawn from the comparison of the simulation results of DSGE models with and without financial intermediation. The models are constructed with the aim to replicate key features of the economy of Mainland China between 2008 and 2012. They are derived from the model with Chinese characteristics published by Chang et al. in 2012.[1] Similar to Chang et al., this paper simulates an external foreign interest rate shock in different models to assess the impact on domestic monetary policy targets.

At its core this paper explores the question, if the existence of frictions in financial intermediation and the implementation of macroprudential regulation changes the assessment of the sustainability of a fixed exchange rate regime in the event of external foreign interest rate shocks. How do the frictions impact the way in which sterilizing interventions are transmitted by the financial sector into the real economy? How does the implementation of macroprudential regulation, namely substantial minimum reserve requirements, shape the effect of foreign interest rate shocks on the domestic economy? To date these links have not been explored in depth through DSGE modeling, especially concerning the specific setup of the Chinese monetary policy framework. Economic research though has documented the use of the minimum required reserves ratio as a sterilization tool by the Chinese central bank.[2]

Mainland China's financial sector and macroprudential regulation have unique features, that set them apart from their western counterparts. The Chinese banking sector and its main actors evolved from the state-controlled economy of China before its economic opening. Compared to other parts of the Chinese economy, modernization and emancipation of the banking sector from the state is happening at a much slower pace. Leo Goodstadt provides an extensive

[1] Chang et al. (2012)

[2] Ma et al. (2011) and Pan et al. (2012)

description of the state of banking sector reform in a 2014 paper.[3] Even after decades of reforms, announcements of reforms and public commitments to banking sector reforms, the relationship between the banking sector and the different layers of government in China remains very close. A relationship that is used by the government as an avenue to enlist the banking sector into supporting the implementation of economic policy.[4] The development of markets for derivatives and OTC financial innovation has been relatively slow. The IMF assesses that the Chinese financial system is still at an early stage of development.[5] China has been relatively slow to open up its financial markets to foreign investors and competitors. The closeness to the state and the slow development of alternative avenues of funding for businesses, heighten the importance of bank lending and frictions in financial intermediation for an assessment of Chinese monetary policy.

The relative dearth of funding options outside of bank lending implies that there could be a strong impact of frictions in financial intermediation on the transmission of monetary policy via a financial accelerator. In the aftermath of the financial crisis of 2008, questions about the impact of financial intermediation on the transmission of monetary policy interventions came into the spotlight of economic research in particular concerning the modeling of policy interventions. A main branch of this research is based around the channels through which policy interventions, especially policy interest rate changes, are transmitted into the real economy. In the context of the Chinese financial sector especially the concept of a transmission of policy interventions through the credit channel is of interest. [6] By reacting to monetary policy the banking sector shapes the way in which policy interventions affect the real economy. Financial intermediation can stabilize or destabilize the status quo of monetary policy. Frictions in financial intermediation can act as a financial accelerator that amplifies the impact of monetary shocks on the real economy. This effect can be observed for the models simulated in this text. [7] This amplification of the effects of monetary shocks on the real economy is documented in multiple studies. [8] In the simulated model, the stronger real economy impact is paired with a reduction of the impact of foreign monetary shocks on domestic monetary policy. Monetary autonomy is compromised to a lesser degree when financial frictions and financial sector regulations are present. Depending on the preferences of the central bank, this can entail a reduction of the aggregated deviation from monetary policy targets.

[3] Goodstadt (2014)
[4] Goodstadt (2014) and also IMF Monetary and Capital Markets Department (2012), p.12
[5] IMF Monetary and Capital Markets Department (2012), p.6
[6] Bernanke (1993), p.55-60
[7] see table (7)
[8] for example Brunnermeier and Sannikov (2014), p.379-380

The closeness of the banks to the state leads to the observation, that the central bank shifts some of the costs created by the sterilization of the effects of the persistent current account surplus onto the banking sector. Ma Guonan et al. propose in a paper from 2011,[9] that the configuration of the Chinese financial sector is significantly influenced by the apparent shift of the costs of sterilization from the central bank to the banking sector via changes to the minimal reserve requirements. The central bank uses regulation - most visibly in the form of reserve requirements - to sterilize the money supply effect of the current account surplus.[10]
Starting from a modified version of the model established by Chang et al., the paper presents a sequence of DSGE models. These models introduce step-by-step financial intermediation and key features of financial sector regulation in China. A setup that allows an assessment of the impact of each newly introduced mechanic on the shock responses of the model variables. Accordingly the paper can not only show the overall impact of financial intermediation and regulation on the sustainability of the monetary policy path but also allows for comparisons between a model without intermediation, one with intermediation and a model with intermediation and regulation characteristic to Mainland China. A second sequence of iterations of the model is introduced to explore the impact of financial intermediation on the assessment of the optimal development path of the monetary policy regime. For this a model with an open capital account, a model with a floating nominal exchange rate and a model where both, capital account liberalization and floating exchange rate are implemented, is simulated.
The paper is structured as follows. The first part provides important background information that has shaped the configuration of the models. It showcases the theoretical framework and highlights important related research. The part furthermore gives an introduction into key aspects of Chinese monetary policy and its development in response to the worldwide financial crisis of 2008. The second part of this paper describes the step-by-step construction of the DSGE models and their different characteristics. It shows the impulse responses of these different models to an exogenous foreign interest rate shock and provides an assessment of the occurring deviation from policy targets. The paper concludes with the third part. This part sums up the results of the different simulations and draws conclusions. Additional figures, schematics and the log-linear equations of the different models can be found in the appendix.

[9] Ma et al. (2011), p.6-7
[10] Ma et al. (2011), p.6

Part II
Research context and Chinese monetary policy

This chapter introduces the two foundations of the present thesis. The chapter starts with a brief description of the concepts of frictions in financial intermediation and sterilization. It also highlights related research publications, that have shaped the conception of the present paper. The second part of this chapter gives an introduction into key aspects of Chinese monetary policy and showcases important developments of the Chinese monetary policy during the worldwide financial crisis.

1 Related research and theoretical background

The following section describes the concept of monetary policy transmission channels and the importance of frictions in financial intermediation and gives an overview on related research. It also provides an introduction on the concept of the sterilization of monetary interventions and related research. The section is divided in two parts, where the first is concerned with monetary policy transmission and the second part is dedicated to sterilization.

1.1 Frictions in financial intermediation

The bankruptcy of the Lehmann Brothers Bank in September 2007 and the ensuing collapse of the market for mortgage-backed securities did not only cause worldwide economic turmoil, it also shook up economic research. Especially for economic research concerned with the workings of monetary policy. The financial crisis originated from the financial sector and policy actions taken as a response, during the crisis and in the post-crisis effort, included monetary policy interventions in a quite important way.[11] The economic downturn following the crisis not only originated in the financial sector, but it were the developments in the financial sector during and after the initial crisis and the scope of the economic contraction, that distinguish the financial crisis from previous economic recessions since the Second World War.[12] Government intervention, in particular the intervention of central banks, chartered new grounds in scale and scope.[13]

[11]Friedman (2013), p.1
[12]Friedman (2013), p.2
[13]Friedman (2013), p.2

The post-crisis effort saw the implementation of so called unconventional monetary policy by central banks. Policies implemented to stabilize the banking sector, through the enlargement of the classes of assets that were accepted by the central bank as collateral and through targeted purchases of assets, specifically mortgage-backed securities by the central bank. The policies were also implemented to solve the conundrum of the inability of conventional monetary policy to further influence markets, when the lower bound of zero for the policy interest rate is reached.[14]

These developments brought the financial sector and its role in the transmission of monetary policy in the limelight of economic research. Specifically since standard macroeconomic models, and even models used by central banks for policy decisions,[15] were not equipped to model or give answers on the effect of unconventional monetary policy and the role of financial intermediation in the transmission of policy interventions.[16] Accordingly researchers set themselves to explore the workings of financial intermediation and in particular the implications of a variety of frictions inherent to the information asymmetries in financial intermediation.[17]

The impact of frictions in financial intermediation on the transmission of monetary policy and the different channels through which monetary policy could be transmitted had already been discussed before the crisis, most notably by Ben S. Bernanke in several publications.[18] The discussion of the financial crisis sparked a new wave of research. This new research explores the impact of financial frictions on the assessment of the optimal monetary policy, expanding on Bernanke's earlier work. One aspect of this research is the implementation of frictions in financial intermediation and unconventional monetary policy into DSGE models. This implementation can be roughly divided in two branches. One branch that is primarily concerned with the effect of frictions on the response to monetary policy interventions, and one branch that aims at providing a framework for the exploration of the effects of unconventional monetary policy. Well cited proponents of both branches are on one hand a contribution to the Handbook of Monetary Economics from October 2009 by Mark Gertler and Nobuhiro Kiyotaki on financial intermediation and credit policy in business cycle analysis and on the other hand a 2011 paper by Mark Gertler and Peter Karadi that provides a model of unconventional monetary policy.

The present thesis locates itself in the branch of papers that explore the effects of frictions in financial intermediation on the response of the model to monetary

[14]Friedman (2013), p.3-4

[15]see for example the NAWM published by the ECB Christoffel et al. (2008)

[16]Friedman (2013), p.2-3

[17]Friedman (2013), p.3

[18]Bernanke (1993), Bernanke (1995) and Bernanke et al. (1999)

shocks and monetary policy interventions. A wide array of different approaches has been employed to explore the implications of financial frictions on monetary policy transmission. A common approach is localization, meaning the introduction of features specific to a country or region into the model configuration. Localization allows for the assessment of the impact of frictions in the context of a specific country. One subject of such localization is Mainland China. Several papers have taken a closed-economy approach at assessing questions of monetary policy transmission and the financial sector in China. This is for example a 2012 paper by Chen Qianying, Michael Funke and Michael Paetz and a follow up paper by Michael Funke and Paetz also published in 2012, that evaluate initiatives and proposals concerning the reform of China's financial system. Another paper by Michael Funke, Petar Mihaylovski and Haibin Zhu from 2015 looks at the implications for monetary policy and policy reform arising from the existence of a shadow banking sector.
Another angle is to expand on the financial sector and to implement interbank markets and frictions in interbank markets into the model to assess the implications. Papers concerned with this angle, that have also strongly influenced the model configuration in the present thesis, are a paper by Ali Dib from 2010 exploring the impact of interbank and credit market frictions, and a similar approach is used by Björn Hilberg and Josef Hollmayr in their 2013 paper on asset prices in the interbank market and unconventional monetary policy. Optimal monetary policy, the effect of macroprudential regulation when frictions are present and the use of countercyclical interventions by the central bank have all been the subject of a variety of different papers. Amongst them a 2013 paper by Leonardo Gambacorta and Frederico M. Signoretti exploring the question if monetary policy should pursue countercyclical interventions. As well as Pierre-Richard Agénor and Luiz A. Pereira da Silva, who discuss the implications of macroprudential regulations on monetary policy transmission in a model with financial frictions, lastly a 2011 paper by Marion Kolasa and Giovanni Lombardo on the optimal monetary policy in an open economy with financial frictions.

A The financial accelerator and monetary policy transmission channels

Financial intermediation plays an important role when looking at the impact of monetary policy interventions on the real economy. Financial intermediation serves as an intermediary between monetary policy and the real economy. And because of this role as a middle man, it can alter the way in which monetary shocks and policy interventions are transmitted to the real economy. The extent of this alteration is dependent on the configuration of the financial sector and the

existence of frictions in financial intermediation.[19]
Financial intermediaries play a central role in credit markets. Due to their specialization in financial markets, intermediaries invest with an informational advantage over other non-specialized market participants. Their expertise allows them to function as a link in the allocation of savings from relatively uninformed investors to uses that are hard to evaluate and need intensive information and monitoring.[20] This allows them to create access to credit for borrowers who would otherwise be unable to obtain external funding. Given this special role, interference with the amount of credit channeled through financial intermediation can be assumed to create noticeable macroeconomic effects. Such interference would stem from bank runs and panics, government restrictions, increased costs, declines in the bank's capital or deposit base and monetary policies that affect the stock of bank deposits.[21]
In a paper from 2002, Bean et al. identify three distinct channels through which monetary policy may be transmitted into the real economy. The interest rate channel, the bank lending channel and the broad credit channel. Of these three only the interest rate channel is not conditional on the existence of financial intermediation.[22] In the following paragraphs the interest rate channel and the broad credit channel are discussed in greater detail.
The interest rate channel is based on the assumption, that changes in nominal interest rates have an effect on the real economy. A link is assumed between interest rates and the relative prices in the economy. Under the condition of price rigidity this spills over into the real economy. The link primarily affects the price for capital and the price for future consumption in terms of present consumption. Higher interest rates provide an incentive for higher savings, while lower interest rates favor present consumption. The channel implies a causal link between movements in short term nominal interest rates and movements in short and long term real interest rates. A link that is then transmitted to real variables and inflation. This is conditional on a slow responsiveness of inflation. This slow responsiveness is brought about by the existence of nominal rigidities in prices and wages.[23]
The basic concept behind the interest rate channel can also be applied to a situation, where controlling the money supply growth is the main instrument of monetary policy. An increase in the money supply creates an inflationary push, that affects the price of future consumption in terms of present consumption. This leads to higher nominal interest rates, prices and wages. With price rigidity,

[19] Beck et al. (2014), p.1-2
[20] Bernanke (1993), p.51-53
[21] Bernanke (1993), p.53
[22] Bean et al. (2002), p.12-13
[23] Bean et al. (2002), p.14

this spills over into the real economy as an expansionary impulse.
The broad credit channel assumes the existence of an external finance premium. The premium captures the difference in cost that entrepreneurs face when sourcing funds for investments. A difference exists between funds that are raised externally and internally generated funds. This premium on external funds reflects the imperfections in credit markets. It is the result of frictions in the process of financial intermediation. These frictions can stem from the asymmetry in information between borrower and lender and the costs associated with the enforcement of contracts. The premium reflects the dead-weight costs associated with the principal-agent problem inherent to the relation between borrower and lender. It encompasses the lender's expected costs for the evaluation, monitoring and enforcement of debt contracts.[24] The premium a borrower faces is assumed to be conditional on the borrower's financial position. The greater the sum of the borrower's liquid assets and marketable collateral, dubbed the borrower's net worth by Bernanke,[25] the lower the premium levied for external financing. A stronger financial position reduces the potential conflict of interest between borrower and lender leading to a reduction of the premium. By this, the borrower's balance sheet has a direct impact on its investment and spending decisions. The overall terms of credit affect investment and spending decisions, creating the 'financial accelerator' effect.[26] The borrower's balance sheet improves with the economic conditions, leading to a decline in the external finance premium. This increases the borrower's spending and enhances economic growth. There is mutual feedback between the financial and real sectors.[27] The financial accelerator influences economic conditions by causing variations in the entrepreneurs' cost of capital in line with the financial health(net worth) of entrepreneurs. This effect is more pronounced when the terms of debt contracts are renegotiable.[28] The existence of an accelerator amplifies the impact of monetary shocks on the real economy and the real economy impact of monetary policy interventions. A reduction of the nominal policy rate for example suppresses market interest rates, reducing the cost for external funds. This would reduce the amount of external funding needed by the entrepreneurs, leading to a higher stake of the entrepreneur in their project. This in turn reduces the external finance premium, further reducing the external financing costs. Through this amplification the effect of monetary intervention on the domestic economy is stronger than it would have been in the absence of financial frictions.[29]

[24] Bernanke (1995), p.10-11
[25] Bernanke (1995), p.3
[26] Bernanke (1995), p.12
[27] Friedman and Woodford (2010), p.4
[28] Bean et al. (2002), p.20
[29] Bernanke (1995), p.12-13

1.2 Sterilization of foreign exchange intervention

Interventions of central banks on domestic money markets that aim at neutralizing the money supply effects of preceding foreign exchange market interventions, have been a subject of economic research for a long time. In the context of ad hoc foreign market interventions, that aim at mitigating short-term fluctuations in exchange rates or that attempt to influence longer-term movements.[30] As well as in the context of the constant foreign exchange market activity in the presence of a fixed exchange rate regime. Maurice Obstfeld describes sterilization as an attempt by the central bank to divorce foreign exchange interventions from domestic money supplies through offsetting operations on domestic financial markets.[31]

Research on sterilization revolved around a variety of aspects in the last decades, for the present paper three aspects are of particular interest. The first aspect is research that concerns itself with foreign exchange interventions, their subsequent sterilization and the question if sterilization can be efficient and what costs are associated with it. The second aspect is the role that sterilization and the accumulation of foreign reserves associated with current account imbalances play in the new global financial architecture that emerged at the beginning of the second millennium.[32] The third aspect is the sustainability of the exchange rate regime chosen by the People's Republic in light of the mid- to longer-term ability to sterilize the persistent current account surpluses.

Literature that has formed the conception of the present thesis that falls under the first aspect is a paper by Richard T. Baillie and William P. Osterberg, that examines the reasons for interventions by central banks into foreign exchange markets for the Dollar/DM and Dollar/Yen exchange rates, exploring the reasons for interventions by central banks on foreign exchange markets in floating exchange rate regimes. A similar subject is examined by Kathryn M. Dominguez and Jeffrey A. Frankel, whose 1993 paper is concerned with the efficiency of foreign exchange interventions by central banks. The relative effectiveness of sterilized and non sterilized foreign exchange market interventions is the subject in a 2005 paper by Keith Pilbeam. The costs associated with sterilization are the subject of a 1991 paper by Guillermo A. Calvo. Using a general equilibrium monetary portfolio choice model of a small economy, Michael Kumhof's 2010 paper examines the theory of sterilized foreign exchange intervention, lastly a 2007 paper from Pierre L. Siklos and Diana N. Weymark that uses evidence from emerging markets as well as Hong Kong, Korea, Japan and Singapore to asses the effectiveness of sterilized foreign exchange intervention.

[30] Genberg (1981), p.451
[31] Obstfeld (1982), p.1-2
[32] Aizenman et al. (2010b), p.616-617

Concerning the discussion of global imbalances and their relation with sterilization, the present thesis has been mostly informed by series of papers from Joshua Aizenman and Collaborators, starting with a 2008 paper from Aizenman on the reasons for the accumulation of international reserves by developing countries, especially the so called East-Asian Tiger States. A 2009 paper by Aizenman and Reuven Glick on the changing pattern and efficiency of sterilization in relation to the increasing integration of emerging market economies into the world economy. A 2010 paper by Aizenman, Menzie D. Chinn and Hiro Ito on the financial integration of Asia in the world economy uses the trilemma of the open economy as a measuring tool. And another paper from 2010 by Aizenman, Menzie D. Chinn and Hiro Ito that investigates the effect different trilemma configurations have on the economic performance of developing countries. The policy trilemma is also the subject of a paper from 2013 by Michael W. Klein and Jay C. Shambaugh, that investigates the case for intermediate configurations of the trilemma. An intermediate configuration would be a scenario, where capital movement has some restrictions, but is neither completely free nor completely restricted. As well as a paper by Michael B. Devereux, Philip R. Lane and Juanyi Xu from 2006 and a 2011 paper by Sebastian Edwards, that both look at exchange rates in emerging market economies. Where Devereux et al. focus on the monetary policies of emerging market economies and Edwards on the empirical regularities found across a variety of emerging countries.
Concerning the sustainability of the Chinese exchange rate regime two papers have been of particular importance for the conception of the present thesis. A 2007 paper by Alice Y. Ouyang, Ramkishen S. Rajan and Thomas D. Willett that investigates the ability of Mainland China to act as a reserves sink, the ability of Chinese monetary policy to continue the sterilization of its increasing foreign reserves. And a 2009 paper by Christer Ljungwall and Xiong Yi and Yutong Zou, that investigates the costs associated with sterilization for the Chinese central bank and the measures implemented to mitigate these costs.

A Trilemma of the open economy

The observation that the choice of a monetary policy path is subject to restrictions, that policy makers can't have it all, is at the root of the monetary policy trilemma. It states that of the three ideal monetary policy configurations (free capital mobility, a stable exchange rate and autonomous domestic monetary policy), only two can ever be achieved simultaneously.[33]

[33]Klein and Shambaugh (2013), p.1, a detailed description can be found in Aizenman et al. (2010b), p.617-621

Accordingly a commitment to a credible fixed exchange rate regime implies forgoing either monetary autonomy or unrestricted capital mobility.[34] The reason for this is the effect of arbitrage. Without effective restrictions on the transfer of capital across the border, investors will seek to profit from arbitrage gains and eventually force an adjustment of interest rates to match those of the base country. To prevent this adjustment through arbitrage and the possibility of credit bubbles that can be created by the influx of investments seeking arbitrage gains, the domestic financial market has to be shielded by capital transfer restrictions from the base country. By controlling capital flows central banks retain the autonomy to set an independent domestic monetary policy at the price of decoupling the domestic financial markets from those of the base country.[35] In consequence domestic monetary autonomy hinges on the effectiveness of the decoupling of the domestic financial markets and the base country. Without integration of the real economy, the central bank's task would be confined to enforcing capital controls. The picture changes when there is economic integration. Decoupling the financial markets is increasingly difficult the more the domestic economy is integrated into international markets.[36] The cross-border exchange of goods and services between economies entails a cross-border flow of funds, that increases with further integration. By committing to a credible currency peg, the central bank promises to provide the currency needed for the cross-border trade at the exchange rate set by the central bank. The central bank intervenes constantly on money markets to purchase foreign currency from exporters and to provide foreign currency to importers. In a scenario with a balanced current account these interventions do not impact monetary autonomy. The central bank would acquire as many foreign currency assets from exporters as it would need to pay for imports. More precisely, the domestic exporters are payed in foreign currency, that they exchange with the central bank for domestic currency and importers exchange domestic currency for foreign currency with the central bank to pay for imports. A current account imbalance on the other hand can infringe on monetary autonomy. Given a large or persistent current account surplus, the central bank would acquire more foreign currency from exporters than is needed to provide for imports. As the central bank exchanges foreign currency for new domestic currency, the domestic money supply grows. This provides an inflationary impulse and prompts an increase of the domestic policy rate. Domestic monetary autonomy is compromised. In the case of a persistent current account deficit, monetary autonomy suffers too. The central bank balance shrinks due to the reduction of

[34] Edwards (2011), p.11

[35] Klein and Shambaugh (2013), p.1

[36] Aizenman (2008), p.490

foreign assets held by the central bank. The reduction in foreign assets is coupled with a reduction in the domestic money supply, as the central bank receives domestic currency for the assets it sells. The domestic money supply declines, causing deflation and prompting a decrease in the domestic policy rate. In the current account deficit scenario the feasibility of the adopted monetary policy has a hard limit, that may become subject to speculation. The policy will become untenable when the central bank's ability to provide foreign assets is depleted. A change in policy will likely occur before this point is reached.[37]
Aizenman describes the phenomenon that central banks of developing nations, especially the so called South-Asian Tiger States, tended to acquire substantial holdings of foreign assets as a means to lean against the wind during a currency crisis [38] thus enhancing the sustainability of the chosen policy path.
To counteract these undesired effects of current account imbalances, central banks engage in sterilization. They intervene on the domestic financial markets to neutralize the changes in the money supply. Thus the ability to efficiently sterilize the change in the money supply is a key part in the sustainability of the adopted monetary policy.

B Methods of sterilization

As stated, the goal of sterilization is to neutralize the change in domestic base money caused by money market interventions of the central bank. This text focuses on the use of sterilization as a tool to neutralize the adverse effects of current account imbalances on domestic base money. In a very narrow sense, only balance sheet neutral interventions constitute actual sterilization. The change in foreign assets has to be matched by a change in the central bank's domestic asset position.
In the case of a current account surplus, the central bank sells domestic bonds that it held to drain liquidity from the money market after a purchase of foreign assets. This is balance sheet neutral as the increase in foreign assets is matched by a decrease in domestic assets held by the central bank.[39]
In the current account deficit case, the central bank sells foreign assets to domestic entities for domestic currency, thus reducing domestic base money. The central bank neutralizes this reduction in base money by purchasing domestic assets with new money, that it created. This would be balance sheet neutral, as the decrease in foreign assets would match the increase in domestic assets on the central bank's balance.[40]

[37]Krugman (1979), p.319
[38]Aizenman (2008), p.490, Aizenman et al. (2010a), p.26
[39]Neely (2000), p.2-3
[40]Neely (2000), p.2-3

In a less narrow definition, sterilization must not necessarily be balance sheet neutral. Measures of the central bank can be classified as sterilization, if they fulfill the goal of neutralizing the undesired change in base money.[41] Sterilization can be conducted through interventions that shift funds in the central bank's balance from base money to another liability or the other way around. A standard procedure in the case of an increase of base money is the issuance of bonds by the central bank. These bonds are sold for domestic currency on domestic financial markets to reduce the liquidity of the market, thus temporarily counteracting the increase of base money. Central banks can use reverse repurchase agreements (reverse from the central bank's point of view) for the same goal. Decreasing base money can be counteracted in the short run by entering in repurchase agreements, where the central bank lends assets against new domestic currency.[42]
A less direct form of sterilization is the management of domestic money market liquidity by the adjustment of regulatory controls. An example of this would be the adjustment of the minimum required reserves ratio of the commercial banks. Minimum reserves have no liquidity and an increase in the minimal reserves requirement would drain market liquidity. Just as a decrease in the ratio would increase liquidity. The desire to increase liquidity on financial markets is what prompted the European central bank to lower the minimal reserve requirements as a response to the European credit crisis. This can also be used to sterilize base money effects of current account imbalances and may be one of the reasons for the relatively high minimal reserve requirements in Mainland China.[43]

C Costs of sterilization

The ability of the central bank to sterilize depends on the costs associated with sterilization. Central banks face two kinds of costs when considering sterilization, balance sheet costs and policy costs. Balance sheet costs are incurred through balance mismatches. The accumulation of foreign assets in the case of a current account surplus will lead to losses for the central bank if foreign interest rates are below domestic interest rates. The central bank would sterilize low paying foreign assets by selling high paying domestic bonds or by issuing central bank bonds with higher remuneration. The same holds in the reverse case, when the bank reduces its holdings of high interest foreign assets in favor of domestic assets with lower remuneration to sterilize a current account deficit.[44]
In addition to interest rates there is also the issue of imperfect asset substitution.

[41] BIS Monetary and Economic Department (2005), p.16-17
[42] Aizenman and Glick (2009), p.779
[43] Ma et al. (2011), p.5
[44] BIS Monetary and Economic Department (2005), p.62

The liquidity, risk profile and payment schedule of the swapped assets may be less desirable. This imperfect substitution becomes a higher burden the longer a current account imbalance persists. The sterilization of the massive portfolio of US treasury bonds acquired by the Chinese government is an imperfect substitution, as domestic interest rates were above US rates after the financial crisis, implying that the central bank incurs losses when sterilizing through the issuance of bonds.[45]
Central banks committed to a fixed exchange rate tend to suffer policy creep. Monetary policy is primarily dictated by what is needed to achieve and maintain the exchange rate regime.[46] Putting the exchange rate first makes monetary policy coordination difficult and can produce inconsistent policy targets. Markets can receive misleading or distracting signals. The need for intervention and sterilization is put above the fulfillment of other policy targets. The central bank misses important policy targets (domestic GDP, inflation, employment) in its quest to maintain the given monetary policy. This can be seen as a loss of overall welfare, as economic development does not reach the state targeted by the central bank. [47]

2 Chinese monetary policy and the financial crisis

The following section is meant as an introduction to key characteristics of monetary policy and the financial sector in China. The characteristics identified in this section are then revisited in the second chapter during the model-building process. This section also contains an overview of the impact of the financial crisis on Chinese monetary policy.

2.1 Framework of monetary policy in China

Three characteristics of the monetary policy framework in China are of particular interest in the construction of the models. The role and scope of central bank activity, the exchange rate regime and its implementation and the role of capital controls and their implementation. The parts below highlight the role of these characteristics and present some key figures.

[45]BIS Monetary and Economic Department (2005), p.61
[46]BIS Monetary and Economic Department (2005), p.2
[47]BIS Monetary and Economic Department (2005), p.2

A The People's Bank of China (PBOC)

The Law of the People's Republic of China on the People's Bank of China, establishes the PBOC as the central monetary authority for the People's Republic. The central bank is tasked to implement monetary policy, to prevent and mitigate financial risks and to maintain financial stability.[48] The objective of monetary policy is to maintain the stability of the value of the currency and to promote economic growth.[49] Unlike other central banks, the PBOC is not independent in the implementation of its policy targets. Its decisions concerning the annual money supply, policy interest rate, exchange rate and other important issues specified by the Chinese Government, are subject to approval by the Government.[50] Monetary policy is carried out in accordance with the overall economic policy of the Chinese government. The main instrument of China's monetary policy framework is the control of broad money growth.[51]

The balance of the monetary authority reflects the effects of the monetary policy path chosen by the Chinese government. A simplified representation is displayed in table(1) for the quarter-end balance of the first quarter of 2008 and the fourth quarter of 2012. The persistent current account surplus coupled with the exchange rate regime has lead to an accumulation of substantial foreign assets by the central bank. Foreign assets account for 80% of all assets in Q4 2012, an increase compared to their share of 75% in 2008. The ratio of foreign assets over currency issue remained stable at 4:1 between Q1 2008 and Q4 2012.[52] The share of government debt and other assets on the balance is persistently small - such that balance sheet neutral sterilization is severely limited.

An important aspect of the liabilities side is the large amount of deposits of financial corporations included in reserve money(deposit reserves). In Q4 2012 deposit reserves accounted for two thirds of all liabilities of the central bank, a notable increase over Q1 2008, where deposit reserves made up only slightly more than one third of total liabilities. This increase in the share of deposit reserves is primarily an effect of the increase in the required reserves ratio. [53]

Interestingly, the trend of an increasing bond issuance observed by Ljungwall et al. for the period between 1999 and 2008, did not continue. The value of announced bond auctions in Q4 2012 is significantly smaller than in Q1 2008. This is not caused by a decrease in sterilization, but by a change in the method of liquidity management by the central bank. Central bank bonds were replaced

[48]National People's Congress of the PRC (2003), §2
[49]National People's Congress of the PRC (2003), §3
[50]National People's Congress of the PRC (2003), §5
[51]Ma et al. (2011), p.10 also Sun (2013), p.56-57
[52]Ljungwall et al. (2009), p.5
[53]see Ljungwall et al. (2009), p.5

by targeted repurchase and reverse repurchase agreements as the tool of choice for the management of financial market liquidity in 2012. Central bank bonds pay market interest rates and are traded on the bond market, they are usually held by financial institutions.[54]

Assets	2008	2012	Liabilities	2008	2012
Foreign Assets	13.7	24.1	Currency Issue	3.3	6.0
Other Assets	4.5	5.3	Deposit Reserves	7.1	19.2
			Bond Issuance	3.9	1.4
			Other Liabilities	3.8	2.8
Total Assets	18.2	29.4	Total Liabilities	18.2	29.4

Table 1: Simplified balance of the Chinese monetary authority in trillion RMB [55]

With the financial crisis and the slowdown in global demand caused by it, the export surplus of Mainland China has been lower in the period between 2008 and 2012 compared to the preceding years. The average of the current account surplus for the period between 2004 and 2008 stood at 5.7% percent of GDP. There is a significant reduction between 2008 and 2009, the surplus reached 9.2 % in 2008, but dropped to 4.8% in 2009. It stood at 3.9% in 2010, 1.8 % in 2011 and 2.5% in 2012.[56] This reduced surplus is also reflected in the growth of the foreign assets held by the central bank. The explosive increase of the pre-crisis period decelerated, foreign assets increased on average by 37.28% between 2004 and 2008 and on average by 17.02% between 2008 and 2012 year-on-year. The graph in figure(1) shows the total reserve assets held by the monetary authority in US-Dollars from 2007 to 2012. The red line depicts the official holdings of US Treasury Bonds by the Chinese government as published by the US Treasury. The central bank uses a variety of tools to conduct monetary policy. Shu et al. list six categories of price and quantity based market and non-market measures. Open market operations, selective transactions, reserve requirements, benchmark interest rates, credit controls and other regulatory means.[58] Of these tools the open market operations and reserve requirements are of particular interest, as

[54] Ljungwall et al. (2009), p.5

[55] Table according to Ljungwall et al. (2009) p.5, data from People's Bank of China (2009) and People's Bank of China (2013)

[56] Data: Worldbank Statistical Database The World Bank (2000-2013)

[57] Data for the graph: People's Bank of China (2008-2012a), U.S. Department of the Treasury (2007-2012)

[58] Shu and Ng (2010), p.7 also Zhang (2009), p.473-474 on the use of price and quantity instruments

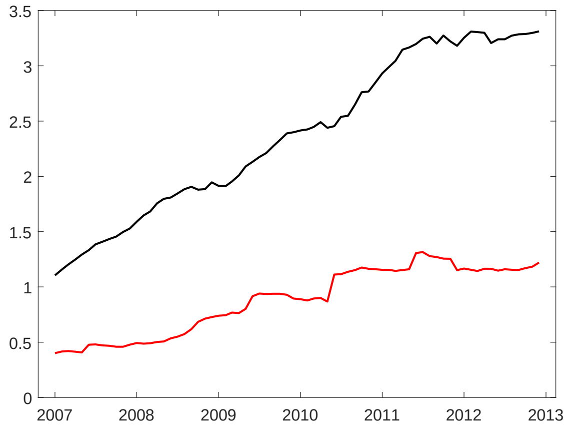

Figure 1: Total reserve assets of the monetary authority (black) and US Treasury Bonds held by the Chinese Government in trillion USD [57]

they are described as being used as tools for sterilization.[59] Benchmark interest rates are of particular interest because of their impact on the amount of funds channeled by financial intermediation.

Open market operations: Open market operations encompass market-based interventions conducted on a regular basis by the central bank. These operations aim at controlling the liquidity of the financial markets. The OMO of the central bank have seen a shift between 2008 and 2012. While the issuance of central bank bonds, of which the PBOC controls the amount, price and maturity, was the preferred method to reduce liquidity at the beginning of the period, they were replaced by reverse repurchase agreements by 2012. Reverse repurchase agreements announced by the central bank usually have fairly short maturities, with the majority of agreements ranging between 7 and 14 days. Repurchase agreements are used to add liquidity to the markets. Prior to 2013 China had no equivalent to the standing short- and mid-term lending facilities established by the ECB and Federal Reserve, that could provide ad hoc short-term liquidity to banks. Meaning that the provision of short term liquidity to the banking sector was tied to a deliberate direct intervention of the central bank. The chart in figure(2) shows a compilation of the volume of the announced open market operations by the central bank for the period between January 2008 and December 2012. The shift from bond auctions to reverse repurchase agreements is clearly visible. The announcements for the auctions of central bank bonds list maturities ranging from 3 to 36 months. It also shows that the central bank is providing short-term liquidity through the means of short maturity repurchase

[59] Ma et al. (2011), p.6

agreements, while it is also draining liquidity in the mid- to long-term through the auction of central bank bonds.

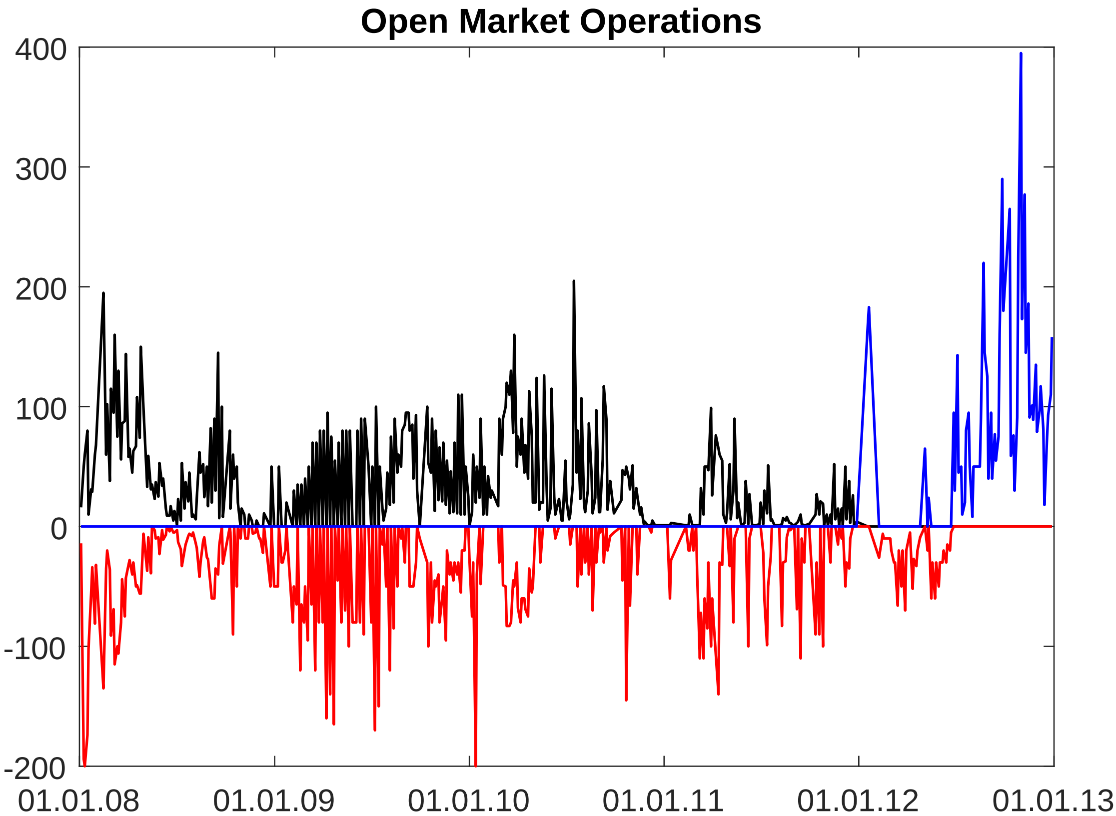

Figure 2: Volume of bond auctions (black), repurchase agreements (red) and reverse repurchase agreements (blue) announced by the PBOC between 2008 and 2012 in billion RMB [60]

Required reserves: As the high amount of deposit reserve in the central bank balance indicates, required reserves are an important characteristic of monetary policy in China. The requirement for depository institutions to hold a share of their deposits as minimum reserves with the central bank is common central bank practice. What sets the Chinese practice apart is the frequency of adjustments to the required reserves ratio. As an answer to the financial crisis, the ECB changed the minimum reserves ratio for the Euro-area once between 2008 and 2012, from 2% to 1%. In the same period the PBOC adjusted the required reserves ratio 25 times, usually by an increment of 50 base points. The

[60] Data compiled from open market announcements of the PBOC, source: People's Bank of China (2008-2012b)

ratio rose from 14.5% in December 2007 to a peak of 21.5% for large banking institutions in June 2011.[61] The requirements are not the same, they differ according to the type of deposit and the financial institution holding them. The reserve requirement on foreign currency deposits is lower than the requirement on local deposits. In 2008 the PBOC has adopted a two-tier system of reserve requirements, where the 6 or 7 largest banks persistently face higher reserve requirements than smaller commercial banks. While rural credit cooperatives and banks have the lowest reserve requirements.[62]
According to Ma et al. required reserves have become a preferred tool to conduct sterilization for the central bank. Changes in the ratio are employed as a tool to control the development of the money supply and to manage the liquidity of the financial market. The importance of required reserves in sterilizing foreign exchange interventions is visible in the high ratio of deposit reserves to foreign assets, that stood at 63% at the end of Q4 2012. Central bank bond issuance in contrast stood at only 6% of foreign assets. Changes in the required reserves ratio serve as a substitute for the net issuance of central banks bonds as a tool to drain the increases of liquidity generated by foreign exchange intervention.[63]
Three motivations are stated by Ma et al. as reasons for the use of the required reserves ratio as a sterilization tool. In contrast to mostly short-dated open market operations (especially the reverse repurchase agreements), liquidity transferred to required reserves is removed permanently from the market until the ratio is lowered.[64] Reserve requirements are cost efficient from the central bank's perspective. The remuneration payed on the required reserves is set by the central bank and independent of market trends and demand. While the interest rate offered on central bank bonds with a one year maturity ranged between 406 and 150 bps from January 2008 to December 2012 with a mean of 270 bps, the interest rate on required reserves changed from 189 to 162 bps in 2008 and remained stable thereafter.[65] Accordingly adjustments of the required reserves ratio can serve as a cheaper alternative to bill issuance and reverse repurchase agreements. This implies a loss of income for the financial sector, forcing the financial intermediates to carry more of the burden of sterilization.[66]
The third motivation for the use of required reserves stems from the impact central bank bond auctions have as a means of signaling policy rate changes and in guiding market expectations. Reserve requirements do neither and so they can serve as tools for liquidity management that do not directly change market

[61] Data compiled from People's Bank of China (2008-2012a), also Pan et al. (2012), p.229
[62] Ma et al. (2011), p.4
[63] Ma et al. (2011), p.7 and Pan et al. (2012), p.235
[64] Ma et al. (2011), p.9
[65] Data from People's Bank of China (2008-2012a)
[66] Ma et al. (2011), p.9

expectations.[67]

Benchmark interest rates : Unlike other central banks, the PBOC does not rely solely on the signaling capacity of the policy interest rate to influence market interest rates. In addition to the policy rate the PBOC also sets benchmark interest rates on deposits and loans. These benchmark rates serve as a boundary around which the interest rates set by the individual financial intermediaries can float. In June 2012 the upper limit of the floating range for the deposit rate was set to 1.1 times the benchmark rate. In the same step the lower limit of the floating range of loan rates was limited to 0.8 times the benchmark rate on loans. The adjustment of the benchmark rates can be assumed to reduce the necessity for adjustments of the policy interest rate. While the ECB policy rate was adjusted 15 times between January 2008 and December 2012, the PBOC policy rate was adjusted once. The benchmark rates though were changed 12 times in the same period.[68] Adjustments of the benchmark rates are used as a tool of macroeconomic management.[69]

B Exchange rate regime

The exchange rate regime in place between 2008 and 2012 for Mainland China was adopted in July 2005. It was announced as a step to emancipate the exchange rate from the USD-peg implemented before. It is referred to as a managed floating exchange rate regime by the PBOC ('guanli de fudong huilü zhidu' in Chinese).[70] The regime rests on two pillars. The first is that unlike the preceding USD-peg, the RMB is no longer pegged to a single currency but to a currency basket. This basket is composed of 11 different currencies, which are seen as important to the Chinese economy. Among these currencies is the USD, the Euro, the Japanese Yen and the Korean Won.[71] The changes of these currencies' exchange rates relative to each other are taken as the basis for the determination of the RMB exchange rate. Currencies in the basket are given weights, that differ according to the relative importance of the currency for the Chinese economy.[72] The distribution of the weights is not published and most likely subject to changes over time.[73]
The second pillar of the exchange rate regime is the inclusion of market demand

[67]Ma et al. (2011), p.9-10
[68]Data from People's Bank of China (2008-2012a)
[69]Shu and Ng (2010), p.8
[70]People's Bank of China (2005), p.1
[71]Frankel (2009), p.4
[72]People's Bank of China (2005), p.1
[73]Frankel (2009), p.51

and supply into the development of the exchange rate.[74] The PBOC sets a central parity for the RMB at the end of each trading day. The exchange rate can then float within a band defined by the PBOC around the central parity on the next trading day, according to market demand and supply. The floating bands can differ between different currencies, the floating band for the USD was changed from 50 bps to 100 bps in Q1 2012.[75]

C Capital controls

Mainland China maintains extensive regulation of cross-border flows. The foreign exchange system draws a clear line between transactions under the current and capital account.[76] In tune with the increasing integration of the Chinese economy into the global economy, transactions under the current account have seen a substantial liberalization. Transactions under the capital account on the other hand remain strictly regulated.[77] The state administration for foreign exchange (SAFE) has authorized financial intermediaries to engage in the onshore sale and purchase of foreign exchange assets for transactions under the current account. The authorized intermediaries form the market makers of the onshore foreign exchange market.[78] The SAFE sets a limit for the scope of the foreign exchange trade of an individual intermediary.[79] Transfers under the current account can be conducted by the financial intermediaries within their allotted limits without a separate approval of the SAFE, if a legitimate reason for the transfer exists. The SAFE defines the necessary documentation and the limits of foreign exchange transfer.[80] The restrictions of transfers under the capital account are much stricter. Direct investments by foreign investors are not only subject to approval by the government institutions relevant for the investment, but also have to be registered with the SAFE. The same applies for the issuance of securities and derivatives by foreign institutions in Mainland China.[81] Outward direct investments and the issuance of securities and derivatives by domestic investors abroad are subject to registration by the SAFE.
The capital control regime in total is discriminatory. It does not only separate between cross-border flows under the current and capital account, but it also discriminates between desired and undesired capital flows. It aims at limiting the

[74] People's Bank of China (2005), p.1
[75] Monetary Policy Analysis Group of the PBoC (2012-2013), p.1
[76] State Council of the PRC (2008)
[77] Ma and McCauley (2007), p.14
[78] State Council of the PRC (2008), p.2
[79] State Council of the PRC (2008), §15 and §20
[80] State Council of the PRC (2008), §12 and §15
[81] State Council of the PRC (2008), §16

influx of speculative capital, while it encourages at the same time direct investments by foreign investors into the Chinese economy.[82]

2.2 Financial intermediation in China

The broad credit transmission channel rests on the assumption, that borrowers are willing to pay an external finance premium for funding through financial intermediation, as they cannot source funds otherwise without incurring higher additional costs or might be unable to source external funds at all.[83] Two characteristics of the financial sector in Mainland China lend themselves to assume that the transmission channel was present in the period between 2008 and 2012. The financial system is dominated by the banking sector with relatively little room for non-bank financial institutions.[84] Stock market funding for example remained below 10% of GDP during most of the period and dropped to a low of 3.82% in 2012.[85] Capital markets remain comparatively shallow and over 60% of outstanding bonds are issued by the government. State-owned policy banks are the second largest issuer of bonds.[86] Despite their rapid development, these markets are still comparatively small, especially concerning corporate debt issuance. Stock market capitalization stood at 44.36% of GDP for 2012.[87] Another characteristic are the close ties between the state and the commercial banks, that enable policy considerations to override credibility and best practice considerations, especially concerning the external funding of state-owned enterprises and local government projects.[88]

Banking sector: The Chinese banking sector has been under constant reform and announcements of reforms for decades. The Chinese government repeatedly pledged its commitment to an opening of China's financial markets to foreign investors, with relatively little effect. Domestic finance markets are gradually opened to foreign investors, but at a slow pace.[89] The banking sector is lagging behind the overall economy in its reform and modernization. Recent research describes the sector as defunct and lacking in efficiency. While official non-performing loan (NPL) levels are small and far from the high numbers

[82] Ma and McCauley (2007), p.14
[83] Friedman and Woodford (2010), p.548
[84] IMF Monetary and Capital Markets Department (2012), p.6
[85] Financial Stability Analysis Group of the PBoC (2013), p.243
[86] IMF Monetary and Capital Markets Department (2012), p.6 Policy banks provide funding for state projects, economic and trade development, comparable to the European Investment Bank
[87] Financial Stability Analysis Group of the PBoC (2013), p.243
[88] see Goodstadt (2012), p.15-16
[89] Goodstadt (2014), p.22

recorded before 2001, the business practices that lead to the crippling NPL levels of the preceding decade are still present in the period between 2008 and 2012.[90] With the transition of the economy and the subsequent collapse of many uncompetitive state-owned enterprises, the banks accumulated record amounts of NPL. In Q4 2004 a staggering amount of 13% of all credit fell in the non-performing category. This situation prompted the creation of asset management companies (essentially bad banks) that bought NPL at face value from the ailing state-owned commercial banks.[91] The NPL were then bundled and auctioned off. This and the recapitalization of the banks alleviated the situation and stabilized the banking sector.[92]

The banking sector was opened gradually to foreign investors and competitors following China's accession to the WTO in 2001. Both foreign investors and the Chinese government attached high hopes with this opening. Foreign investors hoped for a rapid expansion on the yet untapped Chinese banking market and especially the underdeveloped markets for securities and financial derivatives. The Chinese government hoped that stronger competition and the influx of foreign know-how and best practice would provide an incentive for the domestic banks to shape up, improve their competitiveness and adopt best practice business conduct. The opening was also seen as a way to leap frog the development of domestic financial markets and financial innovation.

Few of these high hopes materialized to date, not at least due to the many strings - provisions called prudential regulations by the Chinese authorities - that were attached to the market entry and operations of foreign investors, hamstringing a rapid expansion of foreign competitors and limiting the scale and scope of competition. Foreign investors' enthusiasm subsided with the start of the worldwide financial crisis in 2008. Scarce funds dissuaded foreign banks from expanding/maintaining their not as profitable as hoped operations in China. Due to the institution of benchmark rates on deposits, foreign banks could not offer favorable interest rates to potential customers to compete with the established banks and their visible presence (branch offices) throughout China. Accordingly foreign funded banks relied mainly on the interbank market to fund their operations. A reliance that made operations difficult when worries about the credibility of foreign banks in 2008/2009 raised the cost of interbank financing for foreign funded banks. Foreign funded banks remain a small presence in China, their market share has remained fairly small between 2008 and 2012, holding on average 2% of the assets of all banking institutions.[93]

Chinese interest in the involvement of foreign investors and shareholders in the

[90]Goodstadt (2012), p.1, Goodstadt (2014), p.22-24

[91]IMF Monetary and Capital Markets Department (2012), p.7

[92]Goodstadt (2012), p.1

[93]China Banking Regulatory Commission (2013), p.151

banking sector was founded by two complimentary ailments of the sector - insufficient risk assessment capabilities and business decisions driven by political/ relationship considerations instead of best practice. The state-owned commercial banks and smaller state controlled local banks were entrenched in the local structures of government and the communist party. This enabled collusion and corruption to the detriment of sound risk assessment and best practice. State owned enterprises received credit without proper risk assessment. This was coupled with a generally poor state of management and best practice know-how within the banks.[94] According to Goodstadt, the two practices of political lending and relationship lending are a persistent feature of the banking sector. Political lending refers to a lending practice, where banks are compelled to finance projects because they meet the requirements of a state plan or policy. Relationship lending characterizes a lending practice, where loan applications backed by high-ranking officials cannot be denied.[95] Goodstadt argues, that the remaining control of the state over the banks and their lending decisions is an important lever for the implementation of policy in the Chinese economy.[96]
In official statistics, the banking sector is typically segmented into a variety of different categories according to bank size and ownership structure. A dominant share of the market is held by the five largest commercial banks. These banks are former wholly state-owned commercial banks, that had IPO as part of their restructuring to prepare for the market opening. These banks are banks funded for specific policy goals, that over time reformed into full commercial banks. With their development into commercial banks new policy banks were established. The PBOC sums six banks under the category of large commercial banks: The Industrial and Commercial Bank of China (ICBC), the Bank of China (BOC), the Agricultural Bank of China (ABC), the Chinese Construction Bank (CCB) and the Bank of Communications (BCOM).[97] Together these six banks held around half of all assets of the banking institutions. The market share of these banks has declined in recent years, giving greater importance to localized rural and urban commercial banks and so called joint-stock commercial banks. The joint-stock banks are commercial banks that are partly held by local governments. Table(2) shows the distribution of the assets of the Chinese banking sector among the different categories of banks, excluding the state-owned policy banks. Notable is the relative dominance of the five largest commercial banks and the stagnating share of foreign funded banks between 2008 and 2012. Following the financial crisis of 2008 the banking sector has accompanied the

[94]Goodstadt (2012), p.4-6
[95]Goodstadt (2014), p.6-7
[96]Goodstadt (2014), p.13
[97]China Banking Regulatory Commission (2013), p.145
[98]Own calculations, source China Banking Regulatory Commission (2013), p.151

Institution	2008	2009	2010	2011	2012
Large Commercial	56.65%	56.22%	53.5 %	51.58%	49.06%
Joint-Stock	15.36%	16.29%	17 %	17.68%	19.22%
City/Rural	19.75%	19.77%	21.12%	21.97%	22.76%
Non-bank	2.05%	2.14%	2.38%	2.51%	2.64%
Foreign funded	2.34%	1.86%	1.99%	2.07%	1.94%
New-type/Postal	3.85%	3.73%	4%	4.19%	4.37%

Table 2: Distribution of all assets of Chinese banking institutions excluding policy banks[98]

government stimulus with an explosive increase of loans, especially with loans to local governments, underpinning the stimulus initiated by the central government.[99] Between 2007 and 2012 total loans more than doubled (an increase of 242% over 5 years) reaching 67.3 trillion yuan in 2012. The primary source of funding for the banking sector were deposits included in broad money, which accounted for 64.4% of all liabilities of other depository corporations at the end of Q4 2012. Banking in China is primarily confined to a fairly traditional model of banking. The primary source of funding are deposits, with interbank markets and alternative sources of funding being a distant second source. Funds are lent to domestic customers (households and commercial) predominantly medium to long term. A significant share of assets is allocated to reserves held with the central bank.

2.3 Financial crisis and the PBOC

The financial crisis and the deceleration of worldwide economic activity had a significant effect on China's current account balance. Demand for Chinese exports was reduced in the USA and Europe. The financial crisis sparked a recession in the USA, that reduced demand for exports in China's main trading partner. The liquidity crisis of the European banking sector, lead to a sovereign debt crisis in several European countries and consequently to an economic contraction and reduced export demand. This added to the overall decline in external demand for Chinese goods and the decreased influx of foreign investment into China in late 2008 and early 2009. The current account surplus declined from 108.4 billion USD in the fourth quarter of 2008 to 39.8 billion USD in the third quarter of 2009.[100]

[99] Goodstadt (2012), p.20-21
[100] Data from Federal Reserve Bank of St. Louis (2007-2012)

China's government reacted to the reduced worldwide economic activity by announcing a stimulus package, to sustain growth in China and to further develop China's domestic markets. This stimulus package lead to a rapid growth in bank lending and investment by local governments and stated-owned enterprises. As described, bank loans increased at an explosive pace and grew by 242% between 2007 and 2012.[101]
The economic downturn in the USA and Europe pushed both the Federal Reserve and the ECB to adopt a policy of lowering their policy interest rates in an effort to prop up banking sector liquidity, incite investment and to prevent deflationary developments. The gradual reduction of the policy interest rate by both central banks eventually reached the lower bound of zero percent. Prompted by the inability to further lower the interest rate, the central banks adopted unconventional methods of monetary policy to further influence the economy. Declining policy interest rates and market insecurity precipitated a flight towards safe assets and a decline of the interest earned on these safe assets. Especially US Treasury securities saw a significant reduction in interest rates. Before the financial crisis interest rates in Mainland China were below the interest rates of the Eurozone and the USA. This shifted when the financial crisis shook the US economy. Interest rates in the USA dropped, while the Chinese interest rates remained stable initially.[102] Figure (3) highlights the development of aggregate interbank rates for debt contracts with a 3 months maturity for Mainland China(Shanghai Interbank Offered Rate), the US-Dollar(US-Dollar LIBOR) and the Eurozone(EURIBOR). Interest rates in Mainland China stayed higher than the rates in the USA and remained above these rates for the remainder of the depicted period. The debt crisis in the Euro-zone triggered a gradual reduction of the ECB policy interest rate, ultimately reaching zero percent. This prompted the EURIBOR to decline and to fall below the SHIBOR, where it remained for the remainder of the depicted period.
This clear shift of the interest rate differential at the onset of the recession in the USA is the basis for the use of a shock on the foreign interest rate in the model simulations described in this thesis. The simulation recreates in a simplified way the development of Chinese and US interest rates in the aftermath of the financial crisis.
The change of the interest rate differential and the reduction in value of assets on the US financial markets poses a serious problem for the Chinese central bank. On one hand there is the loss of capital due to the reduction of value for a

[101] Goodstadt (2012), p.20-21
[102] Chang et al. (2015), p.2 for a comparison of the US treasury interest rates and SHIBOR rates
[103] Data from own calculations source: Federal Reserve Bank of St. Louis (2007-2012), Deutsche Bundesbank (2007-2012), China Foreign Exchange Trade (2007-2012)

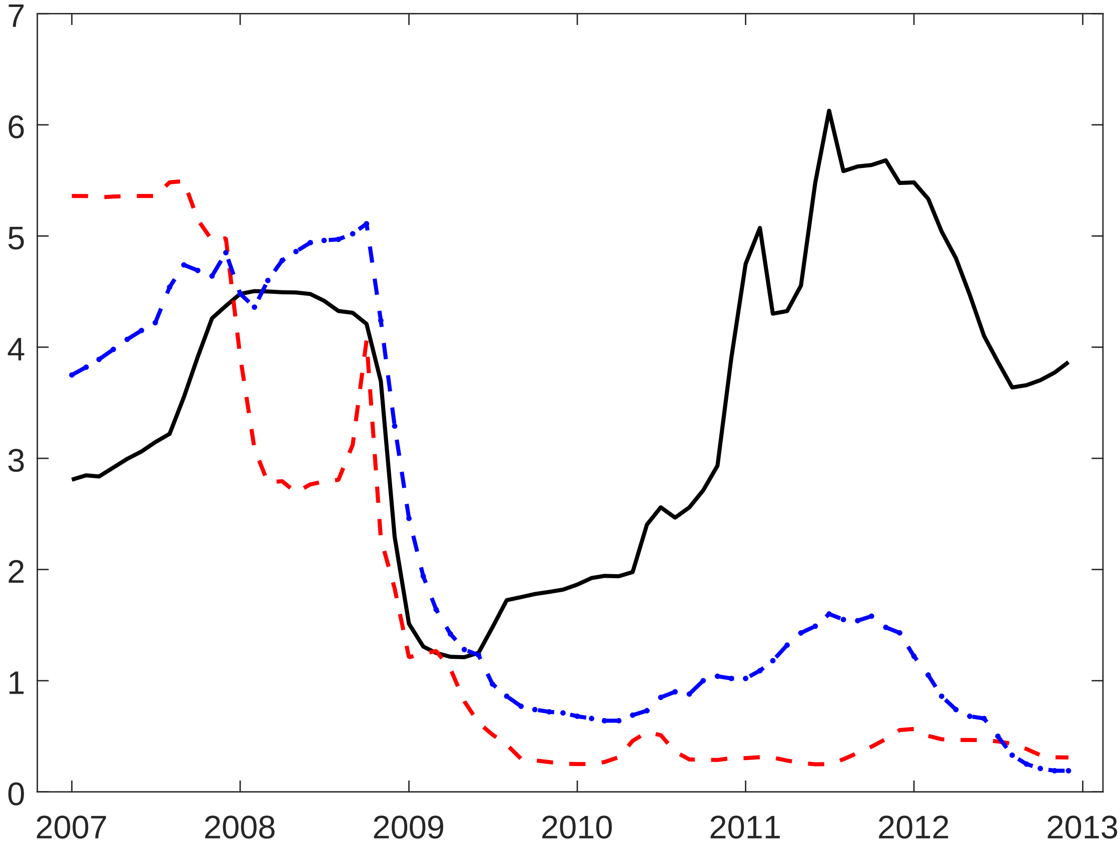

Figure 3: Quarterly averages for SHIBOR (black), US-Dollar LIBOR (red) and EURIBOR (blue) with a 3 months maturity [103]

variety of USD assets held by the central bank. While the PBoC does not publish the composition of its foreign asset holdings, data from the US treasury indicates a significant investment in US treasury securities.[104] The New York Times reports in an article from September 2008, that China's central bank had also invested in mortgage-backed debt issued by Fannie Mae and Freddie Mac, investments that had declined sharply in value.[105]

The reversal of the interest rate differential on the other hand, makes sterilizing foreign exchange interventions via central bank bonds a costly enterprise. Figure(4) shows the percentage of total liabilities of the monetary authority that were held as currency in circulation, deposits by financial institutions (required reserves and excess reserves) and outstanding central bank bonds. The peaks of

[104] U.S. Department of the Treasury (2007-2012)

[105] Bradsher (2008)

[106] Data: own calculations source: People's Bank of China (2008-2012a)

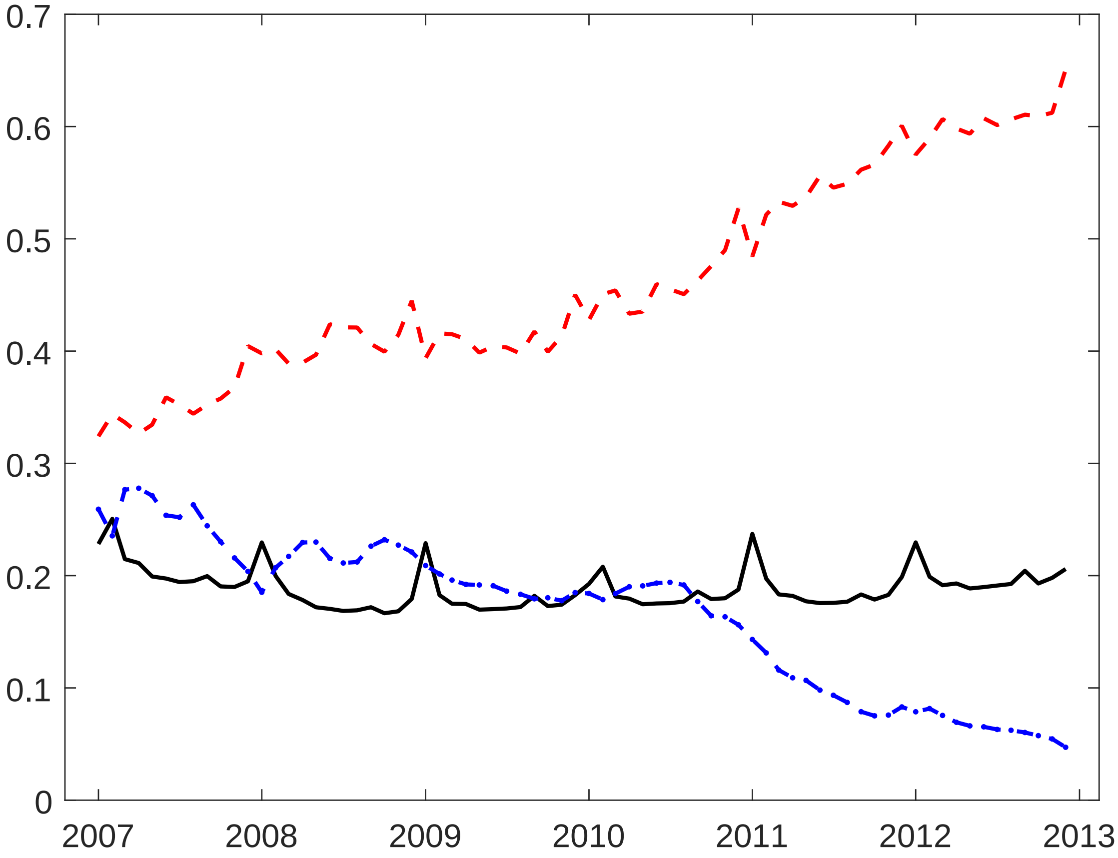

Figure 4: Percentage of total liabilities of the central bank held as currency in circulation (black), deposits of financial institutions at the central bank (red) and central bank bonds outstanding (blue) [106]

the currency in circulation at the start of each year are a cultural phenomenon resulting from the increased demand for cash during the Chinese New Years holidays. The graphs show a strong increase in the percentage of deposits, while the amount of outstanding bonds declines throughout the depicted period and currency in circulation remains relatively stable (excluding the start of the year peaks). Outstanding bonds decline not only relative to the increasing overall liabilities of the central bank, but also in absolute terms. In reflection to the absence of new bond auctions in 2012, outstanding bonds stood at 1.38 trillion RMB in December 2012 with total liabilities of 29.45 trillion RMB, while outstanding bonds stood at 3.433 trillion RMB with total liabilities of 13.25 trillion RMB.[107] This development lends validity to the assumption, that the reversal in the interest rate differential induced a change in the methods and

[107]Data People's Bank of China (2008-2012a)

scope of sterilization of the central bank.
A change in the scope of sterilization, by an increase in the money supply and a reduction in central bank bonds, is the model response to the simulation of a foreign interest rate shock described by Chang et al. [108] A development that is replicated in the simulations described in this thesis.

3 Research question

As shown in figure (3) China faced a distinct problem originating from the financial crisis. In addition to the reduction in worldwide economic activity, the financial crisis also lead to a reversal of the interest differential between China and its main trading partners. The higher pre-crisis interest rates on US securities had provided a favorable environment for the sterilization of the increase in the money supply generated by the current account surplus. The central bank could draw higher interest payments from its foreign reserves, than it had to pay on domestic central bank bonds. This changed with the financial crisis. Now domestic Chinese interest rates surpassed those in China's trading partners. A reversal that happened in addition to the dramatic decline in value of a wide variety of foreign assets. Chang et al. show in the simulation of a negative foreign interest rate shock in their model of the Chinese economy, that this shock precipitates a reduction in the scale of sterilization by the central bank. The stock of central bank bonds is reduced.[109] The shock leads to a deviation of the policy interest rate, inflation, real GDP and the foreign assets to GDP ratio from their steady-state values. This deviation of the policy target variables means that the central bank policy targets are not fulfilled, causing a loss in overall welfare.[110]
Frictions in financial intermediation have an impact on the transmission of monetary policy into the real economy. An often observed phenomenon in the simulation of frictions in financial intermediation is their potential to increase the impact of monetary shocks on the real economy.[111] Given the dearth of alternative funding channels in Mainland China outside of bank lending, the broad credit transmission channel and its impact on monetary policy transmission is particularly pertinent for China. Additionally financial intermediation in China has a set of regulatory characteristics that can influence financial intermediation in general. Minimum required reserves can and are used as a tool for the management of financial sector liquidity and arguably for the

[108] Chang et al. (2012), p.15
[109] Chang et al. (2012), p.13-15
[110] Chang et al. (2012), p.25-26
[111] for example Bernanke et al. (1999), p.1370

sterilization of foreign exchange interventions.[112]
The question derived from these two observations is then, how frictions in financial intermediation alter the reaction of the central bank to the foreign interest rate shock. Do frictions and regulations influence the change in the scale of sterilization by the central bank? How does the implementation of frictions and regulation impact the fulfillment of the central bank's policy targets? Questions that ultimately are aimed at providing an assessment on the question of the sustainability of the monetary policy regime.

[112] Ma et al. (2011), p.6

Part III

DSGE Model configuration and simulation

The first part of this chapter introduces a sequence of three DSGE models, constructed using the same basic setup and parameter calibration. Each new model is a step used to add features, gradually establishing a comprehensive model of the Chinese monetary policy framework. The primary goal of this step-by-step setup is to enable comparisons. These comparisons are the chosen method to examine the effects the inclusion of a financial sector and required reserves have on the assessment of the resilience of the monetary policy stance towards external shocks. The setup is meant to allow for a ceterum paribus assessment of these feature's effects. The secondary aim is one of presentation. The sequential addition of features allows for a more thorough presentation of the thought process guiding the implementation of the features and the rational for the choices made in the construction of the models.[113]

The first model introduced is a model without financial sector or required reserves, that is referred to as the **benchmark model**. The second model introduces a financial sector into the framework set by the first model, it is referred to as the **simple model**. The third model further builds on the second model by introducing required reserves and deposit rate monitoring, it is referred to as the **Chinese model**.

The second part of the chapter consists of a closer examination of the effect different paths of policy reform (opening the capital account, floating the nominal exchange rate or both) have on the assessment of the optimality of monetary policy regime development in the Chinese model.

The DSGE models developed in this paper are a modification of a model proposed by Chang Chun, Liu Zheng and Mark M. Spiegel in a 2012 paper. It further uses concepts from a variety of other current papers on monetary policy in China and frictions in financial intermediation. The model aims to incorporate the current state of DSGE modeling of financial frictions.

The methodology of the model is similar to a 2012 paper by Chen Qianying, Michael Funke and Michael Paetz and a follow up paper by Michael Funke and Paetz also published in 2012.[114] The newer paper evaluates financial system reform initiatives and proposals in China using a closed economy DSGE model. It provides a framework for the implementation of minimum required reserves and deposit rate mandates. This framework is used in the present paper.

[113]The use of a baseline model with the same steady-state is similar to Bernanke et al. (1999), p.1370

[114]Where the second paper builds on and expands the framework established in the older paper

As the original model by Chang et al., the present paper uses a small open-economy approach and a central bank, that uses the money supply growth rate as its main instrument to enact monetary policy. This approach is quite different to the standard of models exploring the effect of financial frictions. In these models, base money can often be omitted and the central bank's main instrument is the nominal policy interest rate. A paper using such a model is a 2010 paper published by Ali Dib. Dib evaluates the role of the banking sector in the transmission of aggregate shocks into the real economy. The banking sector proposed by Dib is the basis for the banking sector implemented in the present paper. Further input into the configuration of the banking sector is derived from a paper published by Björn Hilberg and Josef Hollmayr in 2013. Their paper develops a model similar to the model used by Dib in 2010, in order to analyze liquidity problems on the interbank market, especially when examining unconventional monetary policy.
The capital creator as an important part of the real economy represented in the model was implemented in reference to the capital creator used in the PESSOA model described by Vanda Almeida et al. in a 2013 publication. The paper describes in depth a DSGE model for a small economy within a monetary union (where monetary policy is decided outside of the domestic economy). This is also linked to the New Area Wide Model (NAWM) for the Euro-zone as described by Kai Christoffel, Günter Coenen and Anders Warne in 2008.
The implementation of financial frictions is further inspired by the framework for credit market frictions in business cycle analysis presented by Mark Gertler and Nobuhiro Kiyotaki in the 2010 edition of the Handbook of Monetary Economics. Another source of inspiration is a 2011 publication by Mark Gertler and Peter Karadi concerned with the effects of unconventional monetary policy in the presence of financial frictions. A more recent model examining the effect of financial frictions taken into account in the development of the present paper is a paper published by Markus K. Brunnermeier and Yuliy Sannikov in 2014. The paper examines the dynamics of an economy when financial frictions are present.

4 Benchmark model

The basic setup of the benchmark model is that of a *small open economy* model, where the domestic country represents Mainland China and the foreign country the rest of the world. Households are modeled to derive utility from holding real money balances. Following the SOE setup, the domestic economy is taken to be sensitive to changes in the foreign economy, while the foreign economy is immune to developments on the domestic market. Given this immunity, foreign country variables can be adequately represented by exogenous processes. This applies to the foreign interest rate and foreign inflation as well as the demand for exports.[115] The domestic country is made up of five modules or agents. These are the domestic households, the singular intermediate goods producer and the central bank, a continuum of capital creators and a continuum of entrepreneurs. Households, central bank and the intermediate good producer are mostly the same as in Chang et al..[116] The capital creators are a less complex version of the capital goods producers described in the PESSOA model.[117] The entrepreneur agent is based on Dib and Hilberg.[118]. Entrepreneurs are modeled to own firms that produce a differentiated retail good, these firms are based on Chang et al..[119] The introduction of capital in the model is crucial for the introduction of financial frictions in the later iterations of the model. It is implemented here to increase the cohesion between the different model iterations and the comparability of simulation results. This step assures that the real production side is similar in all model iterations.

The domestic economy is set up in a way that is assumed to reflect the reality of the Chinese economy - it sources an aggregate of raw materials and intermediate/capital goods (assembly parts, machinery) from the foreign country and exports an aggregate of final goods. The economy is geared towards export and has a current account surplus in the initial steady-state. The imported goods are refined by the use of labor and capital into a variety of differentiated final goods in two consecutive steps. The first step is the assembly of an intermediate good using labor and the import goods and the second step is the production of retail goods using the intermediate good and capital. The differentiated retail goods are aggregated into a final good. This final good is consumed domestically by households and exported abroad. [120]

Monetary policy is characterized by a closed capital account and a pegged exchange rate. The crawling peg used in Chang et al. is not recreated in the benchmark model, a hard peg is used instead.[121] This change is implemented to reduce complexity and is possible since this change has no impact on the viability of simulation results.

Imposed by the closed capital account private domestic entities are prohibited from holding foreign currency assets and private foreign entities cannot accumulate domestic currency assets either. The model has no venue for the transfer of capital by private entities between the countries. Foreign entities are

[115] Chang et al. (2012), p.7&12

[116] Chang et al. (2012), p.8-15

[117] Almeida et al. (2013), p.33-36

[118] Dib (2010), p.16-18 and Hilberg and Hollmayr (2013), p.4-6

[119] Chang et al. (2012), p.10-11

[120] Chang et al. (2012), p.7

[121] Chang et al. (2012), p.13

barred from investing on the domestic financial market, which prevents arbitrage. This strict limitation also prohibits foreign direct investment. Accordingly foreign direct investment is not taken into account in the construction of the model.
As in Chang et al., the only government agent fleshed out in the model is the central bank. Non-monetary policy interventions by other government actors (as in investment, government consumption, treasury bonds and taxes) are outside of the scope of the model, as an inclusion would entail a significant increase in complexity without yielding more information concerning the topic discussed in this text.[122]
The central bank in the model is a reflection of the actual Chinese central bank. It deviates from the central bank agent commonly used in the literature on financial frictions in key areas. The common Taylor-rule based central bank reflects western central banking by using the policy interest rate as the primary instrument of monetary policy.[123] In contrast to this, similar to the People's Bank, whose monetary management relies on the use of quantitative targets and administrative controls, the central bank in this model controls the domestic money supply growth rate as its main instrument to conduct monetary policy.[124] The money supply growth rate is subject to a quadratic Ramsey policy function. The central bank adjusts the money supply growth rate conditional to the minimization of welfare losses incurred by deviating from a set of monetary policy targets.[125] Wages and prices are modeled as rigid following Calvo and Rotemberg.[126] With this focus the model centers on the compromises the central bank has to make to minimize its losses through deviation from policy targets and the cost incurred by its sterilization interventions. A schematic of the benchmark model can be found in figure (15) in Appendix A.

4.1 Aggregation

In the model the final good and labor are aggregated composites constructed as shown below.[127]
The retail good ($Y_{u,t}$) produced by the individual entrepreneur is aggregated into the final good (Y_t), which is then exported or consumed locally. The differentiated retail goods are situated on the interval $u \in [0, 1]$ and the aggregation technology for the final good is given by

[122] Chang et al. (2012), p.7
[123] Christiano et al. (2010), p.20-21
[124] Cassola and Porter (2011), p.3
[125] Chang et al. (2012), p.15
[126] Calvo (1983), p.385-387 and Rotemberg (1982), p.1189-1193
[127] Chang et al. (2012), p.8

$$Y_t = \left[\int_0^1 (Y_{u,t})^{\frac{\theta_u - 1}{\theta_u}} \mathrm{d}u\right]^{\frac{\theta_u}{\theta_u - 1}} \tag{1}$$

where θ_u is the elasticity of substitution between retail goods. From this the demand function for the individual retail good $Y_{u,t}$ is given by the function

$$Y_{u,t}^{\nabla} = \left[\frac{P_{u,t}}{P_t}\right]^{-\theta_u} Y_t \tag{2}$$

where $Y_{u,t}^{\nabla}$ is the demand for the differentiated retail good and P_t is the domestic price index which is related to the price of the retail good $(P_{u,t})_{u\in[0,1]}$ by $P_t \equiv \left[\int_0^1 (P_{u,t})^{(1-\theta_u)} \mathrm{d}u\right]^{\frac{1}{1-\theta_u}}$.
The aggregation for labor is similar. The differentiated labor skill $(N_{h,t})$ provided by the individual households is situated on the interval $h \in [0,1]$. The skills are aggregated into the labor composite by the technology given below

$$N_t = \left[\int_0^1 (N_{h,t})^{\frac{\theta_w - 1}{\theta_w}} \mathrm{d}h\right]^{\frac{\theta_w}{\theta_w - 1}} \tag{3}$$

where θ_w is the elasticity of substitution between the differentiated labor skills. The demand function for the labor skill $N_{h,t}$ is then described by the equation

$$N_{h,t}^{\nabla} = \left[\frac{W_{h,t}}{W_t}\right]^{-\theta_w} N_t \tag{4}$$

where W_t is the composite wage related to the wage $(W_{h,t})_{h\in[0,1]}$ of the differentiated labor skill $N_{h,t}$ by $W_t \equiv \left[\int_0^1 (W_{h,t})^{(1-\theta_w)} \mathrm{d}h\right]^{\frac{1}{1-\theta_w}}$

4.2 Household module

The domestic households are modeled according to a standard *money in the utility function* setup taken from Chang et al..[128] Based on this setup the domestic country is populated by a continuum of infinitely lived utility maximizing household agents. These households are situated on the interval $h \in [0,1]$. The inclusion of money in the utility function links the money supplied by the central bank to the real economy. In the symmetric equilibrium money supply and household money balances are equal. Utility is derived from three different sources, consumption, real money balances and leisure. Each household is equipped with a differentiated labor skill. The skill is priced at a wage set by

[128] Chang et al. (2012), p.8

the individual household. Households gain their funds for consumption and real money balances from providing their labor skill to the labor aggregation. Accordingly households face a trade-off between consumption and money balances and the exponential disutility incurred by giving up leisure time for work. The domestic households are modeled as the owner /shareholders of the entrepreneur and capital creation agents, therefore each household receives a share of the aggregated profits of both agents. Funds not consumed in the current period can be transferred into future periods by purchasing domestic central bank bonds. The utility function for the individual household is shown below.

$$U_h = E \sum_{t=0}^{\infty} \beta \left[\ln C_{h,t} + \phi_m \ln \frac{M^{\bullet}_{h,t}}{P_t} - \phi_n \frac{(N^{\nabla}_{h,t})^{1+\eta}}{1+\eta} \right] \tag{5}$$

Where $C_{h,t}$ is real consumption, $\frac{M^{\bullet}_{h,t}}{P_t}$ are the real money balances and $N^{\nabla}_{h,t}$ is the demand for units of labor provided by the household. $M^{\bullet}_{h,t}$ is the nominal money held by the individual household, in the symmetric equilibrium this is equal to the nominal money supplied by the central bank, M_t. The time preference factor indicating the strength of the household's preference for utility earned in the current period over expected utility in future periods, and by this the propensity to save, is represented by β. The real utility weight for holding real money balances is represented by ϕ_m and ϕ_n is the weight of the disutility incurred from exchanging units of leisure for units of labor. η represents the inverse Frisch elasticity for hours worked. E_t is an expectation operator.
Households maximize their lifetime utility by choosing consumption, real money balances, saving and the optimal wage subject to the demand schedule for labor and the real budget constraint. Households take demand for their labor skills as given and are monopolistically competitive in the market for labor skills. The real one period budget constraint for the individual household is stated below.

$$C_{h,t} + \frac{M^{\bullet}_{h,t}}{P_t} + \frac{G_{h,t}}{P_t} = \frac{W_{h,t} N^{\nabla}_{h,t}}{P_t} + \frac{M^{\bullet}_{h,t-1}}{P_t} + \frac{R_{t-1} B_{h,t-1}}{P_t} + \frac{\tau_{h,t}}{P_t} - \frac{\Omega_w}{2} \left(\frac{W_{h,t}}{W_{h,t-1} \bar{\pi}^{\bullet}} - 1 \right)^2 N_t \tag{6}$$

In this equation $\frac{\tau_{h,t}}{P_t}$ represents the real share of dividends the household receives from capital creator and entrepreneur agents, $\frac{G_{h,t}}{P_t}$ are the real holdings of the central bank bonds and R_t is the nominal policy interest rate set by the central bank.
Wages are modeled as rigid. Quadratic adjustment costs provide a threshold for wage adjustments that delay the reaction of wages to shocks. The equation for the quadratic adjustment costs is shown below, where Ω_w is the average wage adjustment cost and $\bar{\pi}^{\bullet}$ is steady-state wage inflation. Wage inflation is defined as $\pi^{\bullet}_t \equiv \frac{W_t}{W_{t-1}}$.

$$\frac{\Omega_w}{2}\left(\frac{W_{h,t}}{W_{h,t-1}\bar{\pi}^{\bullet}}-1\right)^2 \tag{7}$$

In the symmetrical equilibrium, each individual household is presumed to set individual nominal wages and to make identical optimization choices, subscripts can therefore be dropped. Optimality in the symmetric equilibrium is characterized by the first-order conditions of the household's utility maximization. These first-order conditions are the derivation of the utility function conditional on the demand schedule for labor and the one period budget constraint for consumption, real money balances, bonds and wages.

$$\frac{\phi_m}{M_t^{\bullet}\Lambda_t}=\frac{R_t-1}{R_t} \tag{8}$$

$$1=E_t\beta\left[\frac{\Lambda_{t+1}}{\Lambda_t}\frac{R_t}{\pi_{t+1}}\right] \tag{9}$$

$$\Lambda_t=\frac{1}{C_t} \tag{10}$$

Where Λ_t is the Lagrange multiplier for the budget constraint.
The first-order condition for wages, the wage setting rule, is described by the equation below

$$w_t=\frac{\theta_w}{\theta_w-1}\phi_n N_t^{\eta}-\frac{\Omega_w}{\theta_w-1}\left\{\left(\frac{\pi_t^{\bullet}}{\bar{\pi}^{\bullet}}-1\right)\frac{\pi_t^{\bullet}}{\bar{\pi}^{\bullet}}-\beta E_t\left(\frac{\pi_{t+1}^{\bullet}}{\bar{\pi}^{\bullet}}-1\right)\frac{\pi_{t+1}^{\bullet}}{\bar{\pi}^{\bullet}}\right\} \tag{11}$$

where $w_t\equiv\frac{W_t}{P_t}$ is the real wage.

4.3 Intermediate good producer

As in Chang et al. the production sector of the model is split in two parts with two input and one output factor each.[129] The first step of the production path is the single domestic intermediate good producer. It combines aggregate labor and the import good to create the intermediate good. The intermediate good producer is strictly a non-maximizing agent, that takes all demand and prices as given and provides the intermediate good at its real cost.
The intermediate good is produced using a common Cobb-Douglas technology without technology augmenting component. The resulting technology is as follows.

[129] Chang et al. (2012), p.8-9

$$Y_t^\dagger = N_t^\alpha Y_t^{\star,(1-\alpha)} \tag{12}$$

Where α is the expenditure share of aggregate labor, $Y_t^\dagger$ represents the intermediate good and $Y_t^\star$ is the imported good.
The nominal price for the imported good is the foreign price index $P_t^\star$. Accordingly the real price for the good is defined as $Q_t \equiv \epsilon_t \frac{P_t^\star}{P_t}$, where ϵ_t is the nominal exchange rate for the conversion of one unit of foreign currency into domestic currency. By this definition the real price Q_t for the imported good is the real exchange rate.
With this in mind changes in the real exchange rate between periods can be captured by the following equation.

$$\frac{Q_t}{Q_{t-1}} = \frac{\epsilon_t}{\epsilon_{t-1}} \frac{\pi_t^\star}{\pi_t} \tag{13}$$

where $\pi_t^\star$ is the foreign country inflation rate defined as $\pi_t^\star \equiv \frac{P_t^\star}{P_{t-1}^\star}$. The real marginal cost of the intermediate good is given by the following equation,

$$V_t^\dagger = \tilde{\alpha} w_t^\alpha Q_t^{1-\alpha} \tag{14}$$

Optimizing costs yields the following joint cost function

$$w_t N_t = \frac{\alpha}{1-\alpha} Q_t Y_t^\star \tag{15}$$

where $V_t^\dagger$ is the marginal cost and $\tilde{\alpha}$ is defined as $\alpha^{-\alpha}(1-\alpha)^{(\alpha-1)}$.

4.4 Capital creator

The capital creator implemented in this model is based on the capital creator agent presented in PESSOA.[130] Real capital represents a wide variety of infrastructure and machinery used in the production of the domestic retail good. The domestic country is populated by a continuum on infinitely lived capital creation agents situated along the interval $\kappa \in [0, 1]$. New capital is created by a linear production technology combining investments and depreciated capital from the previous period. Capital creators are perfectly competitive in input and output markets. As a simplification to the creation agent in PESSOA, the multiplier of investment is set to one and the price for investment is set equal to the domestic price index.[131] Accordingly the real price for investment is defined

[130] Almeida et al. (2013), p.33-35
[131] Almeida et al. (2013), p.33-34

as $p_{i,t} \equiv \frac{P_{i,t}}{P_t} = 1$. The development path for the capital stock of the individual capital creator is shown below,

$$K_{\kappa,t} = I_{\kappa,t} + (1-\delta)K_{\kappa,t-1} \tag{16}$$

where K_t represents real capital and δ is the domestic depreciation rate for capital.
The maximization problem of the individual capital creator is given below,

$$\tau_{\kappa,t} = p_t^{\diamond} K_{\kappa,t} - I_{\kappa,t} - p_t^{\diamond}(1-\delta)K_{\kappa,t-1} - \frac{\Omega_k}{2}\left(\frac{I_{\kappa,t}}{I_{\kappa,t-1}} - 1\right)^2 I_t \tag{17}$$

where $\tau_{\kappa,t}$ are the real net profits and the last term of the equation captures the quadratic adjustment costs for changes to investment. Ω_k stands for the average adjustment costs. $p_t^{\diamond}$ is the real capital price defined as $p_t^{\diamond} \equiv \frac{P_t^{\diamond}}{P_t}$.
The capital creator (κ) maximizes profit by choosing the optimal investment. Substituting the development path for capital into the profit equation, the following equation can be formed

$$\tau_{\kappa,t} = (p_t^{\diamond} - 1)I_{\kappa,t} - \frac{\Omega_k}{2}\left(\frac{I_{\kappa,t}}{I_{\kappa,t-1}} - 1\right)^2 I_t \tag{18}$$

From this equation the first-order condition for optimal investment can be derived. In the symmetric equilibrium with dropped subscripts the first-order condition is

$$p_t^{\diamond} = 1 + \Omega_k \left[\left(\frac{I_t}{I_{t-1}} - 1\right)\frac{I_t}{I_{t-1}} - \beta E_t \left(\frac{I_{t+1}}{I_t} - 1\right)\frac{I_{t+1}}{I_t}\right] \tag{19}$$

4.5 Entrepreneur

The entrepreneur agent replaces the retail goods firm used in the Chang et al. model. Their setup is a slight modification of the entrepreneur agent used by Dib and Hilberg and Hollmayr in combination with the retail firm agent used in Chang et al.[132] Conceptually the entrepreneurs represent managers of the firms producing the retail goods. These firms refine the intermediate good together with real capital into a differentiated retail good, using a Cobb-Douglas production technology. They are the model equivalent of the large export oriented manufacturing sector that has sprung up in China in the last decades. The domestic country is populated by a continuum of infinitely lived entrepreneurs, which are risk neutral and situated on the interval $u \in [0, 1]$.

[132] Chang et al. (2012), p.10, Dib (2010), p.16 and Hilberg and Hollmayr (2013), p.4-5

Entrepreneurs are set up to be profit maximizing. They maximize their lifetime profits by setting the price for their differentiated retail good. This maximization is subject to the demand for the final good, which is taken as given.
Entrepreneurs are monopolistically competitive for their retail good.
The individual entrepreneur's firm combines real capital and the intermediate good to produce a differentiated retail good, that is then aggregated into the final good aggregate. The retail good production technology with a technology augmenting component is given below,

$$Y_{u,t} = A_t K^{\gamma}_{u,t-1} Y^{\dagger(1-\gamma)}_t \tag{20}$$

where $Y_{u,t}$ stands for the individual retail good and γ is the expenditure share of capital. A_t represents the technology augmenting component, which is the same for all retail firms.
The technology augmenting component is constructed in the same way as in Chang et al..[133] It is composed of a permanent component $A_{\rho,t}$ and a transitory component $A_{m,t}$, the equation for the composition of A_t is $A_t = A_{\rho,t} A_{m,t}$.
$A_{\rho,t}$ follows a random walk process with the drift ψ_t, which is an AR(1) process. The equation for the drift component is given by

$$\ln \psi_t = \rho_\rho \ln(\psi_{t-1}) + (1 - \rho_\rho) \ln \bar{\psi} + \sigma_\rho \varphi_{\rho,t} \tag{21}$$

where ρ_ρ is a persistence parameter and σ_ρ is the standard deviation. φ_ρ is an exogenous shock variable. $\bar{\psi}$ is the steady-state/mean drift.
The technology drift component is used as a trend variable for the transformation of the model. The transformation of the stationary symmetric equilibrium into a balanced growth path is a reflection of the rapid growth of the Chinese economy in the period of reference. It is replicated from Chang et al.. [134]
The transitory component is a stationary (mean-reverting) stochastic process, governed by the equation

$$\ln A_{m,t} = \rho_m \ln A_{m,t-1} + \sigma_m \varphi_{m,t} \tag{22}$$

where ρ_m is a persistence parameter, and σ_m is the standard deviation. φ_m is an exogenous shock variable.
The marginal costs of production for the individual retail good, represented by $V_{u,t}$ are accordingly given by the following equation,

$$V_{u,t} = \frac{\tilde{\gamma}}{A_t} Z^{\gamma}_{u,t} V^{\dagger(1-\gamma)}_t \tag{23}$$

[133]Chang et al. (2012), p.10-11
[134]Chang et al. (2012), p.28

where $\tilde{\gamma}$ is constructed in the same way as $\tilde{\alpha}$. The variable $Z_{u,t}$ stands for the marginal productivity of the capital employed in the production process. This variable is the entry point of the net worth concept into the model and is crucial for the introduction of financial frictions in later iterations of the model. It is introduced here to enhance the cohesion between the model iterations.
Cost optimization then yields the following joint cost function for capital and the intermediate good.

$$Z_{u,t}K_{u,t-1} = \frac{\gamma}{1-\gamma}V_t^{\dagger}Y_{u,t}^{\dagger} \tag{24}$$

Conceptually capital is purchased by the entrepreneur and then rented to the entrepreneur's retail good firm. Capital is purchased in advance - capital used in the current period had to be purchased in the preceding period. In this concept the marginal productivity of capital is the rent the entrepreneur receives for holding capital. Depreciated used capital is resold to the capital creators. The realized marginal productivity and the marginal real price of the resold used capital give the realized marginal returns on holding capital shown in the equation below. Where $R_{u,t}^{\dagger}$ are the realized marginal returns on capital.

$$R_{u,t}^{\dagger} = E_t\left[Z_{u,t} + (1-\delta)p_t^{\diamond}\right] \tag{25}$$

Entrepreneurs retain the returns from holding capital, this is the entrepreneur's net worth and use it to purchase new capital for the following period. The development path for the net worth is captured in the equation below,

$$\Upsilon_{u,t} = R_{u,t}^{\dagger}K_{u,t-1} \tag{26}$$

where $\Upsilon_{u,t}$ is the net worth.
The concept of net worth is relatively superfluous in this model, as it lacks the option for external financing. Accordingly the current net worth is equal to the real value of the capital purchased. The equation below illustrates this relation.

$$\Upsilon_{u,t} = p_t^{\diamond}K_{u,t} \tag{27}$$

As stated, the entrepreneur's optimization problem is to maximize lifetime profits. The equation for the current period profits is given below.

$$\tau_{u,t} = P_{u,t}Y_{u,t}^{\nabla} - V_{u,t}Y_{u,t}^{\nabla} - \frac{\Omega_y}{2}\left(\frac{P_{u,t}}{P_{u,t-1}\bar{\pi}} - 1\right)^2 Y_t \tag{28}$$

Ω_y are accordingly the average adjustment costs and $\bar{\pi}$ is the steady-state domestic inflation. The variable $\tau_{u,t}$ stands for the real net profits and the last term of the equation are the quadratic costs for the adjustment of the price of the retail good.

Solving for the retail good price subject to the demand for the retail good yields the following first order condition for optimality in the symmetric equilibrium. Subscripts are dropped as before.

$$V_t = \frac{\theta_y - 1}{\theta_y} + \frac{\Omega_y}{\theta_y}\left[\left(\frac{\pi_t}{\bar{\pi}} - 1\right)\frac{\pi_t}{\bar{\pi}} - \beta E_t\left(\frac{\pi_{t+1}}{\bar{\pi}} - 1\right)\frac{\pi_{t+1}}{\bar{\pi}}\right] \tag{29}$$

4.6 Foreign country

The open economy aspect of the model is established through the inclusion of the foreign country agent, which conceptually represents the rest of the world. In line with the SOE premise, the foreign country is immune to changes within the domestic country. The foreign country purchases the final good from the domestic country and provides the import good to the intermediate good producer. The foreign country offers foreign currency assets on the foreign finance markets, that pay the foreign interest rate - since the capital account is closed only the domestic government can hold foreign currency assets.[135]
The foreign interest rate is represented by an autoregressive process AR(1) with the equation

$$R_t^\star = \rho_r \ln R_{t-1}^\star + (1 - \rho_r)\ln \bar{r}^\star + \sigma_r \varphi_{r,t} \tag{30}$$

where $R_t^\star$ is the foreign interest rate, $\bar{r}^\star$ is the steady-state foreign interest rate, ρ_r is the persistence parameter and σ_r is the standard deviation of the AR process. The variable $\varphi_{r,t}$ is the exogenous foreign interest rate shock.
Export demand is inversely related to the price of the final good and positively related to the exogenous export demand component . By including the technology drift component a balanced growth of the export demand is assured. The equation for export demand is then as below,

$$X_t = \left(\frac{P_t}{\epsilon_t P_t^\star}\right)^{-\theta_\star} \tilde{X}_t^\star A_{\rho,t} = Q_t^{\theta^\star} \tilde{X}_t^\star A_{\rho,t} \tag{31}$$

where X_t represents exports (which are equivalent to export demand) and $\tilde{X}^\star$ is the exogenous export demand component. $\theta_\star$ is the export demand elasticity.
The exogenous export demand component follows an AR(1) process given by the following equation,

$$\tilde{X}_t^\star = \rho_\star \ln \tilde{X}_{t-1}^\star + (1 - \rho_\star)\ln \bar{\tilde{x}}^\star + \sigma_\star \varphi_t^\star \tag{32}$$

where $\rho_\star$ is a persistence parameter, $\bar{\tilde{x}}^\star$ is the steady-state export demand component, $\sigma_\star$ is the standard deviation and $\varphi_t^\star$ is the exogenous export demand shock.

[135] Chang et al. (2012), p.12

The current account is defined as the sum of net exports and interest income from holding foreign currency assets - as the capital account is closed foreign country agents cannot hold domestic currency assets. The current account is therefore captured by the equation below

$$\Theta_t \equiv X_t - Q_t Y_t^\star + \frac{\epsilon_t (R_{t-1}^\star - 1) B_{t-1}^\star}{P_t} \tag{33}$$

4.7 Central bank

The sole government entity fleshed out in the model is the domestic central bank. In this iteration of the model the central bank is tied to the government's commitment to a fixed exchange rate and a closed capital account and monetary policy is informed by this mandate. A mandate that the central bank has to adhere to regardless of the effort necessary for the maintenance of the framework. The central bank is constructed according to Chang et al..[136] The central instrument of monetary policy used in the simulation, is that the central bank controls the growth of the money supply. The growth rate is set by the central bank and controls the inter-period changes to the domestic money supply, the relation is defined by $\mu_t \equiv \frac{M_t}{M_{t-1}}$.
Conceptually, entrepreneurs acquire foreign currency through their gains from exporting the final good. These gains are then immediately exchanged for domestic currency at the pegged nominal exchange rate, as private entities are barred from holding foreign assets. Imports are payed for by foreign currency that the intermediate good producer exchanges with the central bank for domestic currency. In a second step the central bank invests the foreign currency it acquires through this process in foreign currency assets. The model abstracts this process by omitting the exchange between entrepreneurs and the intermediate good producer with the central bank. So that the net profit from exports and imports is directly reflected in the change of the central bank's foreign asset holdings. Accordingly the current account is tied to the change in the central bank's foreign asset holdings by the relation given below.[137]

$$\Theta_t = \epsilon_t \frac{B_t^\star - B_{t-1}^\star}{P_t^\star} \tag{34}$$

When the current account is negative, foreign asset holdings are reduced. If the negative current account persists long enough or becomes massive enough, the central bank's foreign asset holdings would be depleted and it would have to acquire foreign currency credit to maintain the chosen monetary policy path. In

[136] Chang et al. (2012), p.12-13
[137] Chang et al. (2012), p.12

the case of a current account surplus, the foreign asset holdings of the central bank grow. Over time, as is the case in China, the foreign asset holdings can become fairly large and the influence of the central bank on the market for foreign assets can become an impediment to the conduct of monetary policy. Without subsequent interventions by the central bank, current account imbalances would either increase or decrease the domestic money supply. For the model central bank this is generally undesirable as it would mean to deviate from the bank's policy target on the domestic money supply - which is coupled with policy losses as well as unintended effects on the domestic economy. Consequently the central bank engages in sterilizing behavior to manage the growth of the money supply. This is accomplished by swapping central bank bonds with the private sector for domestic currency. As such the intervention is not neutral to the central bank balance, but it shifts the growth in liabilities from the money supply to fixed term debt - effectively taking the money created by the central bank out of the economy. Complete sterilization of the current account surplus would be reached if the money supply remained unchanged in the event of changes to the current account surplus. The change in the foreign asset holding of the central bank would instead be answered by a change in the central bank bonds, as shown by Chang et al..[138] Conceptually though full sterilization might not be desirable. There is on one hand the issue of costly sterilization, describing a situation where the interest on central bank bonds is higher then the foreign interest rate. On the other hand sterilization interferes with other policy targets, especially with the target on the domestic policy interest rate. Accordingly it can be assumed that sterilization might not be complete, but that the central bank allows for a certain amount of change in the domestic money supply, dependent on the current account. The central bank's flow of funds budget is captured by the equation below.[139]

$$\epsilon_t \left(B_t^\star - R_{t-1}^\star B_{t-1}^\star \right) = M_t - M_{t-1} + G_t - R_{t-1} G_{t-1} \tag{35}$$

4.8 Conditions for market clearing and equilibrium

An equilibrium in the model economy is reached when, taking every price but the price for its own retail good as given, the price and resource allocations for each individual entrepreneur solves its profit maximization problem. The wage and the allocations for each individual household solves the utility maximizing problems, when all prices and wages but its own are taken as given. When each individual capital creator takes all prices and investment allocations as given but

[138] Chang et al. (2012), p.12
[139] Chang et al. (2012), p.12

its own, the investment allocation solves its profit maximizing problem.
Additionally the markets for final goods, the intermediate good, composite labor, composite capital, money balances and bond holdings all clear.[140]
Given government policy, the set of equations below characterize the conditions under which the model economy reaches a symmetric equilibrium.

$$Y_t = C_t + X_t + I_t + \left[\frac{\Omega_y}{2} \left(\frac{\pi_t}{\bar{\pi}} - 1 \right)^2 + \frac{\Omega_w}{2} \left(\frac{\pi^\bullet}{\bar{\pi}^\bullet} - 1 \right)^2 + \frac{\Omega_k}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right] Y_t \quad (36)$$

$$GDP_t = C_t + X_t - Q_t Y_t^\star + I_t \quad (37)$$

$$M_t^\bullet = M_t \quad (38)$$

$$K_t = \int_0^1 K_{u,t} \mathrm{d}(u) \quad (39)$$

$$Y_t^\dagger = \int_0^1 Y_{u,t}^\dagger \mathrm{d}(u) \quad (40)$$

4.9 Quadratic Ramsey Policy Function

Key to the simulation is the concept of optimization by the central bank. This is introduced by attributing a set of different targets for conflicting monetary policy goals into a quadratic Ramsey policy function. Three of these targets are fairly standard and consist of a target for the domestic policy interest rate, the GDP and domestic inflation. The target on the nominal policy rate is a reflection of the central bank's desire for a smoothing of changes in the domestic policy rate. The motive of interest rate smoothing is a common assumption of financial frictions literature, typically expressed by the assumption that policy rate setting is governed by a rate smoothing Taylor rule. If the central bank has to adjust the policy interest rate following a shock on the foreign interest rate, this interferes with the central bank's ability to autonomously set the domestic policy rate. This would create an undesired and unpredicted deviation from the targeted development path of the policy rate. Chang et al. innovate this standard trio by adding a target for the ratio of foreign currency assets held by the central bank to the domestic GDP.[141] Conceptually this is a reflection of the reluctance of the Chinese central bank to conduct disruptive operations on the foreign financial

[140] Chang et al. (2012), p.14
[141] Chang et al. (2012), p.15

market during the international financial crisis and the ensuing US recession. For the simulation the introduction of the target for foreign currency assets is necessary to restrain the model central bank from answering shocks in foreign interest rates solely by selling its foreign currency assets. If in the simulation the foreign interest rate shocks are deemed to impact the domestic economy, then the central bank must be constructed as having a reluctance to radically change its foreign asset holdings.

Attributed to each of the policy targets is a policy weight. These weights reflect the importance the central bank attributes to maintaining a given target. For this simulation the weights used are the same as in Chang et al.. Accordingly the weight on the policy interest rate target is set at $\Delta_r = 5$, the weight on the GDP target is $\Delta_{gdp} = 0.05$, the weight on domestic inflation $\Delta_\pi = 1$ and finally the weight on the GDP to foreign assets ratio is given by $\Delta_\star = 0.01$. The target hierarchy imposed by this choice replicates a central bank with a significant preference for interest rate smoothing and to a lesser degree inflation control over domestic GDP and the GDP to foreign assets ratio.[142]

Given the weights, the central bank optimizes by minimizing the overall loss incurred from target deviation - it minimizes a Quadratic Ramsey Policy Function subject to log-linear optimization conditions.[143] In the simulation the policy targets are set to be equal to the steady-state values of the policy variables. Deviations from targets are then represented by the log-linearized deviations of the variables from their steady-state values. Optimality is accordingly characterized by minimizing the quadratic losses from the log-linearized deviations from the steady-state, captured by the Quadratic Ramsey Policy Function given below.[144]

$$\varsigma_t = \sum_t^\infty \Delta_r(\hat{r}_t)^2 + \Delta_{gdp}(\hat{gdp}_t)^2 + \Delta_\pi(\hat{\pi}_t)^2 + \Delta_\star(\hat{gdp}_t - \hat{b}_t^\star)^2 \tag{41}$$

where ς_t is the overall loss to be minimized, $\hat{r}_t$, $\hat{gdp}_t$, $\hat{\pi}_t$ and $\hat{b}_t$ are the log-linearized deviations of the policy rate, GDP, domestic inflation and central bank bonds from their steady-state value respectively.[145]

A An elaboration on the argument for a weight on the foreign asset to GDP ratio

Key to the experiment undertaken in this paper is the assumption of a central bank that aims at smoothing the development of the domestic country's net

[142] Chang et al. (2012), p.16-17
[143] Chang et al. (2012), p.15
[144] Chang et al. (2012), p.15
[145] Chang et al. (2012), p.17

international position. This is introduced in the model configuration by defining a policy target for the foreign assets to GDP ratio.[146] The formulation of this axiom is crucial for the simulation of the effects of a negative foreign interest rate shock on the domestic monetary policy. It creates a path through which the foreign interest rate shock can affect the domestic economy. Without it the shock can be absorbed by a proportional reduction of the growth of the foreign asset position of the central bank. Accordingly the shock would only affect the current account surplus and the foreign assets position. The transmission of the shock into the domestic economy is dependent upon the existence of a cost associated with a change to the foreign assets to GDP ratio.[147] This quadratic cost assures that the growth of the foreign assets position of the central bank is reduced less than it would have to in order to completely absorb the foreign interest rate shock. The reduction of the growth reaches a point, at which a further decrease is more costly than the deviation of other policy targets would be. Minimization of the Ramsey function then precipitates an increase of money supply growth to prevent a further decrease of the foreign assets growth.
Chang et al. justify their introduction of a central bank with a desire to avoid large fluctuations of its foreign asset holdings relative to GDP with two arguments. The empirical observation, that abrupt changes to the foreign assets to GDP ratio have not been observed in the past, and that the sharp decline in returns on foreign assets following the financial crisis has not caused a substantial sell off of foreign assets by the Chinese central bank. The second argument derives from the dominant position of the PBOC on especially the market for US Treasuries. The PBOC position on the market means, that it is keenly observed by other market participants and that changes in the central bank's behavior are likely to affect world prices.[148] Given the persistence of current account surpluses for Mainland China in the aftermath of the financial crisis, the empirical argument needs further elaboration. The repatriation of earnings from exports and outward investment leads to an accumulation of foreign currency by the central bank in some form and with a positive current account the assets accrued by this are more than is needed to account for the outward flow of funds from China to the rest of the world. Accordingly the argument is not that the persistent growth of the foreign asset position is proof enough for a policy of smoothing concerning the foreign assets to GDP ratio. The argument is more precisely that the reduction in interest rate earnings from foreign assets has not been fully compensated by a proportional reduction in the growth of the foreign asset holdings. Secondly the argument is, that despite the

[146] Chang et al. (2012), p.15
[147] Chang et al. (2012), p.15
[148] Chang et al. (2012), p.15

sharp decline in remuneration for US Treasuries in the direct aftermath of the financial crisis, this has not induced a drastic reconfiguration of the PBOC foreign asset portfolio at that precise point in time.

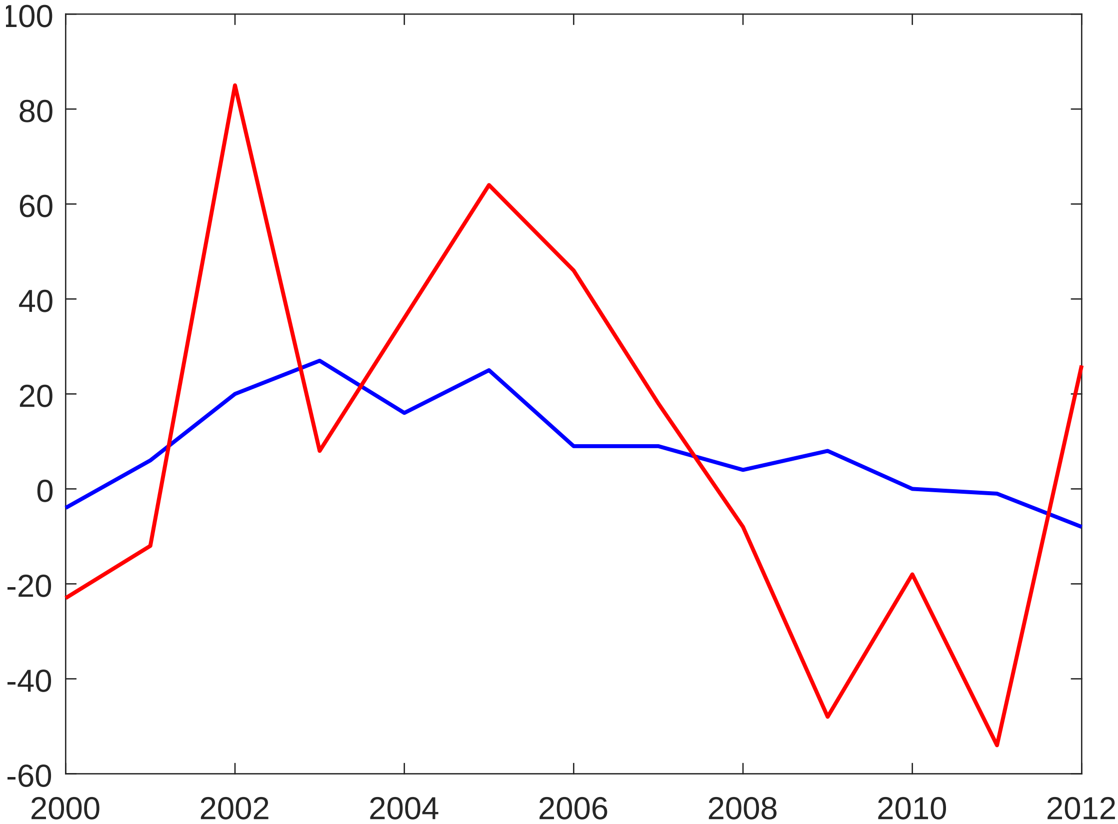

Figure 5: Annual change in percent of the foreign asset to GDP ratio and the current account to GDP ratio for Mainland China [149]

Figure(5) shows the annual changes in percent of the foreign asset to GDP ratio and the current account to GDP ratio. It can be observed, that the fluctuations of the foreign assets to GDP ratio have become more subdued over time and that especially the financial crisis has not induced a strong reaction of the ratio. The foreign asset ratio grew by 4.11% from 2007 to 2008 and by 7.56% from 2008 to 2009, while the current account surplus grew by 19.08% from 2007 to 2008 and declined by 42.16% from 2008 to 2009. The graph also highlights another important factor of the discussion, the assumption of a desire to smooth the development of the foreign assets to GDP ratio by the Chinese central bank is not presumed to be a general rule of the Chinese monetary policy in this paper. It is valid uniquely for the period of the financial crisis and its direct aftermath.

[149] Data: Federal Reserve Bank of St. Louis (2007-2012)

Several factors come together at the onset of the financial crisis, that validate the assumption of a desire to smooth the foreign asset to GDP ratio by the PBOC. The first is the market position argument brought forth by Chang et al.. China's position on the market combined with the uncertainty prevailing in financial markets about the extent of the crisis, meant that the biggest entity in the market for US Treasuries was observed closely by other market participants. Severely limiting the space in which a change to the central bank's behavior could occur without further destabilizing the international monetary framework. Media reports about an alleged threat by China to sell its Dollar reserves were countered with an affirmation of China's role as responsible investor and the long-term nature of its investment. [150]
The second factor derives from the potential market impact of an abrupt change in central bank behavior. A rapid decline in the value of foreign assets would counteract the stated goal of preservation and appreciation of China's national exchange reserves, which is a guiding principle of the State Administration of Foreign Exchange's conduct.[151] The value preservation intention favors an approach that tries to avoid sending strong signals towards other market participants. The SAFE notes, that the financial crisis provided a significant test for the operation and management of foreign reserves. A test that the administration claims to have withstood by adopting a prudent approach towards the effects of the international financial crisis.[152] The SAFE acted for example by purchasing bonds from international financial organizations and by 'buoying up' overseas investment and international cooperation.[153]
The third factor comes from the commitment of the Chinese government to the international effort to contain and reduce the effects of the financial crisis on the international monetary framework. The PBOC participated in the international response to the financial crisis. Among others engaging in the fund raising of the IMF, by purchasing up to 50 billion US-Dollars in IMF Notes.[154]

4.10 Balanced growth path and parameter calibration

For the simulation - as in Chang et al. - the model given above is transformed into a balanced growth path model, where output, consumption, real money balances, current account balances, real domestic debt, real foreign assets, real investment, and the real wage grow at a constant rate. The transformation reflects the rapid growth of the Chinese economy. The balanced growth path is

[150]People's Bank of China (2007)
[151]Chinese State Administration of Foreign Exchange (2009)
[152]Chinese State Administration of Foreign Exchange (2009)
[153]People's Bank of China (2010), p.60
[154]People's Bank of China (2010), p.32

established by stationary transformations as shown below.[155]

$$y_t = \frac{Y_t}{A_\rho} \quad , \quad w_t = \frac{W_t}{P_t A_\rho} \quad , \quad p_t^\diamond = \frac{P_t^\diamond}{P_t A_\rho} \quad , \quad c_t = \frac{C_t}{A_\rho}$$
$$m_t = \frac{M_t}{P_t A_\rho} \quad , \quad g_t = \frac{G_t}{P_t A_\rho} \quad , \quad y_t^\star = \frac{Y_t^\star}{A_\rho} \quad , \quad i_t = \frac{I_t}{A_\rho} \tag{42}$$
$$z_t = \frac{Z_t}{A_\rho} \quad , \quad \tilde{\Theta}_t = \frac{\Theta_t}{A_\rho} \quad , \quad b_t^\star = \frac{B_t^\star}{P_t^\star A_\rho} \quad , \quad \tilde{\Upsilon}_t = \frac{\Upsilon_t}{A_\rho}$$

Following these transformations, the balanced growth equilibrium is summarized by the set of equations for the endogenous variables given below

Domestic household

$$\frac{\phi_m}{m_t \lambda_t} = \frac{r_t - 1}{r_t} \tag{43}$$

$$1 = E_t \beta \left[\frac{\lambda_{t+1}}{\lambda_t \psi_{t+1}} \frac{r_t}{\pi_{t+1}} \right] \tag{44}$$

$$\lambda_t = \frac{1}{c_t} \tag{45}$$

$$w_t = \frac{\theta_w}{\theta_w - 1} \phi_n n_t^\eta - \frac{\Omega_w}{\theta_w - 1} \left\{ \left(\frac{\pi_t^\bullet}{\bar{\pi}^\bullet} - 1 \right) \frac{\pi_t^\bullet}{\bar{\pi}^\bullet} - \beta E_t \left(\frac{\pi_{t+1}^\bullet}{\bar{\pi}^\bullet} - 1 \right) \frac{\pi_{t+1}^\bullet}{\bar{\pi}^\bullet} \right\} \tag{46}$$

$$\frac{w_t}{w_{t-1}} = \frac{\pi_t^\bullet}{\pi_t \psi_t} \tag{47}$$

Intermediate goods producer

$$y_t^\dagger = n_t^\alpha y_t^{\star(1-\alpha)} \tag{48}$$

$$\frac{q_t}{q_{t-1}} = \frac{\pi_t^\star}{\pi_t \psi_t} \tag{49}$$

$$v_t^\dagger = \tilde{\alpha} w_t^\alpha q_t^{(1-\alpha)} \tag{50}$$

$$w_t n_t = \frac{\alpha}{1-\alpha} q_t y_t^\star \tag{51}$$

Capital creator

$$k_t = i_t + \frac{(1-\delta)}{\psi_t} k_{t-1} \tag{52}$$

$$p_t^\diamond = 1 + \Omega_k \left\{ \left(\frac{i_t}{i_{t-1}} - 1 \right) \frac{i_t}{i_{t-1}} - \beta E_t \left(\frac{i_{t+1}}{i_t} - 1 \right) \frac{i_{t+1}}{i_t} \right\} \tag{53}$$

Entrepreneur

$$\tilde{\Upsilon}_t = p_t^\diamond k_t \tag{54}$$

[155] Chang et al. (2012), p.28

$$\tilde{\Upsilon}_t = r^{\dagger}{}_t k_{t-1} \tag{55}$$

$$r^{\dagger}{}_t = z_t + (1-\delta)p_t^{\diamond} \tag{56}$$

$$y_t = A_{m,t} k_{t-1}^{\gamma} y_t^{\dagger(1-\gamma)} \tag{57}$$

$$v_t = \tilde{\gamma} z_t^{\gamma} v_t^{\dagger(1-\gamma)} \tag{58}$$

$$z_t k_{t-1} = \frac{\gamma}{1-\gamma} v_t^{\dagger} y_t^{\dagger} \tag{59}$$

$$v_t = \frac{\theta_y - 1}{\theta_y} + \frac{\Omega_y}{\theta_y} \left\{ \left(\frac{\pi_t}{\bar{\pi}} - 1\right) \frac{\pi_t}{\bar{\pi}} - \beta E_t \left(\frac{\pi_{t+1}}{\bar{\pi}} - 1\right) \frac{\pi_{t+1}}{\bar{\pi}} \right\} \tag{60}$$

Foreign country

$$x_t = q_t^{\theta_{\star}} \tilde{x}^{\star} \tag{61}$$

$$\tilde{\Theta}_t = x_t - q_t y_t^{\star} + q_t \frac{(r_{t-1}^{\star} - 1) b_{t-1}^{\star}}{\pi_t^{\star} \psi_t} \tag{62}$$

Central bank

$$\tilde{\Theta}_t = q_t \left(b_t^{\star} - \frac{b_{t-1}^{\star}}{\pi_t^{\star} \psi_t} \right) \tag{63}$$

$$q_t \left(b_t^{\star} - \frac{r_{t-1}^{\star} b_{t-1}^{\star}}{\pi_t^{\star} \psi_t} \right) = m_t - \frac{m_{t-1}}{\pi_t \psi_t} + g_t - \frac{r_{t-1} g_{t-1}}{\pi_t \psi_t} \tag{64}$$

$$\frac{m_t}{m_{t-1}} = \frac{\mu_t}{\pi_t \psi_t} \tag{65}$$

Equilibrium conditions

$$y_t = c_t + x_t + i_t + \left[\frac{\Omega_y}{2} \left(\frac{\pi_t}{\bar{\pi}} - 1\right)^2 + \frac{\Omega_w}{2} \left(\frac{\pi_w}{\bar{\pi}_w} - 1\right)^2 + \frac{\Omega_k}{2} \left(\frac{i_t}{i_{t-1}} - 1\right)^2 \right] y_t \tag{66}$$

$$gdp_t = c_t + x_t - q_t y_t^{\star} + i_t \tag{67}$$

A Parameter choice

A key part in the simulation of the model presented above is the choice of values for the constant parameters. The choice is inspired by the idea of capturing features of the Chinese economy. The first apparent thing is the higher propensity to save than in more advanced western countries in general, which is introduced by a particularly high time preference factor of $\beta = 0.998$. There is only a relatively small discount for the utility of future consumption and real money balances. As in Chang et al., the weight on real money balances is set at $\phi_m = 0.06$. This implies that real money holdings provide relatively little utility. The weight on the disutility from hours worked is set at $\phi_n = 1.013$, which is the

same as in Dib 2012. The inverse Frisch elasticity for hours worked is set to $\eta = 10$ giving a Frisch elasticity of labor supply of 0.01 as in Chang et al.. The export demand elasticity $\theta_\star$ is set to 1.5 as in Chang et al.. The elasticity of substitution for the differentiated labor skills is set at $\theta_w = 10$ with the average adjustment cost of wage changes given by $\Omega_w = 100$, representing an average duration for the wage contract of four quarters. The elasticity of substitution for the differentiated final good is set to $\theta_y = 10$ and the average adjustment costs are calibrated to $\Omega_y = 30$, which gives an average duration for the retail good price contract of three quarters. Given the idea of sluggish investment adjustment taken form PESSOA, the average investment contract is supposed to last for four quarters, the average adjustment costs are then $\Omega_k = 100$.[156]
The share of labor in the production of the intermediate good is set at $\alpha = 1/2$ giving an equal weight to the imported good in comparison to labor. The share of the real capital in the production of the retail good is set at $\gamma = 1/3$, favoring the intermediate good over capital. The intertemporal depreciation rate is set to 0.025, as in Dib.[157]

Parameter	Value
β	0.998
θ_y	10
θ_k	10
θ_w	10
$\theta_\star$	1.5
Ω_w	100
Ω_y	30
Ω_k	100
η	10
ϕ_n	1.013
ϕ_m	0.06
α	1/2
γ	1/3
δ	0.025

Table 3: Calibrated parameter values

B Steady-state calibration

The second step in the numerical solution of the model is the calculation of an initial steady-state without exogenous processes. This simulation is based on a steady-state, that is calculated using a number of preset key variables meant to reflect the actual Chinese GDP composition in the past decade, as shown in World Bank statistics. For the simulation the GDP is thought to be split between private consumption, government spending, capital formation (investment) and net exports. The statistics yield a GDP composition for 2013 (in brackets the figures for 2000) as consumption is at 36% (47%), government spending at 14% (16%), investment at 48% (35%). Exports were at 23% (21%) and imports at 21% (19%). Which yields average net exports of 2%. As government spending is not part of the model, this is lumped together with private consumption.[158]
Starting from $\bar{gdp} = 1$, the components of GDP are set to consumption $\bar{c} = 0.50$, investment set to $\bar{i} = 0.48$ and net exports set at $\bar{x} - \bar{q}\bar{y}^\star = 0.02$. The steady-state value for the technology drift is set to $\bar{\psi} = 1.02$ as in Chang et al..

[156] Chang et al. (2012), p.16-17, Dib (2010), p.34, Almeida et al. (2013), p.33
[157] Dib (2010), p.34
[158] Source: The World Bank (2000-2013)

Foreign inflation is set to $\bar{\pi}\bar{\psi}$. The domestic interest rate is set to $\bar{r} = 1.01$ and the foreign interest rate is set to $\bar{r}^{\star} = 1.02$ creating an initial interest differential that favors the foreign interest rate as in Chang et al. The stationary technology component is set to unity. [159]

The initial steady-state is subject to a one percent negative shock on the foreign interest rate. The shock is calibrated as relatively persistent - with the persistence parameter set to $\rho_r = 0.97$.

Variable	Value
$\bar{r}$	1.01
$\bar{r}^{\star}$	1.02
$\bar{\psi}$	1.02
$\bar{\pi}$	$\beta\frac{\bar{r}}{\bar{\psi}}$
$\bar{\pi}^{\star}$	$\bar{\pi}\bar{\psi}$
$\bar{A}_m$	1
ρ_r	0.97

Table 4: Calibrated values of preset steady-state variables

4.11 Simulation results

The full set of equations for the steady-state and log-linear form of the endogenous variables of the benchmark model can be found in Appenix A. The impulse response functions (IRF) of the variables represented in the Ramsey function are shown in figure (6).

Broad strokes: As can be seen in the IRF, there are two distinct immediate effects of the foreign interest rate shock. The first is a decline in the nominal policy rate and the second is an initial expansion of the domestic economy. Both developments are linked to the reversal of the differential between the policy rate and the foreign interest rate. In the steady-state, the foreign interest rate was above the policy rate. The shock pushes the foreign interest rate below the policy rate. This puts pressure on the policy rate. Central bank policy though is strongly biased against target deviations of the policy rate. The policy rate declines, but not as much as it would have to reestablish the steady-state interest differential. Which leaves the central bank in an unfavorable position concerning its sterilization of the current account surplus. Domestic bonds now carry higher interest than foreign assets. Accordingly the scale of sterilization decreases, leading to an increase of the money supply. The money supply increase pushes inflation and with sticky prices, this leads to an initial expansion of the domestic economy.

In detail: To assess the results shown in the IRF, it is helpful to look at the way in which the decline of the foreign interest rates propagates through the model. In the log-linear version of the model, there are two endogenous equations, which directly include the foreign interest rate: The equation capturing the current

[159] Chang et al. (2012), p.16-17

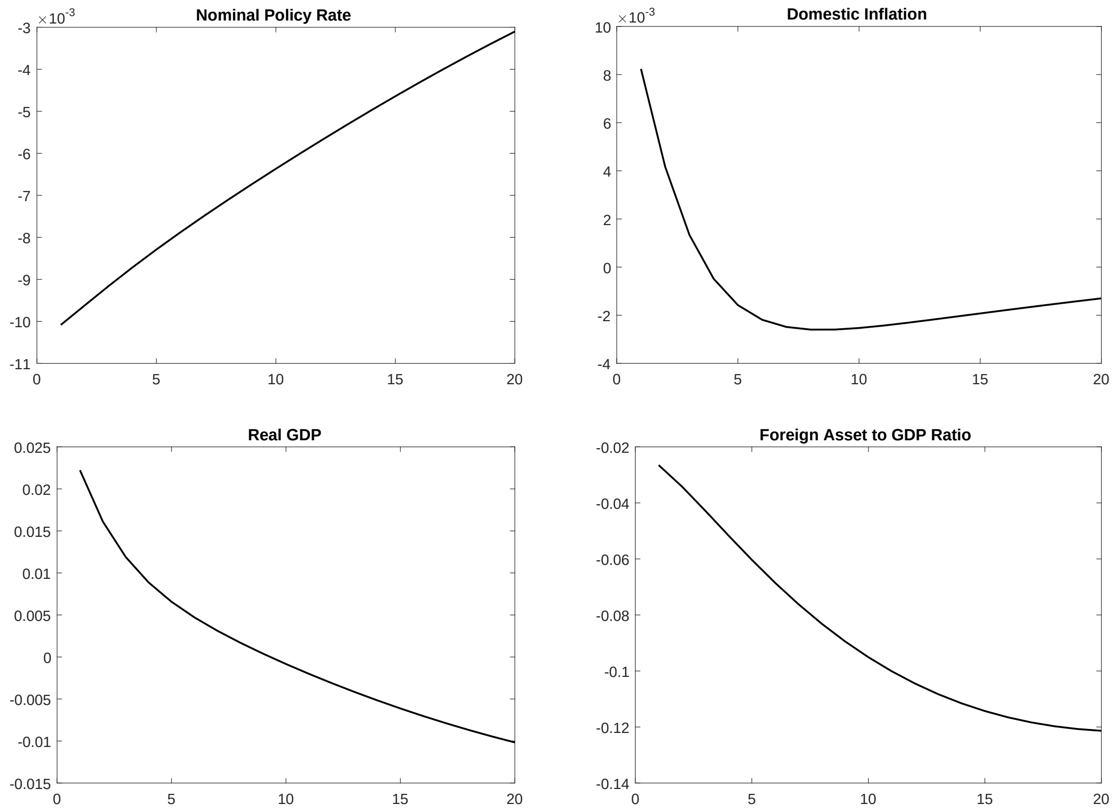

Figure 6: Deviations of log-linearized policy variables from the steady-state over 20 periods in percent after a persistent negative 1% foreign interest rate shock

account surplus and the equation for the central banks flow of funds budget. In both equations the foreign interest rate is included with a one-period lag.[160] Without the policy weight on the foreign asset to GDP ratio, simulating the model shows that only foreign assets, current account surplus and the foreign asset to GDP ratio are affected by the decline of the foreign interest rate. The IRF show a delayed reaction of the endogenous variables to the shock, conforming to the lag on the foreign interest rate; there is no reaction of the model in the initial period. While the second period shows a sharp decline in the current account surplus, due to the reduction in the interest earnings from foreign assets. Foreign assets and foreign asset ratio start to decline slowly after the initial period. The decline in the foreign assets implies that the central bank's flow of funds budget remains balanced throughout. As described, the flow

[160]See equations (174) and (176) in Appendix A

of funds budget of the central bank is given by the equation

$$\epsilon_t \left(B_t^{\star} - R_{t-1}^{\star} B_{t-1}^{\star} \right) = M_t - M_{t-1} + G_t - R_{t-1} G_{t-1} \tag{68}$$

According to this the asset side of the flow of funds budget would increase, if foreign assets remained stable, necessitating an increase on the liabilities side of the budget. But without a weight on the foreign asset to GDP ratio, the central bank reduces foreign assets to match the decline in interest earnings from holding foreign assets in the preceding period. By this the propagation of the decline of the foreign interest rate is kept from affecting the domestic economy, with the drawback of having a massive variance in the foreign asset to GDP ratio of 7.32%.
The description above explains how the foreign interest decline affects the domestic economy, when a weight on the foreign asset to GDP ratio is implemented. With the weight it is prohibitively costly for the central bank to reduce its foreign asset holdings to the degree that would be necessary to match the decline in interest earnings from holding foreign assets in the preceding period. Optimizing the loss function leads to an immediate reaction of the central bank to the decline in the foreign interest rate.
The central bank reduces its holdings of foreign assets in the initial period. Logically the deviations from the steady-state in the steady-state are zero, meaning that variables that enter the model with a one-period lag are zero in the initial period. Accordingly the initial decrease in foreign assets leads to an increase on the asset side of the flow of funds budget. Which has to be matched by a reduction on the liabilities side of the budget.
If there was no weight on the domestic policy rate, the central bank could maintain the steady-state interest rate differential by reducing the domestic policy interest rate accordingly. Then the optimal reaction would be a reduction of central bank bonds in line with the reduction of foreign assets, thus keeping the flow of funds budget balanced. With the weight, keeping the differential is too costly for the central bank, the central bank is forced to intervene to stabilize the domestic policy rate. Accordingly the reduction of the domestic policy rate is not as strong as would be necessary. This makes sterilization through the issuance of central bank bonds less attractive for the central bank. Central bank bonds decline sharply in the initial period, reflecting this reduced desirability for the central bank.
This leaves the flow of funds budget unbalanced. The decrease in liabilities is higher than the decrease in assets. There is only one avenue left open to achieve a balance: an increase in the domestic money supply. The central bank controls the money growth rate and a sharp increase in the growth rate can be observed in the initial period. In the model, the money growth rate is the outcome of the loss minimizing Ramsey function. Given the optimizations of the private entities,

minimizing the loss function results in the money growth rate increase observed in the simulation. The optimization governs how strongly the central bank intervenes and how much it lets the foreign assets to GDP ratio, domestic inflation, real GDP and the domestic policy rate deviate from their steady-state values.
The changes in the central bank's flow of funds budget and the money supply then propagate into the domestic economy. In the log-linear model the equations affected by the changes are the first order conditions of the domestic household. The domestic households are the counterparts to the central bank bonds and are holding real money balances, it is therefore logical that their optimization is affected. Equation (155) and the Euler equation (156) connect the domestic policy rate and money supply with the households' Lagrange multiplier. The strong initial increase in the money supply forces the Lagrange multiplier to decline, while the simultaneous depreciation of the domestic policy rate reduces this effect somewhat.
The Lagrange multiplier is negatively correlated with domestic consumption. A decrease in the Lagrange multiplier entails an increase in domestic consumption. Lower interest rates make saving less attractive and lead to reallocation of household funds into real money balances and consumption. This increase in consumption drives domestic demand, increasing overall output. The economy experiences an expansionary push in the initial period, that would be absent without the intervention of the central bank.
The demand for the imported good increases and the marginal productivity of capital increases, driving the marginal costs for the retail good upwards initially. The initial rise in inflation can be attributed to the increase in marginal costs for the retail good. The higher demand for labor drives real wages upwards. This increase is dampened by the existence of wage rigidities. Wage inflation rises initially in line with the overall inflationary impulse following the increase in the money supply.
The real exchange rate is negatively correlated with domestic inflation. Accordingly the real exchange rate depreciates initially, as inflation increases. This lowers the real price for the import good, reducing the increase in the marginal costs for the intermediate good - and a strong initial expansion of imports. Since export demand is tied to the real exchange rate, export demand declines as the real exchange rate depreciates.
In the post initial period two things occur, the shock on the foreign interest rate begins to fade out of the simulation and the lagged foreign interest rate affects the model through the current account surplus and the flow of funds budget. This is the period with the strongest decrease of the current account surplus. The increase in wages, the depreciation of the real exchange rate and the decline

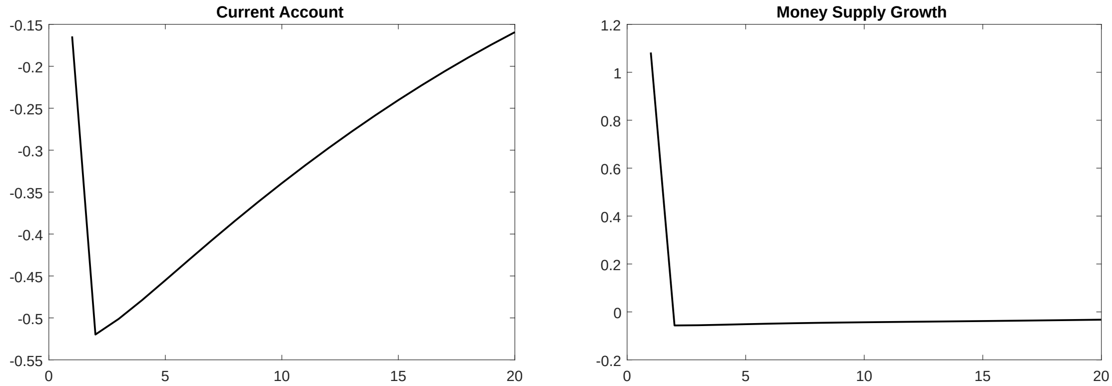

Figure 7: Benchmark model IRF of the current account and money supply growth rate after a persistent foreign interest rate shock

in export demand all have their peak in this period. While the foreign asset holdings of the central bank decline further.
After the initial intervention, there is no subsequent intervention of the central bank, accordingly the money supply starts to decline. This decline is matched by a decline on the assets side of the flow of funds budget, due to the reduced holdings of foreign assets. The central bank's flow of funds budget begins to shift back towards its steady-state setup. As the foreign interest rate shock fades, the interest rate differential moves back towards its steady-state level. Thus sterilization via central bank bonds becomes more attractive and central bank bonds increase. Meaning also, that households shift funds back from consumption into savings, consumption and domestic demand declines. Declining money supply and rising domestic interest rates entail a decrease in domestic inflation. This in turn drives the real exchange rate and export demand. Rising export demand and real interest rate together with the rising foreign interest rate push the current account surplus back to its steady-state level.
Over time, the reduction in the money supply and the appreciation of the policy rate actually translates into a phase of recession for the domestic economy. The decline in inflation pushes the real exchange rate to appreciate above its steady-state level, sharply increasing the costs for the production of the intermediate good and consumption declines below steady-state levels; decreasing domestic demand and suppressing real GDP. This is not superseded by the increase in export demand. The reestablishment of the interest rate differential eventually leads to the establishment of a new steady-state.

Summary: The simulation shows, that the existence of policy weights on the domestic policy rate, inflation, real GDP and the foreign asset to GDP ratio

prompt the central bank to change the scale of sterilization. This reduction in scale is caused by the constraints put upon the central bank through the policy weights. Especially the weight on the foreign asset to GDP ratio and domestic policy rate force an initial increase of the money supply growth rate. This increase of the money supply in turn creates an initially expansionary push in the real economy.
Given the small degree of variation between the model proposed in Chang et al. and the benchmark model used as the basis of this text's analysis, a high degree of similarity of simulation results can be expected. This similarity is a desired outcome, as it validates the choice of a different steady-state and real economy setup in the benchmark model - Changes that have not overshadowed the mechanisms outlined by Chang et al.. As a result of the differences in the steady-states, the amplitudes of the impulse response functions are different, while the motion of the functions is very close to the graphs published by Chang et al..[161]

5 Simple model

The simple model innovates the benchmark model by introducing financial frictions into the model framework. The method of implementation is derived from the model published by Dib and also by Hilberg and Hollmayr.[162] The implementation requires the addition of two new agents: a class of households that owns the commercial banks and provides bank capital to the banks and the commercial banks themselves. Accordingly domestic households are split between those that provide labor (workers) and those that provide bank capital (bankers). Instead of purchasing central bank bonds on the financial market, workers now save by depositing funds with the commercial banks. As is common practice, these deposits are implemented as one-period bonds into the model.[163] Commercial banks collect these deposits and transform them into loans. Loans are one-period bonds taken by the entrepreneurs to finance part of their purchase of real capital. The costs of external funding the entrepreneurs face is influenced by the external finance premium. This premium is a measure of the riskiness of an investment and is based on the ratio between the entrepreneurs net worth and the real value of the total capital purchase. It is assumed that a fraction of the entrepreneurs defaults each period and is replaced with new entrepreneurs endowed with seeding money. This is done to ensure that the entrepreneurs can never fully fund their capital purchase internally and therefore have to rely at

[161] Chang et al. (2012), p.17-18 and Appendix
[162] Dib (2010), p.6-16 and Hilberg and Hollmayr (2013), p.8-10
[163] Dib (2010), p.5 and Gertler and Karadi (2011), p.19

least partly on external funding. The section below further describes the changes and additions to the benchmark model. A schematic of the simple model can be found in figure (17) in Appendix B.

5.1 Aggregation

There are two aggregated composites added to the model, the bank capital composite and the loan composite.
Conceptually each of the individual bankers provides its own differentiated bank capital, further referred to as offered capital. This offered capital differentiates itself by the interest rate attached to it and the specifics of the purchase contract (payment modalities). The offered capital is then aggregated into a bank capital composite, that is rented by the commercial banks. The offered capital is situated on the interval $f \in [0,1]$ and the aggregation technology for the bank capital composite is given by

$$S_t = \left[\int_0^1 (S_{f,t})^{\frac{\theta_f - 1}{\theta_f}} \mathrm{d}f \right]^{\frac{\theta_f}{\theta_f - 1}} \tag{69}$$

where θ_f is the elasticity of substitution between the offered capital. From this the demand function for the individual banker's offered capital $S_{f,t}$ is given in the function below

$$S^{\nabla}_{f,t} = \left[\frac{R^{\circ}_{f,t}}{R^{\circ}_t} \right]^{-\theta_f} S_t \tag{70}$$

where R°_t is the composite interest on bank capital related to the individual offered capital interest rate $(R^{\circ}_{f,t})_{f \in [0,1]}$ by $R^{\circ}_t = \left[\int_0^1 R^{\circ}_{f,t}{}^{(1-\theta_f)} \mathrm{d}f \right]^{\frac{1}{1-\theta_f}}$.
The loan composite is aggregated from the differentiated bank loans offered by the individual commercial banks, which are situated on the interval $j \in [0,1]$. Each bank offers a bank loan $B_{j,t}$, that differentiates itself by the interest rate attached to it and the specifics of the credit contract. The aggregation technology for the loan composite is captured by the equation

$$B_t = \left[\int_0^1 (B_{j,t})^{\frac{\theta_j - 1}{\theta_j}} \mathrm{d}j \right]^{\frac{\theta_j}{\theta_j - 1}} \tag{71}$$

where θ_j is the elasticity of substitution between the differentiated bank loans. The demand function for the bank loan $B_{j,t}$ is accordingly given by

$$B^{\nabla}_{j,t} = \left[\frac{R^{\ddagger}_{j,t}}{R^{\ddagger}_t} \right]^{-\theta_j} B_t \tag{72}$$

where $R_t^{\ddagger}$ is the composite lending rate related to the individual bank lending rate $(R_{j,t}^{\ddagger})_{j\in[0,1]}$ by $R_t^{\ddagger} = \left[\int_0^1 R_{j,t}^{\ddagger}{}^{(1-\theta_j)} \mathrm{d}j\right]^{\frac{1}{\theta_j - 1}}$.

5.2 Workers

The workers are a continuum of infinitely lived utility maximizing household agents. They are situated on the interval $h \in [0, 1]$. Each worker is equipped with a differentiated labor skill and they are price setters for their individual skill. The workers derive utility from consumption and leisure. Workers can save by holding deposits with the commercial banks.[164] Workers do not derive utility from holding real money balances. The anchor for the money supply is instead provided by the bankers, which in turn are modeled to derive utility from holding real money balances. This change is necessary due to the shift in the workers saving behavior. Otherwise the money supply would be tied to the deposit rate, which would cause problems when simulating the model. The money supply would be defined twice, once through the money growth rate and once through the deposit rate. The solution of having the workers no longer derive utility from holding real money balances is chosen over a solution where the money balances are split between workers and bankers. Simulation results are similar but the chosen solution is significantly simpler to implement. The utility function of the worker household reads as follows, where $C_{h,t}^{\bullet}$ is the individual worker's consumption.

$$U_h = E \sum_{t=0}^{\infty} \beta_t \left[\ln C_{h,t}^{\bullet} - \phi_n \frac{(N_{h,t}^{\nabla})^{1+\eta}}{1+\eta} \right] \tag{73}$$

The real one period budget constrain for the individual worker with real deposits $\frac{D_t}{P_t}$ replacing central bank bond holdings is then given by the equation below,

$$C_{h,t}^{\bullet} + \frac{D_{h,t}}{P_t} = \frac{W_{h,t} N_{h,t}^{\nabla}}{P_t} + \frac{R_{(t-1)}^{\bullet} D_{h,t-1}}{P_t} + \frac{\tau}{P_t} - \frac{\Omega_w}{2} \left(\frac{W_{h,t}}{W_{h,t-1} \bar{\pi}^{\bullet}} - 1 \right)^2 N_t \tag{74}$$

where $R_t^{\bullet}$ represents the nominal deposit interest rate.
Following this change, optimality in the symmetric equilibrium is then characterized by the first order conditions given below

$$1 = E_t \beta \left[\frac{\Lambda_{t+1}^{\bullet}}{\Lambda_t^{\bullet}} \frac{R_{t+1}^{\bullet}}{\pi_{t+1}} \right] \tag{75}$$

[164] Dib (2010), p.5

$$\Lambda_t^{\bullet} = \frac{1}{C_t^{\bullet}} \tag{76}$$

$$w_t = \frac{\theta_w}{\theta_w - 1}\phi_n N_t^{\eta} C_t^{\bullet} - \frac{\Omega_w}{\theta_w - 1}\left\{\left(\frac{\pi_t^{\bullet}}{\bar{\pi}^{\bullet}} - 1\right)\frac{\pi_t^{\bullet}}{\bar{\pi}^{\bullet}} - \beta E_t\left(\frac{\pi_{t+1}^{\bullet}}{\bar{\pi}^{\bullet}} - 1\right)\frac{\pi_{t+1}^{\bullet}}{\bar{\pi}^{\bullet}}\right\} \tag{77}$$

5.3 Bankers

Bankers are a second type of infinitely lived households added to the model. They own the commercial banks and receive profits from the bank's operations.[165] They derive utility from consumption and holding real money balances. Bankers save by purchasing central bank bonds and provide differentiated bank capital. It is assumed that they have the same time preference as the worker households. The individual banker's lifetime utility function is given by

$$U_f = E\sum_{t=0}^{\infty}\beta\left[\ln C_{f,t}^{\circ} + \phi_m \ln\frac{M_{f,t}^{\circ}}{P_t}\right] \tag{78}$$

where $C_{f,t}^{\circ}$ is the consumption of the individual banker and $M_{f,t}^{\circ}$ are the money balances held by the banker.
Bankers maximize their lifetime utility by choosing consumption, money balances, bond purchases and the optimal offered capital interest rate subject to the demand schedule for their differentiated offered capital and the real one period budget constraint. They take offered capital demand as given and are monopolistically competitive in the market for offered capital. The real one period budget constraint of the individual banker is given by the equation below,

$$\begin{gathered} C_{f,t}^{\circ} + \frac{G_{f,t}^{\circ}}{P_t} + \frac{S_{f,t}}{P_t} + \frac{M_{f,t}^{\circ}}{P_t} = \\ \frac{R_{f,t-1}^{\circ}S_{f,t-1}}{P_t} + \frac{R_{t-1}G_{f,t-1}^{\circ}}{P_t} + \frac{M_{f,t-1}^{\circ}}{P_t} + \frac{\tau_f}{P_t} - \frac{\Omega_f}{2}\left(\frac{R_{f,t}^{\circ}}{R_{f,t-1}^{\circ}} - 1\right)^2 S_t \end{gathered} \tag{79}$$

where $\frac{\tau_f}{P_t}$ are the banker's share of bank profits and $\frac{G_{f,t}^{\circ}}{P_t}$ are the real central bank bonds held. The choice of the implementation of bank capital lending implies that the banker's income reacts with a one-period delay to changes in the remuneration of bank capital, as there is a one-period lag on the interest earned from lending capital.
It is assumed that an adjustment of the rent levied on the differentiated offered capital provided by the banker is costly, this is modeled by the addition of quadratic adjustment costs.

[165] Dib (2010), p.6

$$\frac{\Omega_f}{2}\left(\frac{R^\circ_{f,t}}{R^\circ_{f,t-1}}-1\right)^2 S_t \tag{80}$$

where Ω_f are the average adjustment costs.
Optimality in the symmetric equilibrium is characterized by the following first-order conditions, subscripts are dropped.

$$\frac{\phi_m}{M^\circ_{f,t}\Lambda^\circ_t}=\frac{R_t-1}{R_t} \tag{81}$$

Λ°_t is the Lagrange multiplier for the banker's maximization.

$$\Lambda^\circ_t=\frac{1}{C^\circ_t} \tag{82}$$

$$1=E_t\beta\left\{\frac{\Lambda^\circ_{t+1}}{\Lambda^\circ_t}\frac{R_t}{\pi_{t+1}}\right\} \tag{83}$$

The optimal bank capital lending rate in the symmetric equilibrium is described by the relation below, where equation (83) is used to substitute the Lagrange multiplier.

$$R^\circ_t=R_t\left[\frac{\theta_f}{\theta_f-1}-\frac{\Omega_f}{\theta_f-1}\left\{\left(\frac{R^\circ_t}{R^\circ_{(t-1)}}-1\right)\frac{R^\circ_t}{R^\circ_{(t-1)}}-\beta E_t\left(\frac{R^\circ_{(t+1)}}{R^\circ_t}-1\right)\frac{R^\circ_{(t+1)}}{R^\circ_t}\right\}\right] \tag{84}$$

5.4 Entrepreneur

With the net worth setup described in the benchmark model it is relatively straightforward to introduce an external finance premium into the framework of the entrepreneur agent. The first addition is a different definition for the net worth that reads as $\Upsilon_{u,t}=\nu\Upsilon^\diamond_{u,t}+(1-\nu)(SeedMoney)$. This definition taken from Dib 2010 establishes, that the net worth in period t is the sum of the not-defaulting entrepreneur's gains from capital $\Upsilon^\diamond_{u,t}$ plus the seeding money received by new entrepreneurs at market entry.[166] While the total of entrepreneurs in the economy remains constant, every period a part of the entrepreneurs default and leave the economy, these are then replaced by new entrepreneurs equipped with seed money. The ratio of default is controlled by the constant ν. The net gains from holding real capital are defined by the equation below

[166] Dib (2010), p.17

$$\Upsilon^{\diamond}_{u,t} = R^{\dagger}_{u,t} K_{u,t-1} - \frac{R^{\ddagger}_t}{\pi_t} \xi_t B_{u,t} \tag{85}$$

where ξ_t is the external finance premium. This equation describes the net worth at the end of the current period as the gains from the capital utilized during the period (capital used in the current period is purchased at the end of the preceding period) less the cost of the externally funded part of the capital purchase at the end of the current period. The value of the loan contracts signed by the entrepreneur in period t is the difference between the value of the capital purchase and the net worth $B_{u,t} = P^{\diamond}_t K_{u,t} - \Upsilon_{u,t}$.

The marginal external financing costs $\frac{R^{\ddagger}_t}{\pi_t}\xi_t$ equal the real lending rate multiplied with the external finance premium. The external finance premium depends on the entrepreneur's leverage ratio. It is defined as a markup on the costs of external financing dependent on the ratio of capital purchases to entrepreneur net worth, the form without an exogenous shock used in this model is given by the equation below,

$$\xi_t = \left(\frac{P^{\diamond}_t K_{u,t}}{\Upsilon_{u,t}} \right)^{\psi_e} \tag{86}$$

where ψ_e is an aggregate risk parameter, as used by Dib, Hilberg and Hollmayr and Bernanke.[167]

This equation establishes the concept, that the external finance premium is dependent on the entrepreneurs stake in the project. A higher quotient signifies a higher reliance on uncollateralized borrowing to fund the entrepreneur's project. This provides not only incentives for the entrepreneur to misreport on the state of the project, but also raises the necessity and costs of monitoring for the lending bank. Given the assumption of shallow finance markets, entrepreneurs have no other equivalent venues to acquire external funds and therefore the costs of monitoring and riskiness can be pushed onto the borrower.

As a means of simplification, the simulation excludes seed money from consideration (as a constant it would not be represented in the log-linear form of the model) and arrives at the following development path for the entrepreneur's net worth

$$\Upsilon_{u,t} = \nu \left[R^{\dagger}_{u,t} K_{u,t-1} - \frac{R^{\ddagger}_t}{\pi_t} \xi_t B_{u,t} \right] \tag{87}$$

The production technology and the profit maximization of the entrepreneur's firm remain the same as in the benchmark model.

[167]Dib (2010), p.17 and Hilberg and Hollmayr (2013), p.5

5.5 Commercial bank

The second agent added to the model are the infinitely lived domestic commercial banks. Commercial banks offer deposits to labor providing households and create loans according to a Leontieff production technology. They acquire bank capital and purchase central bank bonds. The commercial bank described in this section is in essence an amalgamation of the lending and borrowing banks from Dib 2010.[168]
The technology for the creation of loans of the individual bank is given

$$B_{j,t} = \min\left[D_{j,t}, L_{j,t}S_{j,t}\right] \tag{88}$$

where $L_{j,t}$ is the banks leverage ratio. According to the technology, the amount of loans produced is restricted by the smaller one of deposits and leveraged bank capital in the bank's possession. Loans are solely produced from deposits, the bank capital is not transformed in the production process, it serves as a limiting factor for the bank's loan creation capabilities. This reflects the reality of leverage legislation, such as the BASEL criteria, that prescribe a minimal capital ratio for banks. The acquired bank capital is invested in central bank bonds. The implicit demand functions for the factor inputs are captured by the equations below

$$B^{\nabla}_{j,t} = D_{j,t} \tag{89}$$

$$B^{\nabla}_{j,t} = L_{j,t}S_{j,t} \tag{90}$$

To avoid the conundrum of simultaneous optimization of input and output factors, it is assumed that the commercial bank takes loan and deposit demand as given and that the deposit rate is controlled by a linear process. This process is identical for all banks and establishes the deposit rate as a mark down on the policy rate dependent on the proportional deposit administration costs

$$R^{\bullet}_t = R_t - \chi D_t \tag{91}$$

where the constant χ represents the marginal administration costs for deposits. The optimal leverage rate is chosen by the bank. It is subject to the leverage ratio restrictions imposed by regulation. As in Dib 2012, a capital ratio above the required minimum entails convex gains for the bank. The gains for holding excess capital are modeled as quadratic and given by

$$\frac{\Omega_\ell}{2}\left[\frac{L^{\ddagger} - L_{j,t}}{L^{\ddagger}}S_{j,t}\right]^2 \tag{92}$$

[168] Dib (2010), p.8-16

where $L^{\ddagger}$ is the constant representing the regulatory leverage ratio and Ω_{ℓ} is a positive parameter. When the actual leverage ratio matches the regulatory one, there are no gains from excess capital holdings. When $L_{j,t} < L^{\ddagger}$ then the bank has excess capital which reduces the costs of raising bank capital. As bank capital is invested in central bank bonds, the marginal cost of holding bank capital is the difference between the bank capital interest rate and the policy rate $R_t^{\circ} - R_t$. The bank maximizes lifetime profits by choosing the optimal lending rate and optimal leverage. The nominal problem is characterized in the equation below

$$\tau_j = R_{j,t}^{\ddagger} B_{j,t} - V_{j,t}^{\ddagger} + \frac{\Omega_{\ell}}{2}\left(\frac{L^{\ddagger} - L_{j,t}}{L^{\ddagger}} S_{j,t}\right)^2 - \frac{\Omega_j}{2}\left(\frac{R_{j,t}^{\ddagger}}{R_{j,t-1}^{\ddagger}} - 1\right)^2 B_t \tag{93}$$

where the last term represents the quadratic adjustment costs for the lending rate and Ω_j represents the average adjustment costs. The marginal costs $V_t^{\ddagger}$, composed of the interest payed on deposits and the remainder of the difference between the deleveraged bank capital interest rate less the central bank rate and the gains from excess capital holdings, are given by the equation below.

$$V_{j,t}^{\ddagger} = R_t^{\bullet} + \left(R_t^{\circ} - R_t - (R_{j,t}^{\ddagger} - 1)\frac{(L^{\ddagger} - L_{j,t})}{L^{\ddagger}}\right)\frac{1}{L_{j,t}} \tag{94}$$

In the symmetric equilibrium optimality is characterized by the first-order conditions for the lending rate and the leverage ratio given below

$$V_t^{\ddagger} = \frac{\theta_j - 1}{\theta_j} R_t^{\ddagger} + \frac{\Omega_j}{\theta_j}\left\{\left(\frac{R_t^{\ddagger}}{R_{t-1}^{\ddagger}} - 1\right)\frac{R_t^{\ddagger}}{R_{t-1}^{\ddagger}} - \beta E_t\left(\frac{R_{t+1}^{\ddagger}}{R_t^{\ddagger}} - 1\right)\frac{R_{t+1}^{\ddagger}}{R_t^{\ddagger}}\right\} \tag{95}$$

$$L_t = L^{\ddagger}\left(1 - \frac{R_t^{\ddagger} L^{\ddagger}}{\Omega_{\ell} S_t}\right) \tag{96}$$

5.6 Equilibrium

In addition to the equilibrium conditions stated in the description of the benchmark model, the symmetric equilibrium is characterized by meeting the conditions below.

Overall consumption equals the sum of the consumption of workers and bankers

$$C_t = C_t^{\bullet} + C_t^{\circ} \tag{97}$$

The total amount of central bank bonds equals the bond holdings of bankers and commercial banks, the bond holdings of banks equal their bank capital holdings $G_{j,t} = S_t$

$$G_t = G_t^{\circ} + S_t \tag{98}$$

The markets for bank capital, deposits and loans clear

$$B_t = \int_0^1 B_{u,t}\mathrm{d}(u) \tag{99}$$

$$D_t = \int_0^1 D_{h,t}\mathrm{d}(h) \tag{100}$$

$$S_t = \int_0^1 S_{j,t}\mathrm{d}(j) \tag{101}$$

5.7 Calibration parameters and steady-state

Where possible the steady-state configuration of the model uses the same parameter values and steady-state presets as the numerical solution of the benchmark model. The rational for the values of the additional parameters is as follows. As in Dib 2010 the positive parameter in the quadratic gains from excess bank capital is set to $\Omega_\ell = 14.45$ and the mandated maximal leverage is set at $\ell_\ddagger = 12.5$ which is the inverse of the BASEL II mandate of an 8% capital to deposits ratio. The steady-state bank leverage is $\bar{\ell} = 11.5$, meaning that banks hold a small amount of excess bank capital in the steady-state.[169] The elasticity for the differentiated bank capital is set to $\theta_f = 10$ and the elasticity for the differentiated loans is set to $\theta_j = 10$. (Aggregate) Lending rates and bank capital rates are assumed as being relatively sticky with a contract change occurring on average every 4 quarters, average lending rate adjustment costs are $\Omega_j = 100$ and average bank capital adjustment costs are given as $\Omega_f = 100$. Furthermore it is assumed, that about 2.5% of entrepreneurs every period default, which makes the rate of default equal to the depreciation rate accordingly the survival parameter for the entrepreneurs is given by $\nu = 0.975$. The proportional costs for the administration of deposits is assumed to be at 20 base points per year which gives $\chi = 0.0005$. Finally the aggregate risk parameter of the external finance premium is chosen in accordance with Dib set to $\psi_e = 0.005$. [170]
Furthermore for the steady-state calibration the following additional presets are used for the calculation. Entrepreneur net worth in the steady-state is set to

Parameter	Value
Ω_ℓ	14.45
Ω_f	100
Ω_j	100
ν	0.975
$\ell^\ddagger$	12.5
χ	0.0005
ψ_e	0.005
θ_j	10

Table 5: Calibrated values for the model parameters

[169]Dib (2010), p.35
[170]Dib (2010), p.34

$\bar{\Upsilon} = \frac{1}{2}\bar{p}^{\diamond}\bar{k}$, which calibrates real net worth as well as real loans to half of the real value of the steady-state capital. Consumption is split between worker's consumption and banker's consumption by $\bar{c}^{\bullet} = \frac{1}{2}\bar{c}$. Steady-state banker's central bank bond holdings are set to zero, in accordance with Dib 2010.[171] Following this steady-state bank capital is equal to steady-state central bank bonds.
The initial steady-state calculated with the given presets and parameters is then used as the starting point of the simulation of a one-percent negative interest rate shock on the foreign interest rate, creating a positive interest rate differential between domestic policy rate and foreign interest rate. The shock is calibrated with the same value for the persistence parameter as in the benchmark simulation.

5.8 Simulation results

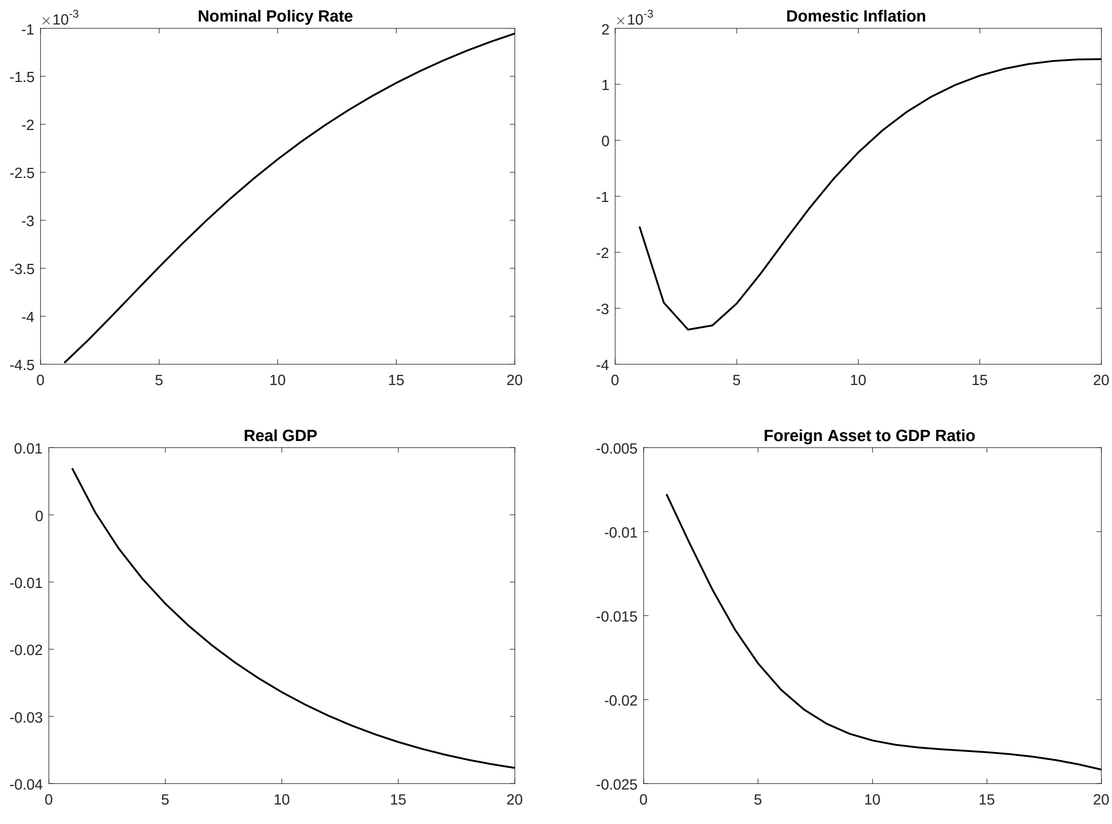

Figure 8: Simple model IRF of policy variables after a persistent foreign interest rate shock

[171] Dib (2010), p.21

The log-linear form of the equations of the endogenous variables of the Simple model can be found in Appendix B.2 . Figure (8) shows the impulse reaction functions of the target variables to a one percent decline of the foreign interest rate.

Broad strokes: The IRF of the Simple model show the two effects of the foreign interest rate shock, which could also be observed in the Benchmark model; an initial decrease in the nominal policy rate and an initial expansion of domestic real GDP. The development of inflation notably deviates from the Benchmark IRF. This can be attributed to the existence of proportional administration costs for deposits. As in the Benchmark model, the reversal of the differential between policy rate and foreign interest rate is at the root for the changes of GDP and policy rate. The decline in the foreign interest rate puts pressure on the policy rate, whose decline is constraint by the policy target on policy rate stability. The changed interest rate differential raises the costs of sterilization for the central bank, leading to a reduction in the scale of sterilization. Smaller scale sterilization leads to an initial increase in the money supply. Different from the Benchmark model, the expansion of the domestic economy is not pushed by an increase in consumption by the worker households. The decline in inflation suppresses domestic wages and reduces worker consumption. The apparent increase in aggregate demand is instead coming from an increased initial consumption of the banker households. The decline in the policy rate leads to a decline in the bank lending rate, reducing the external finance premium. Entrepreneurs need less credit to finance their capital purchase, credit demand declines and banks draw less bank capital from bankers. Bankers adjust their allocation accordingly.

In detail: The simulation of the Simple model without the weight on the foreign asset to GDP ratio yields a similar result to the simulation of the benchmark model. Outside of the foreign assets, current account and the foreign asset to GDP ratio, there is no reaction of the endogenous variables to the foreign interest rate decline. This shows, that the quadratic costs on the foreign assets to GDP ratio and the restrictions they put on the reduction of the foreign asset growth, are necessary for the propagation of the shock into the real domestic economy. The initial decline of foreign assets is much smaller than in the benchmark simulation. The initial changes to the central bank's flow of funds budget are similar too: Central bank bonds decline and the domestic policy rate depreciates, while the money supply increases. The central bank intervenes initially by increasing the money supply growth rate. The extent of the money supply growth spike is lower than in the benchmark model, the intervention is less forceful. The decline in foreign assets and central bank bonds is less pronounced, accordingly a smaller increase of the money supply is needed to balance the flow of funds budget in the initial period.

These differences are a result of the different counterparts that the central bank has for its liabilities in the domestic economy. The counterparts for the central bank bonds are no longer the domestic households, but commercial banks and the bankers. Real money balances are held by the banker households instead of the worker households.

By the bankers' first order conditions, money supply and the domestic interest rate are connected with the bankers' Lagrange multiplier and domestic inflation. Similar to the benchmark model, the increase in the money supply is coupled with a decrease of the Lagrange multiplier. Bankers' consumption grows initially. Their income is subject to a one-period lag, as they receive the gains from lending bank capital in the preceding period. Accordingly their income is initially unperturbed by the decline in interest rates triggered by the central bank. But the decline in interest rates affects the allocation of funds by the bankers in the initial period, as prospected gains from lending bank capital are reduced, leading to higher consumption and larger real money balances held by the bankers.

It is assumed that in the symmetric equilibrium bankers' central bank bonds holdings are zero, therefore central bank bonds are modeled as being equal to bank capital in the log-linear model. The commercial banks invest the bank capital they hold in central bank bonds. Accordingly the demand for central bank bonds is dependent on the amount of bank capital acquired by the commercial banks, and this in turn is governed by the banks' leverage and the demand for loans.

The propagation of the expansionary impulse coming from the bankers' increase in consumption is clearer to see when the model is simulated without taking proportional deposit administration cost into account. The rise in bankers' consumption leads to an increase in aggregate demand and an increase in output. This expansionary push drives factor demand and the marginal costs for the retail good, leading to an initial upturn of inflation, wage inflation and a slight increase in real wages. This, in turn, drives workers' consumption, who reallocate funds from saving to consumption. Inflation decreases the real exchange rate, lowering the price for the import good.

The effect of the proportional administration costs is that a decrease of deposits, a reduction in saving by the worker households, is coupled with an increasing deposit rate. This increase counteracts the effect a decrease in the policy rate has on the deposit rate. Accordingly the impulse response of the deposit rate is highly dependent upon the parameter choice for the administration costs. Without the proportional costs deposit rate and policy rate are the same whereas

high administration costs would cause an increase of the deposit rate in spite of an environment of overall decreasing interest rates. Model simulations were conducted without and with proportional administration of 0.05% to assess the robustness of results.
The existence of the adverse effect of administration costs dampens the impact of the decreasing domestic policy rate on the demand for deposits. Meaning that workers reduce their saving to a lower degree than they would otherwise. Workers' consumption declines initially, slightly dampening the expansionary impulse created by the increase of bankers' consumption. This also eliminates the initial increase in wages, translating to an absence of the initial spike in wage inflation and overall domestic inflation.
The expansion of output leads to an increase in use of the intermediate good in the production of the retail good, while the use of capital remains stable. This initially increases the marginal productivity of capital, while the gains from holding capital decrease in line with the drop in the real price of capital. The real price of capital declines as a reaction to the decline of investment in the initial period. With stable capital use, the decline in the real price of capital reduces the funds needed to acquire the capital used in the next period. This lowers the demand for loans and rises the relative share of the entrepreneur in the funding project, which in turn drives the external finance premium down, further reducing the amount of external funds needed for the purchase of capital. The lower demand for loans is coupled with lower loan creation costs following the reduced interest paid on bank capital and deposits, leading to a reduction in the lending rate. Additionally the commercial banks deleverage initially, a reaction to the shift in the optimal leverage rate due to the lower domestic policy rate and lending rate.
There are two factors at play that are responsible for the change in the model response to the foreign interest rate shock. One factor is the different anchor for the central bank bonds in the economy. The initial decline in central bank bonds and the domestic policy rate is tied to a decline of bank capital and the deposit rate. The reduction in the decline of central bank bonds in comparison to the benchmark model is observable with and without the existence of a financial accelerator. The initial suppression of interest rates and the lower use of bank capital have a strong effect on the financial sector - not only do the commercial banks acquire less bank capital, they also deleverage. Causing a decline in credit and deposits, that is stronger than the decline in central bank bonds. Meaning that the economic repercussion of a decline of the domestic policy rate and central bank bonds are stronger than in the benchmark model. This affects the central bank's optimization, resulting in a reduced initial expansion of the money supply.

The second factor is the existence of the financial accelerator. In the simulation with the external finance premium the expansive phase of the economy does not outlast the initial period. Without the premium real GDP develops similar to the benchmark model, leading to a higher variance of GDP with the financial accelerator.

Summary: Overall there is a clear difference in amplitude observable between the impulse response functions of the benchmark model and the model with a simple financial sector. The motion of the functions is in general fairly similar in both models. The introduction of a financial sector amplifies the impact of the central bank's response to the foreign interest rate shock on the domestic economy. The variance of real GDP is significantly higher than in the benchmark model. The change in the external finance premium acts as an accelerator of central bank policy. This increase in the impact on the real economy is coupled with a dampening of the effect of the shock on the other policy targets. In comparison to the benchmark model the deviation from policy rate, inflation and foreign asset to GDP targets is reduced. This effect is more pronounced with administration costs than without. The initial injection of money by the central bank is significantly smaller than in the benchmark model, creating a smaller initial expansionary push. Figure (9) illustrates the differences between the IRF of money supply growth and the policy rate between the models.

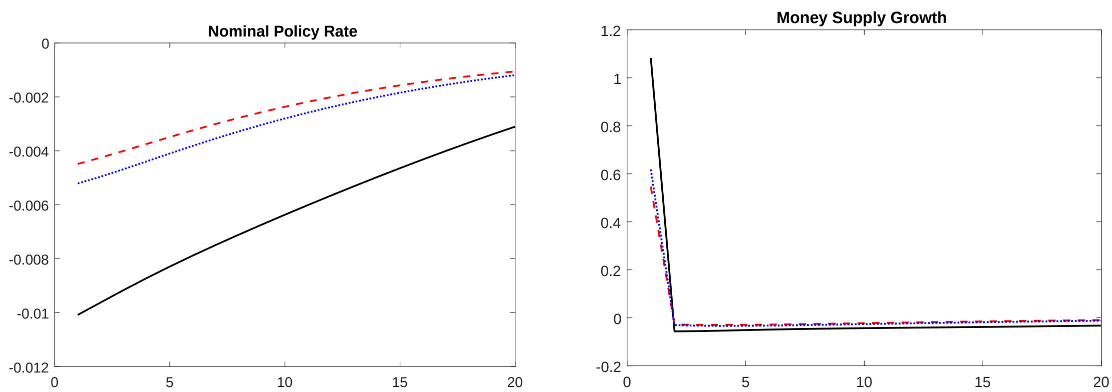

Figure 9: IRF of policy rate and money supply growth rate for the Benchmark model (black), Simple model (red) and the Simple model without administration costs (blue)

Like the benchmark model, the impulse response function for the current account resembles a check mark. The strongest decline of the current account surplus happens after the initial period, prompted by the decline in the foreign interest rate. Contrary to the benchmark model, there is no decline of the real exchange rate and the reduction in the current account surplus is of a smaller magnitude than in the benchmark model. As the real exchange rate increases in correlation with the disinflation in the domestic country, the demand for the import good drops and the foreign demand for exports increases. The lower current account reduces the need for sterilization. This coincides with the gradual fading of the foreign interest rate shock. The differential between the policy rate and the foreign interest rate progresses towards steady-state levels prompting central bank policy to move back towards its own steady-state configuration.

6 Chinese model

The next iteration of the model is concerned with widening the complexity of the simple model to incorporate two important characteristics of the actual Chinese monetary policy framework. One is the existence of fairly substantial minimum reserve requirements for the commercial banks. The other is the policy of mandating interest rate bands on deposit and loan rates. The introduction of the interest rate mandates is based on Funke and Paetz.[172] As a matter of fitting it into the existing model framework, only mandates on the deposit rate are implemented - the price setting authority of the individual commercial banks for their differentiated loans remains intact. Implementing required reserves requires changes to the commercial bank agent, as well as changes to the balance of the central bank. The required reserves are a fraction of the deposits held by the commercial banks and earn interest. With the given steady-state and parameter choices, the model given below can simulate required reserves ratios between 0% and 25%. If not stated otherwise, the discussion of the results refers to a simulation with a 10% required reserves ratio, equal to the rate used in Chen et al. and Funke and Paetz.[173]. A schematic of the Chinese model can be found in figure (19) in Appendix C.

6.1 Commercial banks

The commercial bank agent is changed to allow for the introduction of the mandated deposit rate band as well as a requirement to hold a constant fraction of deposits as reserves with the central bank. Funke and Paetz introduce mandates on deposit rates in their model through an optimization.[174] Given that the upper deposit rate mandate sets the ceiling for the interest on deposits,

[172] Funke and Paetz (2012), p.14-15
[173] Chen et al. (2012), p.15 and Funke and Paetz (2012), p.17
[174] Funke and Paetz (2012), p.14

banks choose the smaller of the market or mandated rate as the actual rate, $R_t^{\bullet} = \min(Mandate, Market)$, though competition provides banks with an incentive to opt for the mandated rate even when market rates would be smaller. In the past deviations from the upper band of mandated deposit rate were quite rare in the Chinese banking sector. Accordingly it is assumed that deposit rates are mainly determined by the mandated rate. Allowing for a minor influence of the market rate, deposit rates are modeled as the weighted sum of the market rate and the upper mandated rate.
With the introduction of required reserves, the loan creation process is changed. Instead of converting all acquired deposits into loans, banks now have to acquire one plus the required reserves ratio units of deposits to create one unit of loans. Required reserves are treated as one-period bonds and earn interest below market rates for the commercial bank. Accordingly the commercial bank agent is represented by the following set of equations.
The deposit rate is the weighted sum of the upper mandated rate and the market rate. Below the log-linear form of the equation governing the development path of the deposit rate is given.

$$\hat{r}_t^{\bullet} = \theta_m \hat{\Xi}_t + (1 - \theta_m)\left(\bar{r}\hat{r}_t - \chi \bar{d}\hat{d}_t\right) \tag{102}$$

where θ_m is the weight of the mandated rate in the deposit rate creation process and Ξ_t is the upper mandate for the deposit rate set by the central bank.
Loans are created according to the following Leontieff technology

$$B_{jt,} = \min\left[(1 - \theta_\zeta)D_{j,t}, L_{j,t}S_{j,t}\right] \tag{103}$$

where θ_ζ is the constant required reserves ratio.
The implicit demand functions for the factor inputs are accordingly

$$B_{j,t} = (1 - \theta_\zeta)D_{j,t} \tag{104}$$

$$B_{j,t} = L_{j,t}S_{j,t} \tag{105}$$

The gains from holding excess capital are the same as before

$$\frac{\Omega_\ell}{2}\left[\frac{L^{\ddagger} - L_{j,t}}{L^{\ddagger}}S_{j,t}\right]^2 \tag{106}$$

The bank maximizes lifetime profits as before by choosing the optimal lending rate and optimal leverage. The nominal problem is the same as before

$$\tau_j = R^{\ddagger}_{j,t}B_{j,t} - V^{\ddagger}_{j,t} + \frac{\Omega_\ell}{2}\left(\frac{L^{\ddagger} - L_{j,t}}{L^{\ddagger}}S_{j,t}\right)^2 - \frac{\Omega_j}{2}\left(\frac{R^{\ddagger}_{j,t}}{R^{\ddagger}_{j,t-1}} - 1\right)^2 B_t \tag{107}$$

Marginal costs are given by the equation below,

$$V_{j,t}^{\ddagger} = R_t^{\bullet} - \theta_\zeta \zeta_t + \left(R_t^{\circ} - R_t - (R_{j,t}^{\ddagger} - 1) \frac{(L^{\ddagger} - L_{j,t})}{L^{\ddagger}} \right) \frac{1}{L_{j,t}} \tag{108}$$

where ζ_t is the required reserves interest rate.
The first order conditions for the lending rate and the leverage ratio in the symmetric equilibrium remain the same

$$V_t^{\ddagger} = \frac{\theta_j - 1}{\theta_j} R_t^{\ddagger} + \frac{\Omega_j}{\theta_j} \left\{ \left(\frac{R_t^{\ddagger}}{R_{t-1}^{\ddagger}} - 1 \right) \frac{R_t^{\ddagger}}{R_{t-1}^{\ddagger}} - \beta E_t \left(\frac{R_{t+1}^{\ddagger}}{R_t^{\ddagger}} - 1 \right) \frac{R_{t+1}^{\ddagger}}{R_t^{\ddagger}} \right\} \tag{109}$$

$$L_t = L^{r\ \ddagger} \left(1 - \frac{R_t^{\ddagger} L^{\ddagger}}{\Omega_\ell S_t} \right) \tag{110}$$

6.2 Central bank

With the implementation of required reserves and mandates on the deposit rate the scope of central bank policy is widened. The development path for the upper mandate of the deposit rate is formed according to a technology taken from Funke and Paetz. [175] The development path is dependent on the policy rate multiplied with the quotient of the steady-state deposit and policy rates. The interest rate on required reserves is similarly formed as dependent on the policy rate. Taken from the substantial resilience of the required reserves interest rate during the sample period in China, the development path is modeled with interest rate smoothing and a high persistence parameter for the interest rate of the previous period. Finally the flow of funds balance is augmented with the implementation of the required reserves as a liability for the central bank.
Accordingly the central bank is characterized by the following set of equations
The current account equals the changes in foreign assets held by the central bank

$$\Theta_t = \epsilon_t \frac{B_t^{\star} - B_{t-1}^{\star}}{P_t^{\star}} \tag{111}$$

Required reserves are added to the central bank's flow of funds balance

$$\epsilon_t \left(B_t^{\star} - R_{t-1}^{\star} B_{t-1}^{\star} \right) = M_t - M_{t-1} + G_t - R_{t-1} G_{t-1} + \theta_\zeta \left(D_t - \zeta_t D_{t-1} \right) \tag{112}$$

[175] Funke and Paetz (2012), p.15

The upper mandate for the deposit rate is formed by the following technology[176], where ρ_d is the weight for the deposit rate of the previous period

$$\Xi_t = \rho_d \ln R_t^{\bullet} + (1-\rho_d)\left(\frac{\bar{r}^{\bullet}}{\bar{r}}\right)^{(1-\rho_d)} \frac{\ln R_t}{\ln R_{t-1}} \tag{113}$$

The interest rate on required reserves is subject to the following technology

$$\zeta_t = \rho_\zeta \ln \zeta_{t-1} + (1-\rho_\zeta) \ln R_t \tag{114}$$

where ρ_ζ is the weight for the required reserves interest rate of the previous period.

6.3 Calibration parameters and steady-state

As before, the steady-state configuration is build using the same preset values as in the previous model iterations where applicable. There are three new parameters added to the model: the required reserves ratio, the weight of the deposit rate mandate and the persistence parameter of the reserves interest rate. As mentioned before, the required reserves rate is set at 0%, 10% and 25% alternatively to examine the impact of rising required reserve ratios on the impulse responses of the model variables. Where 0% represents a scenario without reserves, 10% and 25% are both ratios that the Chinese monetary policy has oscillated between in the last decades with a peak of a 21% ratio in 2011. The weight for the deposit rate is set at $\rho_d = 0.7$. Given the idea that the interest rate on reserves is very resilient, the persistence parameter is set to $\rho_\zeta = 0.9$. The weight for the mandated interest rate is set to $\theta_m = 0.7$. The only new preset for the numerical solution of the steady-state is the addition of a steady-state value for the interest on reserves. Arithmetically this rate has to be smaller than the deposit rate, as the model could not be simulated otherwise. With that in mind the rate is set at $\bar{\zeta} = 1.005$ representing an interest of one percent per annum.

Parameter	**Value**
$\bar{\zeta}$	1.005
θ_ζ	0.1
ρ_ζ	0.9
ρ_d	0.7
θ_m	0.7

Table 6: Calibrated parameter and steady-state values

6.4 Simulation results

The log-linear equations configuring the endogenous variables of the Chinese model can be found in Appendix C.2. Figure (10) shows the impulse response

[176]Funke and Paetz (2012), p.14

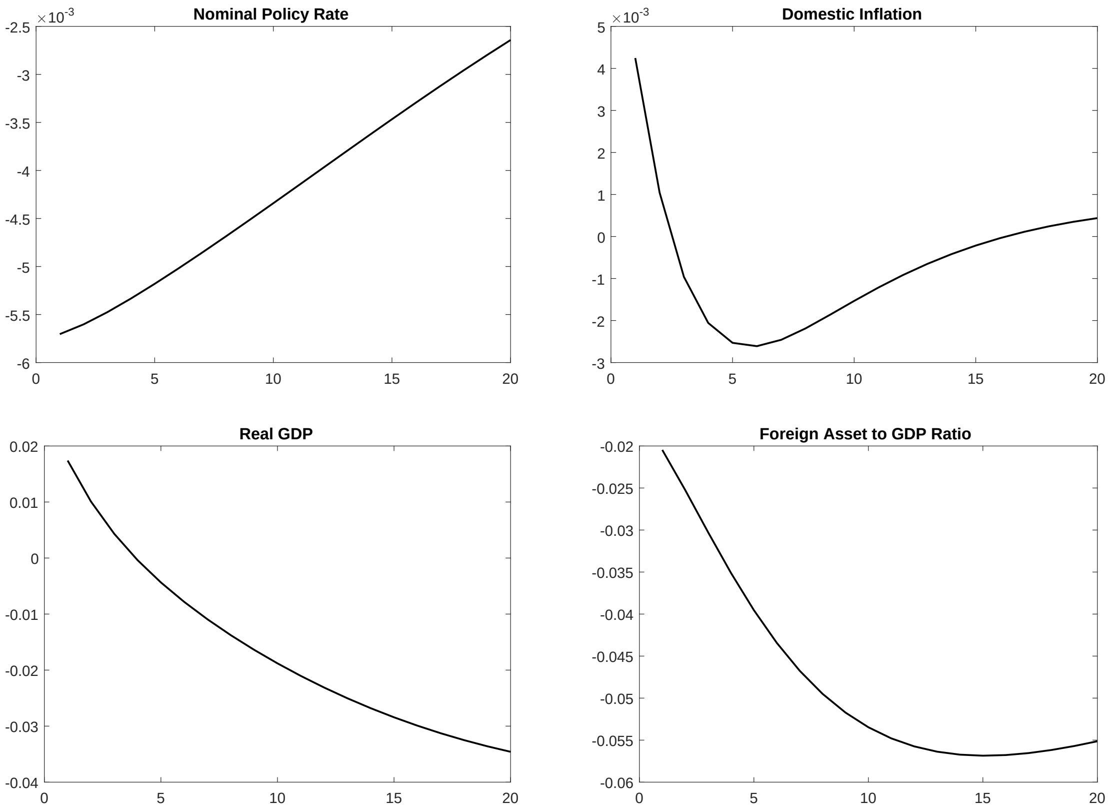

Figure 10: Chinese Model IRF of policy variables after a persistent foreign interest rate shock

functions of the target variables when the steady-state of the model described above is subjected to a one percent decline in the foreign interest rate. The required reserves ratio is set to 10%, following Funke et al. 2012.

Broad strokes: The IRF again document the two effects of the foreign interest rate shock. An initial decline of the nominal policy rate coupled with an initial increase in domestic GDP and inflation. The root for this response is as before the change in the differential between the policy rate and the foreign interest rate. The decline of the foreign interest rate puts pressure on the policy rate, which is constraint in its ability to decline due to the policy target on policy rate stability. Sterilization through central bank bonds becomes costly for the central bank, as domestic bonds carry higher interest than foreign assets. This causes a reduction in the scope of sterilization and an initial increase in the money supply. Inflation increases and aggregate demand grows as worker's and banker's consumption increases.

What sets the Chinese model apart form the Simple model is the effect required reserves have on the amplitude of the deviation of real GDP and the policy rate. Required reserves reduce the deviation of the real economy, while they enlarge the deviation of the policy rate. An effect that is scalable with the ratio of required reserves.

In detail: A simulation of the Chinese model without a policy weight on the foreign assets to GDP ratio yields a result similar to the previous model iterations. The propagation of the decline of the foreign interest rate into the domestic economy again hinges on the existence of the policy weight. Without the weight only the current account, foreign assets and foreign asset to GDP ratio are affected by the decline of the foreign interest rate.
The way in which the intervention of the central bank is transmitted into the domestic economy is changed in two ways from the Simple model. The addition of the mandate on the deposit rate significantly lessens the increasing effect that a reduction of deposits had in the Simple model, due to the reduced influence of the proportional administration costs on the development of the deposit rate. And the introduction of required reserves adds another tie between the financial sector and the flow of funds budget of the central bank.
The initial response to the decline in the foreign interest rate is similar to the previous iterations: Foreign assets and central bank bonds decline slightly. Additionally the domestic policy rate depreciates, a depreciation that is more pronounced than in the Simple model, but significantly smaller than in the Benchmark model. It is similar to the decline in the Simple model without administration costs. The difference in the amplitude of the initial decline of central bank bonds can be seen clearly when comparing the IRF and is also documented in the variances, which for central bank bonds is at 8.8% in the Simple model and at 5.67% in the Chinese model.
The central bank intervenes initially by expanding the money supply growth rate. Comparing the variances for the money supply growth rate shows that the intervention in the Chinese model is between the Simple model and the Benchmark model in its amplitude - the variance of the money supply growth for the Benchmark model is 1.18%, for the Simple model 0.3% and the Chinese model 0.45%. The initial increase in the money supply growth is determined by the Ramsey function, which means that the minimization differs significantly between the different models.
Through simulations with different configurations for the deposit rate, it can be ascertained that the difference in the optimization does not result form the addition of the mandate on the deposit rate or the reduced impact of the proportional administration costs. Accordingly the change can be attributed to

the inclusion of required reserves into the model. It scales with the required reserves ratio, the variance of the money supply growth rate rises to 0.56% with a required reserves ratio of 25% and drops to 0.37% with a required reserves ratio of 0%. The same scaling effect is true for the variance of the central bank bonds, the variance is lower at higher required reserves ratios.

Required reserves tie the development of deposits to the central banks flow of funds budget. The amount of deposits taken on by the commercial banks is correlated with the demand for loans and the banks' leverage. A depreciation of the domestic policy rate has a depreciative effect on the financial sectors interest rates. For the deposit rate this is enforced through the mandate, which is correlated with the domestic policy rate. This reduces loan creation costs and leads to a decline in the lending rate on bank loans. The lower lending rate leads to a reassessment of the optimal leverage ratio for the banks and in turn to a reduction of bank leverage. The reduction in central bank bonds is reflected in a decline of bank capital. Lower leverage and less bank capital both force a reduction of the amount of credit in the economy and the deposits held by the banks. A reduction of deposits, in turn, reduces the liabilities of the central bank proportionally to the required reserves ratio. The link between central bank and deposits created by the banks means that the budget effects of a reduction of central bank bonds are enhanced by a joint decline of required reserves.

By implementing required reserves, a fraction of deposits is effectively taken out of the loan creation process. Meaning that the impact of the decline in central bank bonds is transmitted in a reduced form to the real economy. Especially since the deleveraging of the banks is less pronounced when required reserves are implemented. The variance of the leverage ratio changes from 0.03% with 10% required reserves, to 0.07% without reserves and 0.01% with a reserves ratio of 25%. This creates a higher resilience of the real economy towards the depreciation of the domestic policy rate. Which allows for a change in the optimization of the central bank, that leads to a more forceful intervention than in the Simple model.

The dampening effect of required reserves on the impact of monetary shocks on the real economy is a phenomenon that is also observed by Dib.[177] Simulating the Chinese model with a required reserves ratio of 0%, 10% and 25% shows that the dampening effect, as observed in the variance of real GDP, scales with the ratio. The variance shifts from 0.17% to 0.10% between a simulation without required reserves and one with a ratio of 10%. It drops further to 0.053%, when the ratio is raised to 25%.

As in previous iterations, the impulse response function of the current account resembles a check-mark. The steepest decline is after the initial period, when the

[177]Dib (2010), p.30

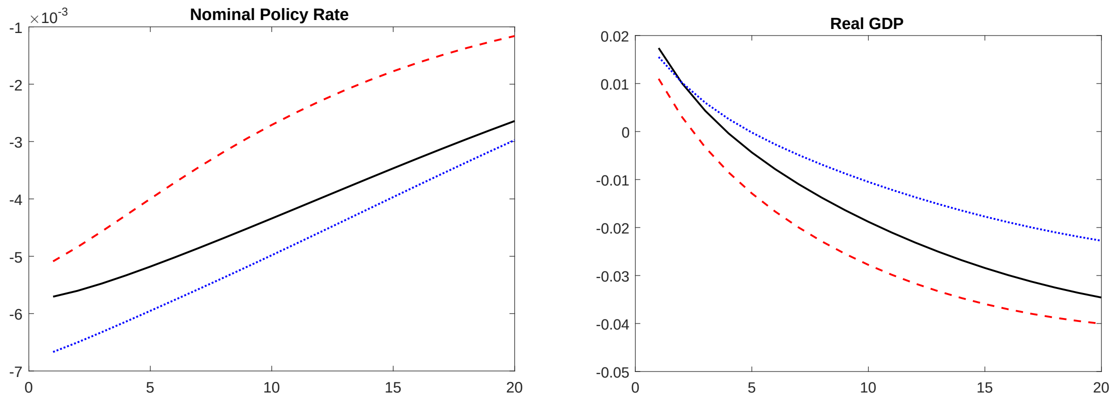

Figure 11: Chinese model IRF of policy rate and GDP with 10% required reserves (black), no required reserves (red) and 25% required reserves (blue)

one period lag of the foreign interest rate affects the calculation of earnings from foreign assets included in the current account. This also coincides with the strongest decline of the real exchange rate. This reduces the need for sterilization and as the differential between the policy rate and the foreign interest rate return to steady-state levels, the model moves back to its steady-state configuration.

Summary: The IRF of the Chinese model show, that it resembles the Benchmark model in the movement of the policy variables. The policy rate declines and the real GDP and inflation both increase initially. The difference is in the amplitude of the disturbances caused by the foreign interest rate shock. The deviation of the policy rate is stronger than in the Simple model, but smaller than in the Benchmark model. While the deviation of real GDP is less pronounced than in the Simple model but higher than in the Benchmark model. Two effects are at work in the Chinese model, on one hand the financial accelerator and on the other hand the dampening effect of required reserves. The financial accelerator amplifies the disturbance of the real economy from the change in the central bank's balance, hence the deviation of real GDP is higher than in the Benchmark model. Required reserves counteract this effect to a degree, while their implementation also increases the deviation of the policy rate.

7 Monetary policy reform

This section explores the impact policy reform has on the responses to a depreciation of the foreign interest rate. It builds on the Chinese model described above. Three different scenarios are considered, capital account liberalization, the implementation of a floating exchange rate and the joint implementation of an open capital account and a floating exchange rate. [178]

7.1 Capital account reform with imperfect capital mobility

The first scenario of policy reform to be explored is one where the capital account is opened, while the fixed nominal exchange rate regime remains. Under the trilemma of monetary policy this reform would imply that the domestic country would have no monetary autonomy. Given perfect capital mobility, arbitrage would enforce a synchronization of domestic and foreign interest rates. With a continuation of the exchange rate peg the uncovered interest parity condition states that domestic and foreign interest rates are identical. Such that $R_t = R_t^\star$ would hold for all periods of the simulation. [179]

It is however assumed, that even after reform the central bank does retain an interest in monetary autonomy. Such that the stability of the domestic policy rate remains one of the main targets of monetary policy. As observed by Aizenman[180], the central bank's foreign assets holdings can serve as a cushion to mitigate the effect of terms-of trade shocks on the domestic economy. In consequence there is an incentive for the central bank to maintain some level of sterilization. With sterilization, which serves as a mechanism to control capital flows, the central bank creates room for some degree of monetary autonomy. Autonomy that results in the possibility of deviating from the identity between foreign interest rate and the domestic policy rate.[181]

The outlined scenario does not reflect on the implications of so called *hot money*, which describes the influx of foreign investments on the domestic financial markets fueled by expectations of exchange rate appreciation and interest rate differentials. Foreign investors are outside of the model's scope. Accordingly all foreign assets are held by either the central bank or domestic private entities and all domestic bonds are held by domestic entities. This limitation is also found in Chang et al.. In consequence the opening of the capital account is integrated in a relatively one-sided manner, that is deemed sufficient to answer the question of

[178] the scenarios are the same as in Chang et al. (2012), p.19-23

[179] Chang et al. (2012), p.19-23

[180] Aizenman (2008), p.490-491

[181] Chang et al. (2012), p.19-23

the validity of a chosen path of monetary policy reform.[182]

A Implementing an open capital account

The Chinese model described above has two agents that can hold domestic bonds. The banker households and the commercial banks. It is assumed that only the commercial banks have access to the foreign financial markets, whereas the bankers are restricted to domestic bonds. This restriction eliminates the necessity to introduce an additional first order condition for the optimization of the bankers. Additionally it is maintained, that the bankers' investment in bonds is constant, such that their bond investment is not present in the log-linearized state of the model.
Overall investment in foreign assets is bound to the following additional equilibrium condition,

$$B_t^\star = B_{g,t}^\star + B_{j,t}^\star \tag{115}$$

where $B_{g,t}^\star$ is the central bank's share of foreign assets and $B_{j,t}^\star$ is the commercial banks' share.
Commercial banks invest their acquired capital in foreign assets and central bank bonds. Accordingly bank capital is defined as $S_t \equiv G_{j,t} + \epsilon_t B_{j,t}^\star$, where $G_{j,t}$ are the central bank bonds held by the commercial banks. They invest with the goal to maximize the earnings from their investment. In a scenario where foreign assets and central bank bonds are perfect substitutes this would be a binary choice, banks would always invest all bank capital into the asset with higher interest. With adjustment costs this is no longer the case as changes to the composition of the investment portfolio generate additional costs. Accordingly the commercial banks maximize the interest earned from their investment portfolio by choosing the optimal portfolio share of central bank bonds. This optimization is subject to the adjustment costs. The portfolio share of central bank bonds is given by the equation below.[183]

$$\partial_t = \frac{G_{j,t}}{G_{j,t} + \epsilon_t B_{j,t}^\star} \tag{116}$$

where ∂_t is the portfolio share.
The quadratic adjustment costs are given by the equation below

$$\frac{\Omega_x}{2}\left(\frac{G_{j,t}}{G_{j,t} + \epsilon_t B_{j,t}^\star} - \bar{\partial}\right)^2 S_t \tag{117}$$

[182] Chang et al. (2012), p.23-25
[183] Chang et al. (2012), p.20

where Ω_x are the average portfolio adjustment costs and $\bar{\partial}$ is the steady-state portfolio share.
The commercial banks maximize their gains according to the equation given below, where $\tau^{\ddagger}_{j,t}$ are the gains from investment.

$$\max \tau^{\ddagger}_{j,t} = \varpi_{j,t} S_{j,t} - \frac{\Omega_x}{2}\left(\frac{G_{j,t}}{G_{j,t} + \epsilon_t B^{\star}_{j,t}} - \bar{\partial}\right)^2 S_t \tag{118}$$

the term $\varpi_{j,t} S_{j,t}$ is the interest earned from the portfolio held by the individual bank and is defined by

$$\varpi_{j,t} S_{j,t} \equiv R_t G_{j,t} + \epsilon_t R^{\star}_t B^{\star}_{j,t} \tag{119}$$

Given the definition of bank capital above, the nominal marginal interest on bank capital can be expressed as

$$\varpi_t = R_t \frac{G_{j,t}}{G_{j,t} + \epsilon_t B^{\star}_{j,t}} + R^{\star}_t \frac{\epsilon_t B^{\star}_{j,t}}{G_{j,t} + \epsilon_t B^{\star}_{j,t}} \tag{120}$$

which can be transformed into

$$\varpi_t = \partial_t R_t + (1 - \partial_t) R^{\star}_t \tag{121}$$

Bank capital and total interest are then substituted by their definitions into the maximization problem

$$\max \tau^{\ddagger}_{j,t} = R_t G_{j,t} + R^{\star}_t \epsilon_t B^{\star}_{j,t} - \frac{\Omega_x}{2}\left(\frac{G_{j,t}}{G_{j,t} + \epsilon_t B^{\star}_{j,t}} - \bar{\partial}\right)^2 G_{j,t} - \frac{\Omega_x}{2}\left(\frac{G_{j,t}}{G_{j,t} + \epsilon_t B^{\star}_{j,t}} - \bar{\partial}\right)^2 \epsilon_t B^{\star}_{j,t} \tag{122}$$

Deriving the first order conditions for foreign assets and central bank bonds and combining them yields the following condition for the optimal portfolio share in the symmetric equilibrium

$$R_t - \epsilon_t R^{\star}_t = (1 - \epsilon_t)\frac{\Omega_x}{2}\left(\partial_t - \bar{\partial}\right)^2 \tag{123}$$

The marginal interest on bank capital replaces the interest on central bank bonds in the marginal loan creation cost function, yielding the following equation

$$V^{\ddagger}_t = R^{\bullet}_t - \theta_{\zeta}\zeta_t + \left(R^{\circ}_t - \varpi_t - (R^{\ddagger}_t - 1)\frac{(L^{\ddagger} - L_t)}{L^{\ddagger}}\right)\frac{1}{L_t} \tag{124}$$

Since the foreign assets are split between the commercial banks and the central bank, the foreign assets are replaced by the share of foreign assets held by the central bank in the central bank's flow of funds budget constraint

$$\epsilon_t\left(B^{\star}_{g,t} - R^{\star}_{t-1} B^{\star}_{g,t-1}\right) = M_t - M_{t-1} + G_t - R_{t-1} G_{t-1} + \theta_{\zeta}\left(D_t - \zeta_t D_{t-1}\right) \tag{125}$$

B Parameter calibration and steady-state

The simulation follows Chang et al. in the choice of the average adjustment costs of the banks' portfolio and the steady-state presets for the new variables.[184] Accordingly the average costs are set to $\Omega_x = 0.22$. The portfolio share of central bank bonds in the steady-state is set to $\bar{\partial} = 0.9$. Another important ratio for the steady-state is the share of foreign assets held by the banking sector. This is defined by $\partial^\star \equiv \frac{B^\star_{j,t}}{B^\star_t}$ and is set to $\partial^\star = 0.55$. With these parameters and presets, a numerical solution can be found, that is used as the steady-state in the simulation of the model.

C Simulation results and variance comparison

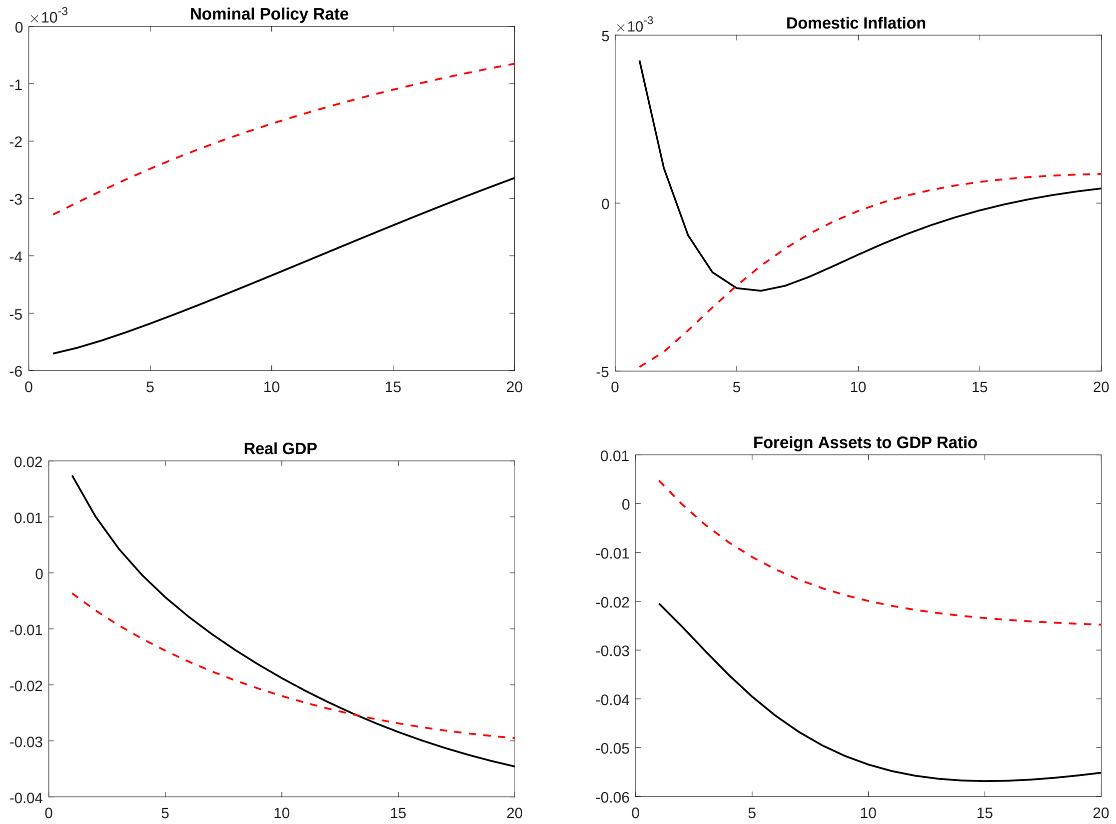

Figure 12: IRF of policy variables after a persistent foreign interest rate shock, Chinese model without (black) and with an open capital account (red)

[184] Chang et al. (2012), p.22

Figure (12) shows the IRF of the target variables to a one percent decline of the foreign interest rate. The initial effects of the decline of the foreign interest rate are similar to the previous simulations. With a significant difference, the propagation of the depreciation of the foreign interest rate into the domestic economy no longer depends on the existence of a policy weight on the foreign assets to GDP ratio. The portfolio readjustment of the banks following the depreciation operates as a second channel for the propagation of the foreign interest shock. The reversal of the interest rate differential changes the optimal portfolio configuration and leads to a sharp initial decline of foreign assets held by the commercial banks. Forcing the central bank to intervene. With the weight on the total foreign assets to GDP ratio, a sharp reduction of foreign assets by the banks causes welfare losses for the central bank. Accordingly the central bank initially increases its foreign asset holdings despite the less favorable interest rate differential. Which remarkably coupled with growing export demand leads to a growth of the current account surplus in the initial period.

The decline of the foreign interest rate increases the cost of sterilization, leading to a reduction of central bank bonds and a decrease of the domestic policy rate. Since foreign assets held by the central bank are not reduced, this triggers an expansion of the money supply to balance the flow of funds budget. The optimization of the Ramsey function leads to an initial increase of the money supply growth rate. An increase that is significantly smaller than in the simulation with a closed capital account. The money supply growth rate varies by 0.13% in comparison to the variance of 0.45% in the simulation with a closed capital account.

The expansionary impulse generated by this expansion of the money supply has in consequence much less of an impact on the domestic economy than in previous iterations. The reduction of central bank bonds by the central bank is reflected in a decline of bank capital and bank leverage. Banks reduce both their central bank bond and their foreign asset holdings, though the reduction in foreign assets is significantly stronger. This is evident in the variances. Central bank bonds vary by 0.02% while foreign assets held by the banks vary by 5.06%. Financial sector interest rates decline in line with the decrease of the domestic policy rate. Leading to an adjustment of the leverage ratio and a reduction of credit in the economy.

Investment contracts initially. This contraction was present when the capital account was closed, it is a reflection of the declining demand for capital in the post-initial period. Capital used in the next period must be created in the initial period. The expansionary impulse generated by the smaller initial intervention is overridden by the contraction of investment. The expansionary impulse is not strong enough to push the economy towards an initial expansion. It is observable from the IRF of real GDP and output, that it has an initially mitigating effect on the contraction suffered by the domestic economy. The reduction in investment suppresses the real price for capital and the marginal cost for the retail good. The forward looking nature of capital acquisition implies that the initial reduction in output cannot be compensated initially by a reduction in capital usage. Accordingly the reduction in output translates into a reduction of the usage of the intermediate good. Which results in a lower demand for labor and a reduction in wages, coupled with a reduction of consumption by the worker households.

Inflation decreases initially, leading to an increase in the real exchange rate. This increase in the real exchange rate in turn leads to a decline in imports and a growth in export demand.

The current account contracts after the initial period, when the one period lag of the foreign interest rate affects the calculation of earnings from foreign assets included in the current account. With the decline of the current account the central bank starts to reduce its foreign asset position, as the reversed interest rate differential causes losses for the central bank. As the shock on the foreign interest rates fades out of the simulation, commercial banks readjust their portfolios and reapproach the steady-state distribution. In turn the model moves back to its steady-state configuration.

7.2 Floating exchange rate

The next reform considered is the implementation of a floating nominal exchange rate. As in Chang et al., the central bank lifts the exchange rate peg but maintains capital controls.[185]

A Implementing a floating exchange rate

The first step in introducing the floating exchange rate into the Chinese model is to add a variable that defines the growth rate of the nominal exchange rate. It is given by $\gamma_t^\epsilon \equiv \frac{\epsilon_t}{\epsilon_{t-1}}$, where γ_t^ϵ is the growth rate.[186] Since the capital account remains closed, the exchange rate cannot be bound to the interest rate differential, uncovered interest parity is not enforced. Accordingly the nominal anchor for the exchange rate must be provided by different means. Chang et al. solve this by applying an unspecified money growth rule as a nominal anchor for the exchange rate. [187]

[185] Chang et al. (2012), p.23
[186] Chang et al. (2012), p.13
[187] Chang et al. (2012), p.24

Richard C. K. Burdekin and Pierre L. Siklos, propose a money demand equation for Mainland China. In this equation they establish money supply as the sum of the consumer price index, real GDP and the benchmark deposit lending rate set by the central bank, given a set of constants attached to each variable.[188] The equation is as follows,

$$\ln M_t = \vartheta_\pi \ln \Pi_t + \vartheta_{gdp} \ln GDP_t + \vartheta_r \Xi_t + \vartheta \tag{126}$$

where ϑ_π, ϑ_{gdp}, ϑ_r and ϑ are constants. Burdekin and Siklos then use empirical analysis to estimate the values of the different constants.[189]
This estimated equation forms the basis for the implementation of a nominal anchor for the nominal exchange rate in the present paper. For this the money supply is replaced with the change of the nominal exchange rate and the benchmark deposit lending rate is replaced with the policy interest rate. The log-linear version of this modified money demand function used in the actual simulation is shown below. The equation uses the log-linear form of the model variables.

$$\hat{\epsilon}_t = \hat{\epsilon}_{t-1} - 1.54\hat{\pi}_t - 1.35\hat{gdp}_t + 0.06\hat{r}_t \tag{127}$$

Which establishes, that the log-linear deviation from the steady-state of the nominal exchange rate is negatively related to the deviations from the steady-state of inflation and GDP and positively related to the deviations of the policy rate. This nominal anchor was chosen in particular as the results of the simulation of the benchmark model using this equation are similar in motion to the simulation results of Chang et al..[190]
Given that the change of the nominal exchange rate is no longer one, the definition of the real exchange rate must be updated. This provides the avenue for changes in the nominal exchange rate to affect the real economy. The updated equation is given by:

$$\frac{Q_t}{Q_{t-1}} = \gamma_t^{\epsilon} \frac{\pi_t^x}{\pi_t} \tag{128}$$

B Simulation results

Figure (13) shows the IRF of the target variables to a one percent decline of the foreign interest rate. As the capital account is again closed, the propagation of the decline of the foreign interest rate into the domestic economy depends on the existence of a policy weight on the foreign asset to GDP ratio, similar to the

[188]Burdekin and Siklos (2008), p.856
[189]Burdekin and Siklos (2008), p.856
[190]Chang et al. (2012), p.13

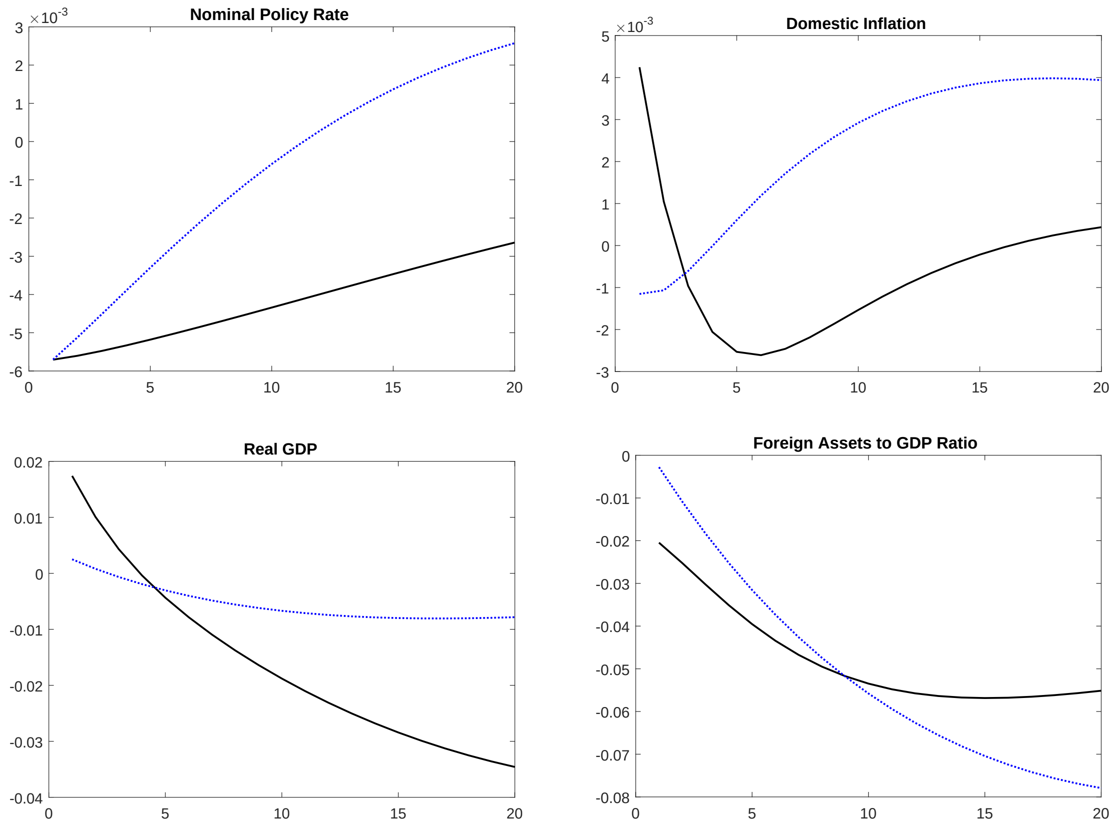

Figure 13: IRF of policy variables after a persistent foreign interest rate shock, Chinese model with fixed exchange rate (black) and floating exchange rate (blue)

Chinese model with a fixed nominal exchange rate. Different to the fixed nominal exchange rate scenario, foreign assets do not deviate from their steady-state value in the initial period. What deviates though are central bank bonds, which decline initially. This initial decline is matched with an intervention by the central bank, that leads to an initial increase in the money supply. According to the variances this intervention is similar in force to the intervention in the fixed nominal exchange rate simulation, the money supply growth rate varies by 0.45%. This is coupled with a significantly smaller variance for the central bank bonds, which vary by 0.92%.
The increase in the money supply provides an expansionary impulse, which translates to an increase in consumption by the banker households. This increase in consumption is in turn strong enough to override the contraction of investment and to push for an increase in aggregate demand. Which, given that export demand remains stable initially, leads to an economic expansion. The

increase in output drives factor demand, leading to a higher initial demand for the intermediate good. Since capital used in the initial period is acquired in the preceding period, it cannot be adjusted to reflect the increase in factor demand in the initial period.
The marginal cost for the retail good decline, in line with a decline in domestic inflation. This initial disinflation is reflected in the decline of wage inflation and a less pronounced reduction in real wages. The reduction in real wages, in turn, reduces the income available to the worker households and results in a decline in the workers' consumption.
The initial disinflation is not transmitted to the real exchange rate initially, which remains at its steady-state level in the initial period. This is a result of the sharp decline of the nominal exchange growth rate, which neutralizes the impact of the disinflation on the real exchange rate. In correlation with the real exchange rate export demand too remains stable. In other iterations, the decline in the real exchange rate was enhancing economic growth by reducing the price for the import good, allowing for a dampening of the increase of marginal costs for the intermediate good despite the increase in wages. In the present scenario this effect does not occur, which reduces the expansionary effect of the central bank intervention.
The graph for the current account surplus again resembles a check-mark, it reaches its lowest point after the initial period. The steepest decline is after the initial period, when the one period lag of the foreign interest rate affects the calculation of earnings from foreign assets included in the current account. This is also the point when the trend of the domestic economy reverses. The changed interest rate differential causes losses for the central bank and forces a reduction of the central bank's foreign asset holdings. This decline in the foreign asset holdings is coupled with a reduction in the money supply. Consumption declines, as the reduced earnings from lending capital and the slowly rising demand for bank capital cause a decline in banker's consumption. The economy enters a period of economic contraction. Overall consumption declines as lower output suppresses wages further. The nominal exchange rate appreciates, the relative value of the domestic currency falls. This increase in the nominal exchange rate overrides the effect that rising inflation would have on the real exchange rate and instead leads to an appreciation of the real exchange rate. This increases the export demand, and raises the costs for imports. Declining imports, rising exports and the growing real value of foreign assets together with the waning of the foreign interest rate shock lead to a return of the current account surplus to steady-state levels.

7.3 Floating exchange rate and capital account liberalization

The last scenario examined is one where the exchange rate regime and the capital account are both reformed. The simulation is done with a modification of the Chinese model, where the floating exchange rate and the capital account liberalization are implemented.
Accordingly the model used for the simulation is one that contains the opened capital account as described above and the nominal floating exchange rate tied to a money supply growth rule. Since the nominal exchange rate was a constant in the simulation with the capital account liberalization, the log-linear equation governing the optimal portfolio share for commercial banks takes now the following form.

$$\bar{r}\hat{r}_t - \bar{r^x}\hat{r^x}_t = \Omega^x * \bar{\partial}\hat{\partial}_t + \bar{\gamma^e}\hat{\gamma^e} \tag{129}$$

As the nominal exchange rate is assumed to be constant in the steady state, the steady-state growth of the exchange rate is set to $\bar{\gamma^e} = 1$.

A Simulation results

As before, figure (14) captures the IRF of the target variables to a one percent decline of the foreign interest rate. The decline of the foreign interest rate leads to a reduction in earnings from holding foreign assets. These reduced earnings lead to a reduction of the share of foreign assets held in the investment portfolio of the commercial banks. The foreign asset holdings of the central bank initially increase, which stabilizes the overall holdings of foreign assets at their steady-state level in the initial period. Central bank bonds and the domestic policy rate decline initially. The effect of this decline on the central bank's flow of funds budget is enhanced by the reduction in required reserves precipitated by the reduction in deposit demand. Deposit demand declines in line with bank capital and bank leverage. The overall deviation from the steady-state of these variables is less pronounced than in the simulation without liberalization. Central bank bonds vary by 0.01%, deposits by 2.92% and bank leverage varies by 0.02%. The minimization of the Ramsey function triggers an initial expansion of the money supply growth rate. An intervention that is significantly less forceful than in the simulation without full liberalization, the variance of the money supply growth rate does not exceed 0.13%. This less pronounced intervention creates an expansionary impulse and increases bankers' consumption. Similar to the simulation with an open capital account, the impulse though is not strong enough, to supersede the initial economic contraction following the decline in investment and aggregate demand.

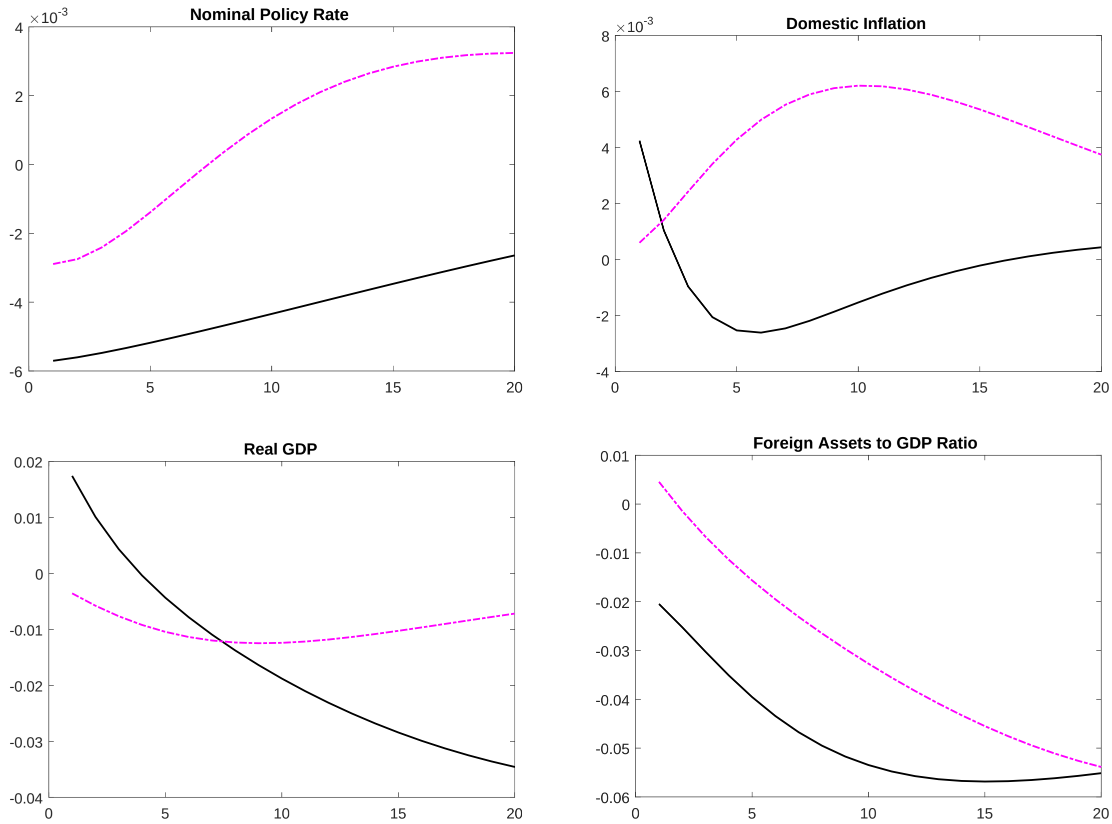

Figure 14: IRF of policy variables after a persistent foreign interest rate shock, unreformed Chinese model (black) and full liberalization (violet)

Since the capital used in the current period has been bought in the previous period, the change in factor demand due to the contraction is pushed upon the intermediate good. Accordingly demand for the intermediate good declines. In consequence labor demand and imports are reduced. This leads to a decline in the real wage, which is mitigated by a depreciation of wage inflation. Lower wages result in a reduction in consumption by the worker households superseding the expansion of bankers' consumption and forcing aggregate consumption to contract.

The floating nominal exchange rate disassociates the development of the real exchange rate somewhat from the development of domestic inflation, meaning that the initial stabilization of inflation and the subsequent rise in inflation is pushing the real exchange rate to decline. Accordingly export demand remains stable and the price for the import good does not decline initially. This is coupled with an initial increase in the nominal exchange rate growth rate.

The lag on the foreign interest in calculating the current account surplus again causes the steepest decline of the surplus to occur after the initial period. This decline in the surplus deepens the economic contraction. The recession deepens before the increase in exports and the fading out of the foreign interest rate shock gradually restore the current account surplus and in turn return the economy on its steady-state level. A factor in the deepening of the economic contraction is the rearrangement of the commercial bank's portfolio. The distribution of shares in the portfolio is dependent on the real values and not on the development of the interest rates. This causes a short lived stabilization of the portfolio on the steady-state level after the initial period, which reduces the earnings from the portfolio and raises the loan creation costs.

Part IV
Conclusion

The concluding chapter is divided in three sections. The first section is dedicated to a discussion of the limitations of the analysis presented in the present thesis. The second section uses the variances of the endogenous policy target variables to assess the shock responses in each model iteration on a numerical basis. The final section of the chapter provides a review of the findings gathered in this thesis and an assessment of the impact of frictions in financial intermediation on the sustainability of the Chinese monetary policy stance in the light of a foreign interest rate shock.

8 Discussion of limitations

Limitations for the validity of the observations provided by this work originate mainly from three different sources: Necessary assumptions, specificity and scope. Necessary assumptions are assumptions taken in the configuration of the models that are necessary for the simulation to work, but that are design choices by the author, which are naturally debatable. The most tenuous of these assumption is certainly the introduction of a central bank target for the foreign asset to GDP ratio. It is crucially important for the simulation to obtain a transmission of the foreign interest shock into the domestic economy, beyond the current account surplus. But it is not a common assumption in DSGE modeling, and there is no PBoC announcement or such specifically declaring the target as a goal of Chinese monetary policy. The discussion of the Quadratic Ramsey Function in Part II provides the reasoning for its inclusion by the author.
Another point for debate is the design choice for the implementation of the financial sector and the construction of the different interest rates. While these are derived from published research and implemented with the goal to resemble the Chinese financial sector, there are certainly alternative configurations and designs that may have provided different results.
Specificity is meant to capture the fact, that the simulation results are necessarily dependent on the choice of the values for parameters and weights. The parameters chosen and the rational behind the choice for each parameter is given in the description of the different models, underlying all choices is the attempt to represent the Chinese economy. The most prominent example of this specificity can again be found in the Quadratic Ramsey Policy Function. The choice of the weights for the four policy targets of the central bank attributes a hierarchy of importance to the different policy goals. Changes to these weights

also fundamentally change the simulation results, especially the variances of the policy target variables. Different values for the weights would lead to a different assessment of the welfare impact of a foreign interest rate shock in each model iteration.
Lastly the analysis faces limitations due to its scope. There are aspects of financial intermediation and the Chinese economy in general, that are not within the scope of the present thesis. One simplification is that the government is represented only by the central bank in the models. Accordingly government intervention, and specifically the stimulus program by the Chinese government are outside of the scope of this work. Another simplification is that the required reserves ratio is implemented as a constant rather than as an endogenous variable that could be adjusted following the foreign interest rate shock. This dynamic adjustment is outside of the scope of this work, as well as foreign direct investment and foreign investors on domestic financial markets. Another part that is not included is the interbank market, which could be an interesting field for further research, given the liquidity fluctuations on the market.

9 Variance based comparison

This section uses the variances of endogenous variables to compare the impact of the negative foreign interest rate shock in the different model iterations. First for the Benchmark, Simple and Chinese model and secondly for the different steps of monetary policy reform.[191]

9.1 Benchmark, Simple and Chinese model

The variances of the endogenous variables after a foreign interest shock can be used as a venue for the comparison of the different model configurations. With the advantage that this provides numerical measures, which are straightforward to compare between the different models. Such comparison is deemed possible, as all model iterations and steady-states are derived from the same benchmark model. Accordingly it is assumed, that differences in the variances can be attributed to the innovations introduced in each iteration.
In each model iteration there are four policy targets held by the central bank: to minimize the deviation from the steady-state for the policy interest rate, domestic inflation, real GDP and the foreign assets to GDP ratio. Each of these variables has a weight attributed to it. These weights indicate the importance the minimization of each variable's deviation has for the central bank. All

[191] Chang et al. (2012), p.25

Iteration	Policy Rate	Inflation	GDP	FX Ratio	Welfare Loss
Benchmark	0.55	0.02	0.09	0.70	1.36
Simple	0.09	0.00	0.74	0.45	1.28
Simple no admin.	0.12	0.00	0.86	0.46	1.44
Chinese	0.24	0.01	0.51	0.4	1.11
Chinese no req.	0.12	0.01	0.79	0.49	1.41
Chinese 25% req.	0.33	0.01	0.27	0.42	1.03

Table 7: Comparison of the aggregated weighted variances of policy rate, inflation, real GDP and foreign asset to GDP ratio [193]

iterations use the same weights for the policy targets. These weights guide the minimization introduced by the Ramsey Function.
The weighted deviation of a policy variable that occurs after the minimization is taken as a loss for the central bank. The sum of all weighted losses incurred by the central bank from deviations of the policy variables from the steady-state, is taken as the overall welfare loss that the central bank incurs as the result of a foreign interest rate shock in a given model iteration.[192] The deviation from the steady-state is the variance of a variable. Accordingly the variances of the policy target variables weighted with the policy weights are used to assess the loss incurred by the central bank. When comparing the overall welfare loss incurred in the different model iterations it is assumed, that a higher loss signifies a configuration that is less resilient towards foreign interest rate shocks.
The overall welfare loss is calculated by a simple addition of the weighted variances of the policy target variables. Table (7) displays the weighted variances for the policy targets as well as the overall welfare loss for each model iteration. As in the simulation by Chang et al. the main contributors to the welfare loss for the central bank in the benchmark model are the high variance of the domestic policy rate and the foreign assets to GDP ratio.[194]
Comparatively, the variance of the domestic policy rate and the foreign assets to GDP ratio are lower when financial frictions are implemented into the model. This is likely a result of the changed anchoring of the liabilities of the central bank's flow of funds budget in the domestic economy. Central bank bonds are no

[192]Adopted from Chang et al. (2012), p.25-26

[193]In this figure the weighted variances are multiplied by 100 for display purposes. (Benchmark) stands for the Benchmark model, (Simple) is the Simple model, (Simple no admin.) is the Simple model without proportional administration costs, (Chinese) is the Chinese model with 10% required reserves, (Chinese no req.) is the Chinese model without required reserves and (Chinese 25% req.) is the Chinese model with required reserves of 25%

[194]Chang et al. (2012), p.17-18

longer held directly by the labor providing households, but by commercial banks and bankers instead. The banking sector transmits the policy interest rate change to the domestic economy, amplifying the change through the financial accelerator. The higher impact of a change of the policy interest rate on the domestic banking sector and the stronger effect of a decline of central bank bonds affect the optimization of the central bank. This higher impact results in a less steep initial increase in the domestic money supply growth rate. This less forceful initial intervention is accompanied by a higher disturbance of the real economy. Figure(7) highlights that this change in the variances results in a decrease in the overall aggregated welfare loss, if proportional deposit administration costs of 0.05% are taken into account. The proportional costs have an offsetting effect. The lower proportional costs incurred as the result of a decline of the stock of deposits, offset partly the reduction of deposit interest rates due to the declining policy interest rate. Deposit rates are higher than they would be without proportional costs. In the absence of administration costs the disturbance of the real economy is even more pronounced and the aggregated welfare loss surpasses the loss incurred in the simulation of the benchmark model. The Simple model without administration costs and the Chinese model with required reserves of 0% are very similar in their distribution of variances and the overall welfare loss. Which is intended as there is very little difference between these models. The impact of the administration costs on the deposit rate is significantly reduced in the Chinese model due to the introduction of deposit rate mandates.

The comparison changes when looking at the simulations of the Chinese model with a required reserves ratio of 10% and 25%. The effect by which the required reserves reduce the impact of monetary shocks on the real economy is visible in the variance of real GDP. It is lower when required reserves are implemented and the reduction scales with the required reserves ratio. It also shows the trade-off the central bank faces when implementing required reserves. While the variance of real GDP drops and the variance of the foreign asset ratio is fairly stable, the variance of the policy rate increases with higher required reserve ratios. This is coupled with a higher initial increase in the money supply than in the Simple model. The strength of the initial increase in the money supply scales with the required reserves ratio.

The amplifying effect frictions in financial intermediation have on the disturbance the real economy suffers from monetary shocks is a common finding in frictions research.[195] The dampening effect of macroprudential regulation, specifically minimum reserve requirements, has also been described in economic

[195] for example Brunnermeier and Sannikov (2014), p.379-380

Iteration	Policy rate	Inflation	GDP	Foreign asset ratio	Loss
Chinese	0.24	0.01	0.51	0.4	1.11
Open	0.04	0.01	0.39	0.13	0.57
Float	0.47	0.09	0.01	0.41	0.98
Complete	0.21	0.07	0.01	0.15	0.44

Table 8: Comparison of the aggregated weighted variances of policy rate, inflation, real GDP and foreign asset to GDP ratio

research.[196] That these two effects in turn shape the scope and scale of monetary policy interventions is visible in the variances of the policy variables and the changes to the initial increase of the money supply between the different model configurations. The policy target weights used in the simulations emphasize the importance of policy rate smoothing and price stability over disturbances to the real GDP and the foreign asset to GDP ratio. In the context of these weights, variance comparison shows that the effects of frictions, required reserves and deposit rate mandates have a positive impact on the welfare loss incurred in the event of a foreign interest rate shock. The overall welfare loss is lower than in the benchmark model, and the Chinese model with required reserves has the lowest welfare loss.

A significant role for the credit channel in policy transmission (financial accelerator), required reserves and interest rate mandates, are key characteristics of the Chinese monetary policy framework, as it existed during the worldwide financial crisis. The variance comparison shows that these characteristics have an impact on the response to foreign interest rate shocks. The disturbance of monetary policy targets by foreign interest rate shocks is less severe. This suggests, that the framework of the Chinese monetary policy and the Chinese financial sector grant a higher resilience towards foreign interest rate shocks.

9.2 Variance effects of policy reform

Table (8) compares the weighted variances of the different steps of policy reform. All simulations use a required reserves ratio of 10%.

The table shows, that the welfare loss varies strongly between the different steps of reform. Implementing an open capital account almost halves the aggregated welfare loss. While the reduction achieved through a floating nominal exchange rate is less pronounced. A complete reform, opening the capital account and floating the nominal exchange rate, results in the lowest welfare loss.

[196] Dib (2010), p.30

The variances show, that the model with an open capital account shows a strong decrease of the variance of the policy rate and the foreign assets to GDP ratio. As commercial banks are allowed to hold foreign assets, they can react to the decline in the foreign interest rate without the constraints put upon the central bank. Compared to the capital account liberalization, the variance of the policy rate is significantly higher when only a floating nominal exchange rate is implemented. The variance of real GDP on the other hand is drastically smaller. Under a complete reform, the variance of the policy rate is similar to the variance in the Chinese model, whereas the variance of inflation and real GDP are close to the model with a floating nominal exchange rate. The variance of the foreign assets to GDP ratio is comparable to the model with an open capital account. As described by Chang et al., the lower losses in scenarios with an open capital account are a result of the costs of sterilization.[197] While costly sterilization persists in a scenario with a floating nominal exchange rate and a closed capital account, this is not the case when the capital account is opened. Opening the capital account eliminates the costs of sterilization, expressed in a lower variance of the policy rate.[198]

Accordingly policy reform should focus primarily on the removal of capital controls. This would eliminate the biggest constraint to an optimal central bank policy, costly sterilization. While the sterilization costs are negative in the steady-state equilibrium, sterilizing foreign assets with domestic central bank bonds provides a benefit to the government, this reverses after the foreign interest rate shock. Sterilization becomes costly.[199] This is reflected in realty, where the financial crisis suppressed US-Libor and EURIBOR interest rates below their Mainland Chinese counterparts.

[197] Chang et al. (2012), p.25-26
[198] Chang et al. (2012), p.25
[199] Chang et al. (2012), p.26

10 Concluding remarks

By introducing financial frictions into a model with Chinese characteristics this paper provides a frame of reference for the impact of financial frictions on the sustainability of Chinese monetary policy in the advent of a negative foreign interest rate shock. The models are build on the model with Chinese characteristics published by Chang et al. and on the setup for the implementation of financial frictions provided by Ali Dib.[200] The calibration of the parameters and the initial steady-state is informed by Chinese economic data for the period between 2008 and 2012.

Financial intermediation matters. The simulations demonstrate that frictions in financial intermediation have a significant impact on responses to a foreign interest rate shock, under the assumptions and axioms underlying this paper. In the models, intermediation and the frictions in the channeling of funds by the financial sector act as a stabilizing force in the event of a negative foreign interest rate shock. They reduce the impact of this persistent shocks on the fulfillment of domestic monetary policy targets. This effect occurs despite the amplifying effect that the frictions in financial intermediation have on the impact of shocks on the real economy. The variance of real GDP is significantly higher when financial intermediation is implemented. Accordingly the stabilizing effect of financial frictions is dependent on the choice of policy weights. With the weights chosen in this paper, which favor policy rate stability and stable inflation over changes to the real GDP, the higher variance in real GDP is outweighed by the strong decrease in the variance of the nominal policy rate. In consequence the loss incurred by the central bank in the event of a negative foreign interest rate shock is reduced when financial intermediation is taken into account. Taking the deviation of the policy rate from its target as a measure of domestic monetary autonomy, it can be stated that monetary autonomy is enhanced when financial intermediation is included in the models.

Ma Guonan describes in a paper from 2011, how the use of the required reserves ratio as a tool of sterilization reduces the costs of sterilization for the central bank. This can be seen as a shifting of the cost of sterilization from the central bank onto the shoulders of the financial intermediates.[201] Implementing required reserves and simulating the resulting model with different required reserves ratios yields a similar observation. The welfare loss incurred by the model's central bank decreases with higher required reserves ratios. And as mentioned by Ma, there also appears to be a possible turning point, where the negative effects of the ratio start to outweigh the positive effects. In the simulation, required

[200] Chang et al. (2012) and Dib (2010)

[201] Ma et al. (2011), especially p.6

reserves reduce the overall welfare loss by decreasing the volatility of the real economy. In line with the observation of Ali Dib, required reserves act as a shield that lessens the impact of the negative foreign interest rate shock on the real economy.[202] The implementation of required reserves in the models reduces the variance of real GDP, a reduction that scales with the height of the required reserves ratio. Required reserves on the other hand also generate a scalable increase in the variance of the nominal policy rate, higher ratios cause a higher variance. This may eventually outweigh the reduction in the variance of real GDP, given the preference for a stable policy rate. Implying that apart from the impact of higher ratios on the financial sector and its profitability, there is also a limit to the ratio from an optimal monetary policy standpoint. The volatility of the nominal policy rate is one of the limitations of the models, the simulations do not capture the full scope of the management of financial market interest rates implemented by the Chinese central bank. Accordingly the nominal policy rate is more volatile than the Chinese nominal policy rate. The central bank would most likely not implement changes through a change of the policy rate, but by an adjustment of the benchmark rates.

Chen et al. state in their conclusion, that the current Chinese non-conventional monetary policy toolbox represents a work of art.[203] The unique toolbox for the conduct of monetary policy and the configuration of financial markets in China interact and influence each other. They create a situation where despite the persistence of current account surpluses, the cost of sterilization remains manageable for the central bank. Partially by creating a situation where the financial sector carries some of the costs. Through this setup the chosen monetary policy path gains sustainability. A sustainability that a monetary framework with a closed capital account and fixed exchange rate but without the specific Chinese characteristics wouldn't be able to replicate. This higher sustainability is expressed by a higher resilience to a negative foreign interest rate shock. In consequence China can be assumed to have a greater ability to cope with outside disturbances than other countries with similarly closed capital accounts and fixed exchange rates by virtue of the specific characteristics of financial intermediation and macroprudential regulation in Mainland China.

This though does not suggest that the Chinese model is better equipped to absorb a negative foreign interest rate shock, than a monetary policy with an open capital account and a floating exchange rate. By implementing monetary policy liberalization into the model it can be shown that the disturbance suffered by a completely liberalized monetary policy is by far smaller than the disturbance suffered by the replication of the current Chinese monetary policy.

[202] Dib (2010), p.29-30

[203] Chen et al. (2012), p.27

In these findings the simulations replicate the results found by Chang et al., that suggest that a complete liberalization is the optimal path of monetary reform.[204] The greatest difference is caused by the liberalization of the capital account. The response of the financial sector to a change in the interest rate differential vastly reduces the scope of central bank intervention. This is in line with observations from a paper published by Sebastian Edwards in 2011.[205]

With the growing integration of China into international trade and the recent push of the government to establish the Renminbi as a currency of international impact, a reform of the Chinese monetary policy seems inevitable in the long run, yet the interaction between financial intermediation and monetary policy in Mainland China may provide more resilience to the status quo in the short-run.

[204] Chang et al. (2012), p.26-27

[205] Edwards (2011), p.10

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A Benchmark model

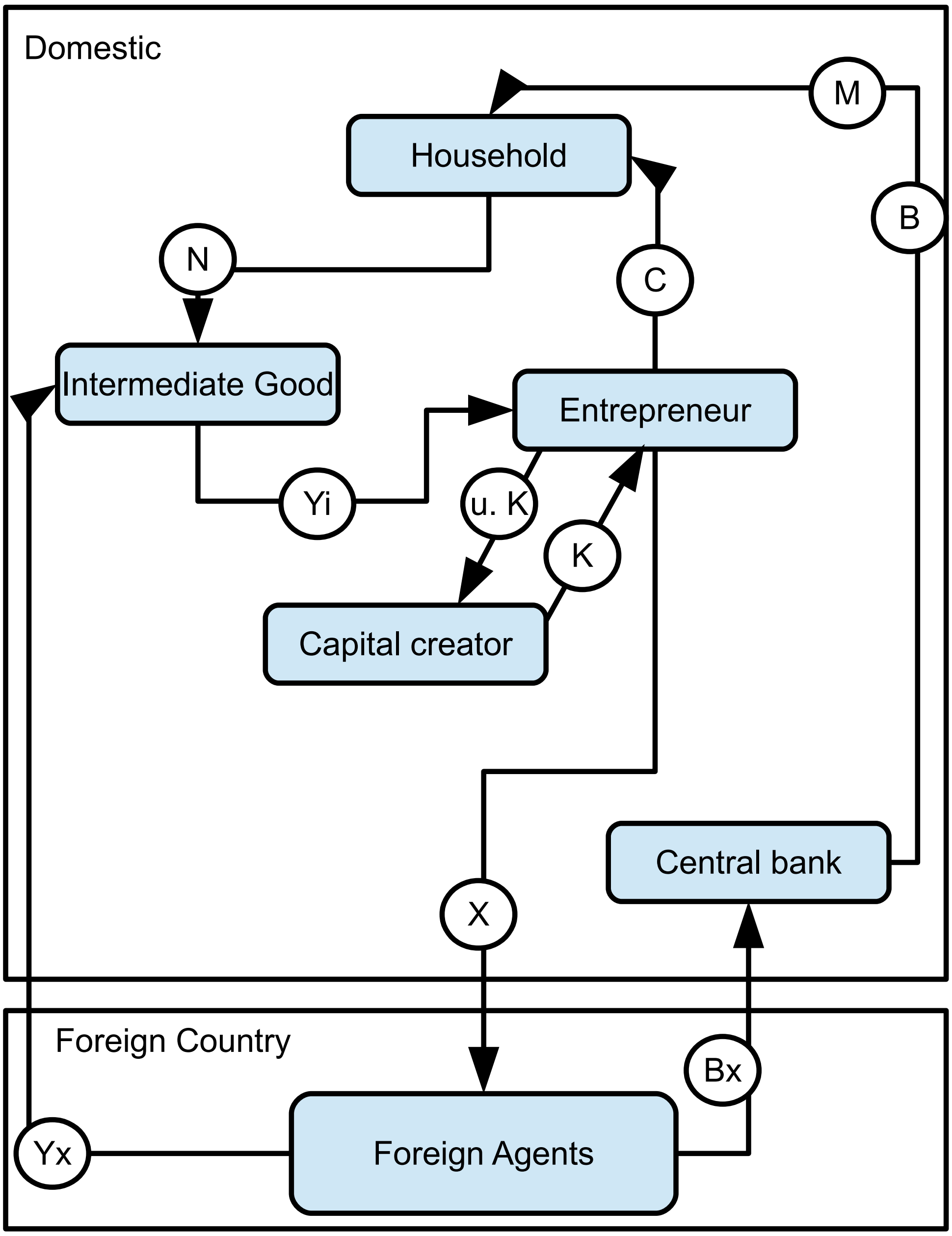

Figure 15: schematic benchmark model

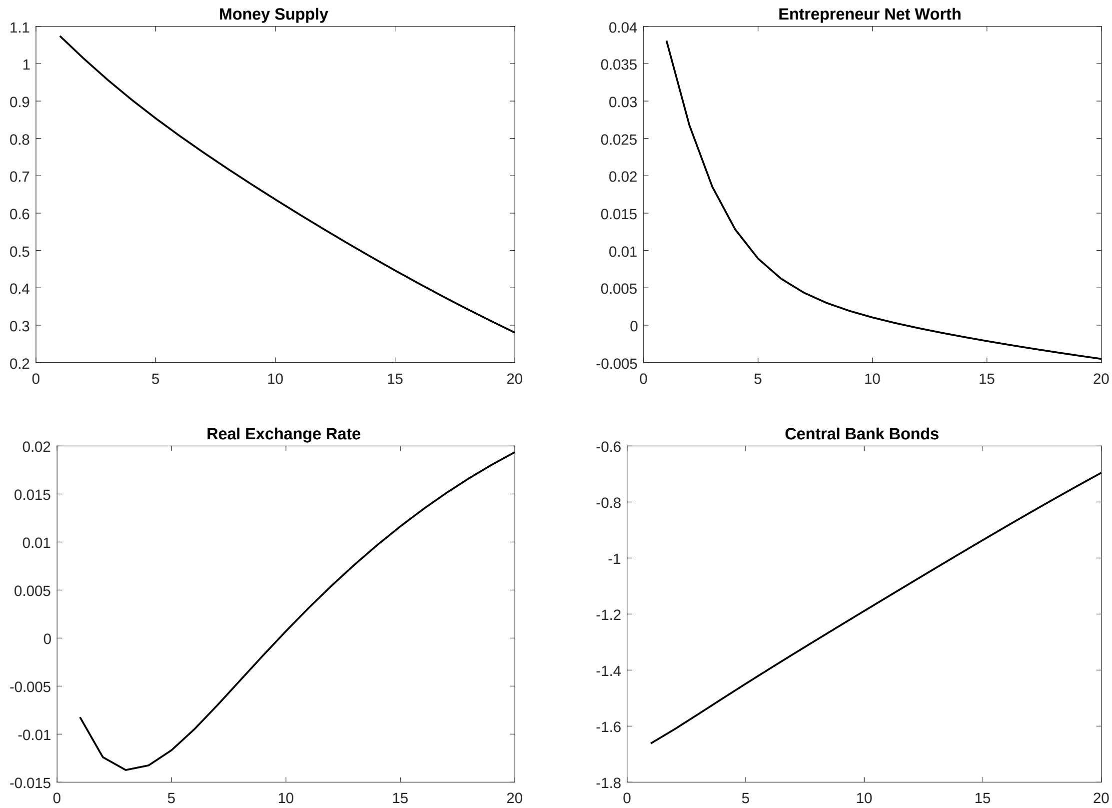

Figure 16: Benchmark model IRF of other variables after a persistent foreign interest rate shock

A.1 Steady-state and log-linear equations

A Steady-state

household

$$\frac{\phi_m}{\bar{m}\bar{\lambda}} = \frac{\bar{r}-1}{\bar{r}} \tag{130}$$

$$1 = \beta\frac{\bar{r}}{\bar{\pi}\bar{\psi}} \tag{131}$$

$$\bar{\lambda} = \frac{1}{\bar{c}} \tag{132}$$

$$\bar{w} = \frac{\theta_y}{\theta_y - 1}\phi_n \bar{n}^{\eta}\bar{c} \tag{133}$$

$$1 = \frac{\bar{\pi}^{\bullet}}{\bar{\pi}\bar{\psi}} \tag{134}$$

intermediate

$$\bar{y}^{\dagger} = \bar{n}^{\alpha}\bar{y}^{\star,(1-\alpha} \tag{135}$$

$$\bar{v}^{\dagger} = \tilde{\alpha}\bar{w}^{\alpha}\bar{q}^{(1-\alpha)} \tag{136}$$

$$1 = \frac{\bar{\pi}^{\star}}{\bar{\pi}\bar{\psi}} \tag{137}$$

$$\bar{w}\bar{n} = \frac{\alpha}{(1-\alpha)}\bar{q}\bar{y}^{\star} \tag{138}$$

capital creator

$$\bar{i} = \left(1 - \frac{(1-\delta)}{\bar{\psi}}\right)\bar{k} \tag{139}$$

$$\bar{p}^{\diamond} = 1 \tag{140}$$

entrepreneur

$$\bar{\Upsilon} = \bar{r}^{\dagger}\frac{\bar{k}}{\bar{\psi}} \tag{141}$$

$$\bar{\Upsilon} = \bar{p}^{\diamond}\bar{k} \tag{142}$$

$$\bar{r}^{\dagger} = \bar{z} + (1-\delta)\bar{p}^{\diamond} \tag{143}$$

$$\bar{y} = \bar{A}_m\left(\frac{\bar{k}}{\bar{\psi}}\right)^{\gamma}\bar{y}^{\dagger,(1-\gamma)} \tag{144}$$

$$\bar{v} = \frac{\tilde{\gamma}}{\bar{A}_m}\bar{z}^{\gamma}\bar{v}^{\dagger,(1-\gamma)} \tag{145}$$

$$\bar{z}\frac{\bar{k}}{\bar{\psi}} = \frac{\gamma}{(1-\gamma)}\bar{y}^{\dagger}\bar{v}^{\dagger} \tag{146}$$

$$\bar{v} = \frac{(\theta_y - 1}{\theta_y} \tag{147}$$

foreign country

$$\bar{x} = \bar{q}^{\theta_{\star}}\bar{\tilde{x}}^{\star} \tag{148}$$

$$\bar{\Theta} = \bar{x} - \bar{q}\bar{y}^{\star} + \bar{q}\bar{b}^{\star}\frac{(\bar{r}^{\star}-1)}{\bar{\pi}^{\star}\bar{\psi}} \tag{149}$$

central bank

$$\bar{\Theta} = \bar{q}\bar{b}^{\star}\left(1 - \frac{1}{\bar{\pi}^{\star}\bar{\psi}}\right) \tag{150}$$

$$\bar{q}\bar{b}^{\star}\left(1 - \frac{\bar{r}^{\star}}{\bar{\pi}^{\star}\bar{\psi}}\right) = \bar{m}\left(1 - \frac{1}{\bar{\pi}\bar{\psi}}\right) + \bar{g}\left(1 - \frac{\bar{r}}{\bar{\pi}\bar{\psi}}\right) \tag{151}$$

$$1 = \frac{\bar{\mu}}{\bar{\pi}\bar{\psi}} \tag{152}$$

equilibrium conditions

$$\bar{y} = \bar{c} + \bar{x} + \bar{i} \tag{153}$$

$$g\bar{d}p = \bar{c} + \bar{x} - \bar{q}\bar{y}^{\star} + \bar{i} \tag{154}$$

B log-linear model

household

$$\hat{m}_t + \hat{\lambda}_t = -\frac{1}{\bar{r}-1}\hat{r}_t \tag{155}$$

$$0 = E_t\left\{\hat{\lambda}_{t+1} - \hat{\lambda}_t - \hat{\psi}_{t+1} + \hat{r}_t - \hat{\pi}_{t+1}\right\} \tag{156}$$

$$\hat{\lambda}_t = -\hat{c}_t \tag{157}$$

$$\hat{\pi}_t^{\bullet} = \frac{\theta_w}{\Omega_w}\phi_n\bar{n}^{\eta}\bar{c}\left(\eta\hat{n}_t + \hat{c}_t - \hat{w}_t\right) + \beta E_t\hat{\pi}_{t+1}^{\bullet} \tag{158}$$

$$\hat{w}_t = \hat{w}_{t-1} + \hat{\pi}^{\bullet} - \hat{\pi}_t - \hat{\psi}_t \tag{159}$$

intermediate good

$$\hat{y}_t^{\dagger} = \alpha\hat{n}_t + (1-\alpha)\hat{y}_t^{\star} \tag{160}$$

$$\hat{v}^{\dagger} = \alpha\hat{w}_t + (1-\alpha)\hat{q}_t \tag{161}$$

$$\hat{q}_t = \hat{q}_{t-1} + \hat{\pi}_t^{\star} - \hat{\pi}_t - \hat{\psi}_t \tag{162}$$

$$\hat{w}_t + \hat{n}_t = \hat{q}_t\hat{y}_t^{\star} \tag{163}$$

capital creator

$$\hat{k}_t = \frac{\bar{i}}{\bar{k}}\hat{i}_t + \frac{(1-\delta)}{\bar{\psi}}\left(\hat{k}_{t-1} - \hat{\psi}_t\right) \tag{164}$$

$$\hat{i}_t - \hat{i}_{t-1} = \frac{\hat{p}_t^{\diamond}}{\Omega_k} + \beta E_t\left(\hat{i}_{t+1} - \hat{i}_t\right) \tag{165}$$

entrepreneur

$$\hat{\Upsilon}_t = \hat{r}_t^{\dagger} + \hat{k}_{t-1} - \hat{\psi}_t \tag{166}$$

$$\hat{\Upsilon}_t = \hat{p}_t^{\diamond} + \hat{k}_t \tag{167}$$

$$\bar{r}^{\dagger}\hat{r}_t^{\dagger} = \bar{z}\hat{z}_t + (1-\delta)\bar{p}^{\diamond}\hat{p}_t^{\diamond} \tag{168}$$

$$\hat{y}_t = \gamma\left(\hat{k}_{t-1} - \hat{\psi}_t\right) + (1-\gamma)\hat{y}_t^{\dagger} + \hat{A}_{m,t} \tag{169}$$

$$\hat{v}_t = \gamma\hat{z}_t + (1-\gamma)\hat{v}_t^{\dagger} \tag{170}$$

$$\hat{z}_t + \hat{k}_{t-1} - \hat{\psi}_t = \hat{v}_t^{\dagger} + \hat{y}_t^{\dagger} \tag{171}$$

$$\hat{\pi}_t = \frac{\theta_y - 1}{\Omega_y}\hat{v}_t + \beta E_t\hat{\pi}_{t+1} \tag{172}$$

foreign country

$$\hat{x}_t = \theta^\star \hat{q}_t + \hat{\tilde{x}}^\star_t \tag{173}$$

$$\bar{\Theta}\hat{\Theta}_t = \bar{x}\hat{x}_t - \bar{q}\bar{y}^\star\left(\hat{q}_t + \hat{y}^\star_t\right) + \bar{q}\frac{\bar{b}^\star(\bar{r}^\star - 1)}{\bar{\pi}^\star\bar{\psi}}\left(\hat{q}_t + \hat{b}^\star_{t-1} + \frac{\bar{r}^\star}{\bar{r}^\star - 1}\hat{r}^\star_{t-1} - \hat{\pi}^\star_t - \hat{\psi}_t\right) \tag{174}$$

central bank

$$\bar{\Theta}\hat{\Theta}_t = \bar{q}\bar{b}^\star\left(\hat{b}^\star_t + \hat{q}_t\left(1 - \frac{1}{\bar{\pi}^\star\bar{\psi}}\right) - \frac{1}{\bar{\pi}^\star\bar{\psi}}\left(\hat{b}^\star_{(t-1)} - \hat{\pi}^\star - \hat{\psi}\right)\right) \tag{175}$$

$$\begin{aligned}&\bar{q}\bar{b}^\star\left(\hat{b}^\star_t + \hat{q}_t\left(1 - \tfrac{\bar{r}^\star}{\bar{\pi}^\star\bar{\psi}}\right) - \tfrac{\bar{r}^\star}{\bar{\pi}^\star\bar{\psi}}\left(\hat{b}^\star_{t-1} + \hat{r}^\star_{t-1} - \hat{\pi}^\star_t - \hat{\psi}_t\right)\right)\\ &= \bar{m}\left(\hat{m}_t - \tfrac{1}{\bar{\pi}\bar{\psi}}\left(\hat{m}_{t-1} - \hat{\pi}_t - \hat{\psi}_t\right)\right) + \bar{g}\left(\hat{g}_t - \tfrac{\bar{r}}{\bar{\pi}\bar{\psi}}\left(\hat{g}_{t-1} + \hat{r}_{t-1} - \hat{\pi}_t - \hat{\psi}_t\right)\right)\end{aligned} \tag{176}$$

$$\hat{m}_t = \hat{m}_{t-1} + \hat{\mu}_t - \hat{\pi}_t - \hat{\psi}_t \tag{177}$$

equilibrium conditions

$$\bar{y}\hat{y}_t = \bar{c}\hat{c}_t + \bar{x}\hat{x}_t + \bar{i}\hat{i}_t \tag{178}$$

$$g\bar{d}pg\hat{d}p_t = \bar{c}\hat{c}_t + \bar{x}\hat{x}_t - \bar{q}\bar{y}^\star(\hat{q}_t + \hat{y}^\star_t) + \bar{i}\hat{i}_t \tag{179}$$

B simple model

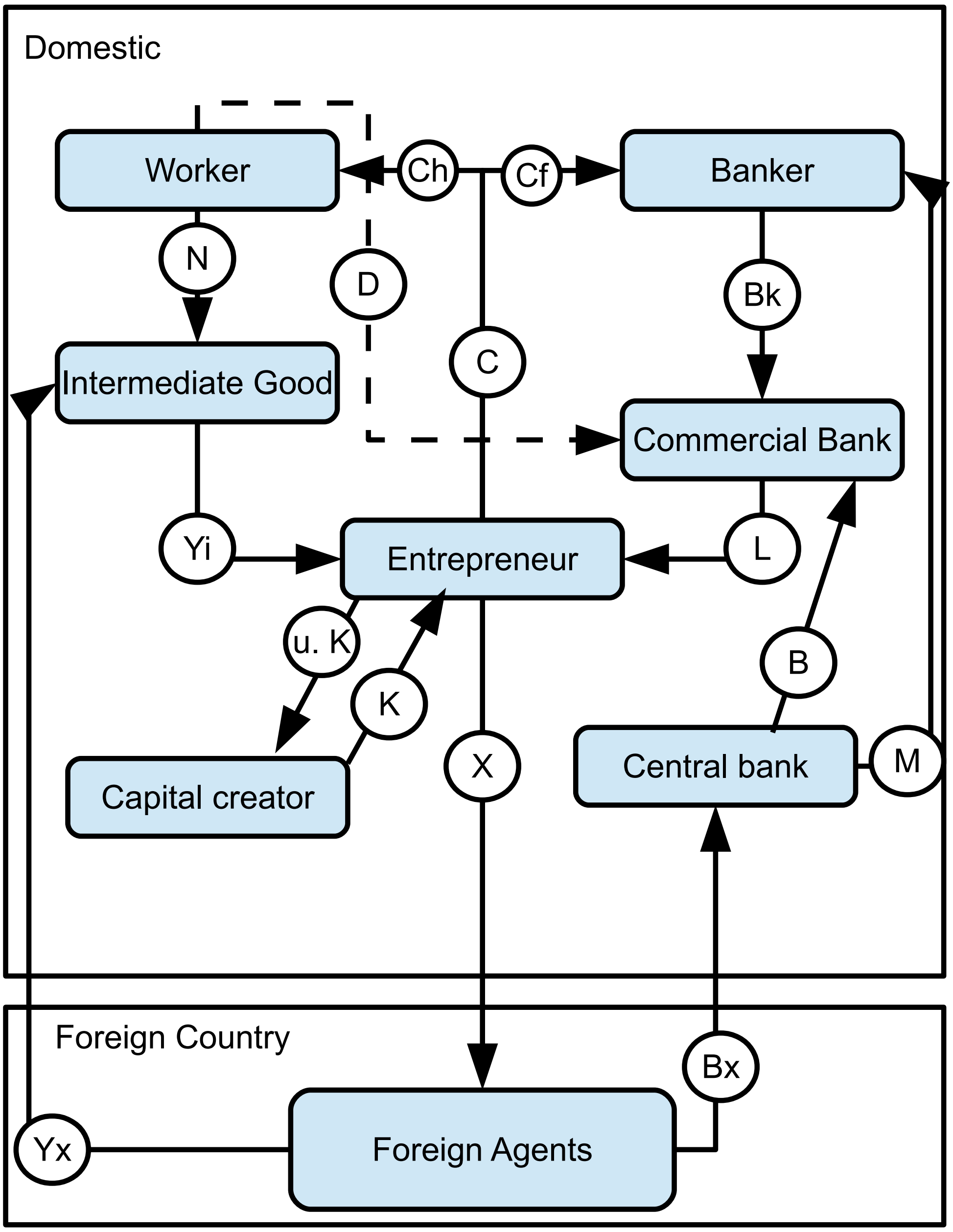

Figure 17: schematic simple model

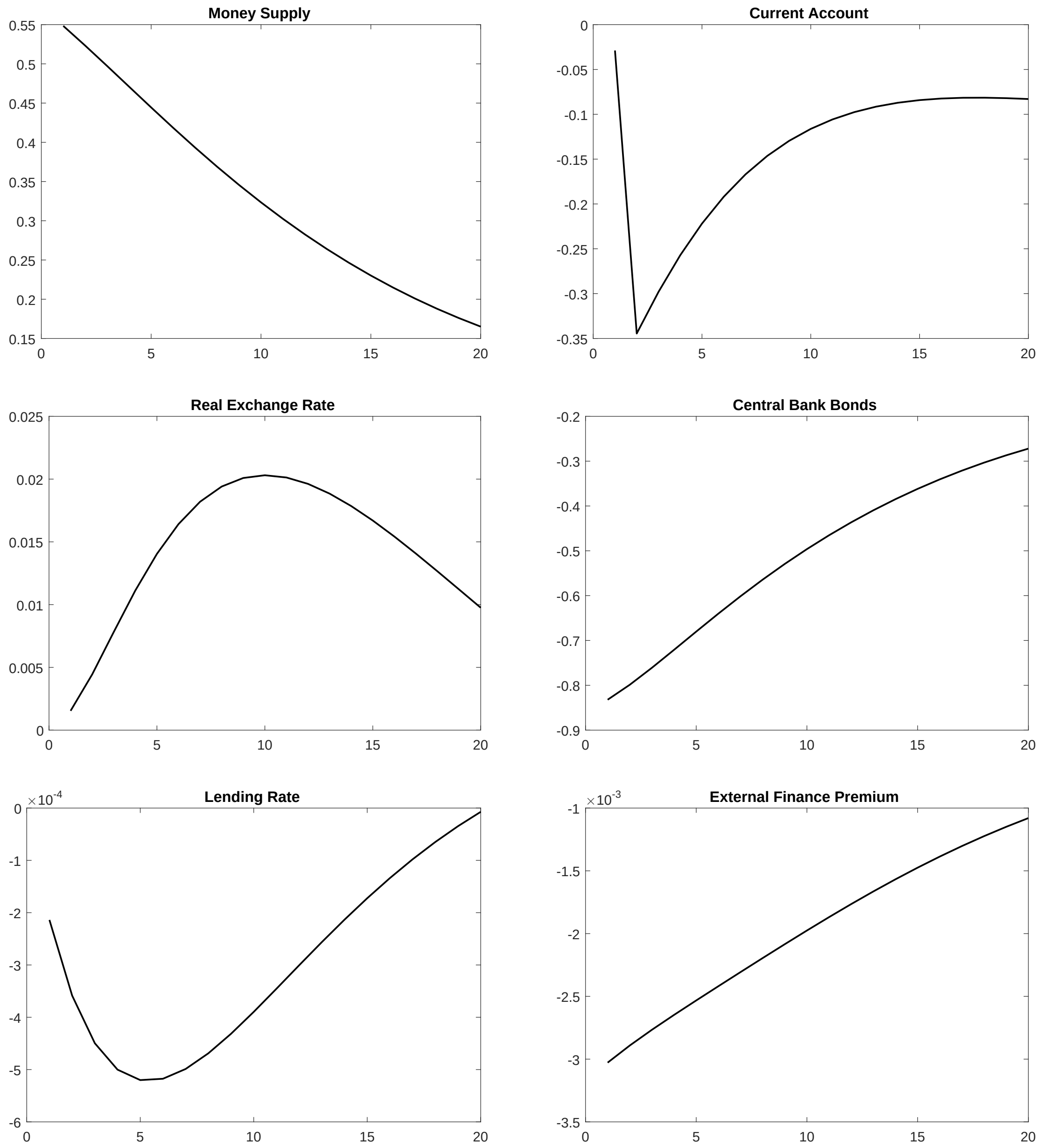

Figure 18: Simple model IRF of other variables after a persistent foreign interest rate shock

B.1 Log-linear model

worker

$$0 = E_t \left\{ \hat{\lambda}^{\bullet}_{t+1} - \hat{\lambda}^{\bullet}_t - \hat{\psi}_{t+1} + \hat{r}^{\bullet}_t - \hat{\pi}_{t+1} \right\} \tag{180}$$

$$\hat{\lambda}^{\bullet}_t = -\hat{c}^{\bullet}_t \tag{181}$$

$$\hat{\pi}^{\bullet}_t = \frac{\theta_w}{\Omega_w} \phi_n \bar{n}^{\eta} \bar{c}^{\bullet} \left(\eta \hat{n}_t + \hat{c}^{\bullet}_t - \hat{w}_t \right) + \beta E_t \hat{\pi}^{\bullet}_{t+1} \tag{182}$$

$$\hat{w}_t = \hat{w}_{t-1} + \hat{\pi}^{\bullet} - \hat{\pi}_t - \hat{\psi}_t \tag{183}$$

banker

$$\hat{\lambda}^{\circ} = -\hat{c}^{\circ}_t \tag{184}$$

$$0 = E_t \left\{ \hat{\lambda}^{\circ}_{t+1} - \hat{\lambda}^{\circ}_t + \hat{r}_t - \hat{\pi}_t - \hat{\psi}_{t+1} \right\} \tag{185}$$

$$\hat{r}^{\circ}_t - \hat{r}^{\circ}_{t-1} = \frac{\theta_f}{\Omega_f} \left(\hat{r} - t - \hat{r}^{\circ}_t \right) + \beta E_t \left(\hat{r}^{\circ}_{t+1} - \hat{r}^{\circ}_t \right) \tag{186}$$

$$\hat{m}_t + \hat{\lambda}^{\circ}_t = -\frac{1}{\bar{r} - 1} \hat{r}_t \tag{187}$$

intermediate good

$$\hat{y}^{\dagger}_t = \alpha \hat{n}_t + (1 - \alpha) \hat{y}^{\star}_t \tag{188}$$

$$\hat{v}^{\dagger} = \alpha \hat{w}_t + (1 - \alpha) \hat{q}_t \tag{189}$$

$$\hat{q}_t = \hat{q}_{t-1} + \hat{\pi}^{\star}_t - \hat{\pi}_t - \hat{\psi}_t \tag{190}$$

$$\hat{w}_t + \hat{n}_t = \hat{q}_t \hat{y}^{\star}_t \tag{191}$$

capital creator

$$\hat{k}_t = \frac{\bar{i}}{\bar{k}} \hat{i}_t + \frac{(1 - \delta)}{\bar{\psi}} \left(\hat{k}_{t-1} - \hat{\psi}_t \right) \tag{192}$$

$$\hat{i}_t - \hat{i}_{t-1} = \frac{\hat{p}^{\diamond}_t}{\Omega_k} + \beta E_t \left(\hat{i}_{t+1} - \hat{i}_t \right) \tag{193}$$

entrepreneur

$$\hat{y}_t = \hat{A}_{m,t} + \gamma \left(\hat{k}_{t-1} - \hat{\psi}_t \right) + (1 - \gamma) \hat{y}^{\dagger}_t \tag{194}$$

$$\hat{v}_t = \gamma \hat{z}_t + (1 - \gamma) \hat{v}^{\dagger}_t - \hat{A}_{m,t} \tag{195}$$

$$\hat{z}_t + \hat{k}_{t-1} - \hat{\psi}_t = \hat{y}^{\dagger}_t + \hat{v}^{\dagger}_t \tag{196}$$

$$\hat{\pi}_t = \frac{\theta_y - 1}{\Omega_y} \hat{v}_t + \beta E_t \hat{\pi}_{t+1} \tag{197}$$

$$\bar{r}^{\dagger} \hat{r}^{\dagger}_t = \bar{z} \hat{z}_t + (1 - \delta) \bar{p}^{\dagger} \hat{p}^{\dagger}_t \tag{198}$$

$$\hat{\xi}_t = \psi_e(\hat{p}_t^\diamond + \hat{k}_t - \hat{\Upsilon}_t) \tag{199}$$

$$\begin{gathered}\tfrac{1}{\nu}\bar{\Upsilon}\hat{\Upsilon}_t = \\ \tfrac{\bar{r}^\dagger \bar{k}}{\bar{\psi}} \left(\hat{r}_t^\dagger + \hat{k}_{t-1} - \hat{\psi}_t\right) - \tfrac{\bar{r}^\ddagger}{\bar{\pi}} \overline{\xi b} \left(\hat{r}_t^\ddagger + \hat{\xi}_t + \hat{b}_t - \hat{\pi}_t\right)\end{gathered} \tag{200}$$

$$\bar{b}\hat{b}_t = \bar{p}^\diamond \bar{k}(\hat{p}_t^\diamond + \hat{k}_t) - \bar{\Upsilon}\hat{\Upsilon}_t \tag{201}$$

commercial bank

$$\hat{b}_t = \hat{d}_t \tag{202}$$

$$\hat{b} = \hat{\ell}_t + \hat{s}_t \tag{203}$$

$$\bar{r}^\bullet \hat{r}_t^\bullet = \bar{r}\hat{r}_t - \chi \bar{d}\hat{d}_t \tag{204}$$

$$\hat{r}_t^\ddagger - \hat{r}_{t-1}^\ddagger = \frac{\theta_j}{\Omega_j}(\hat{v}_t^\ddagger - \hat{r}_t^\ddagger) + \beta E_t(\hat{r}_{t+1}^\ddagger - \hat{r}_t^\ddagger) \tag{205}$$

$$\begin{gathered}\bar{v}^\ddagger \hat{v}_t^\ddagger = \\ \bar{r} \bullet \hat{r}_t^\bullet + \tfrac{1}{\bar{\ell}} \left(\bar{r}^\circ \hat{r}_t^\circ - \bar{r}\hat{r}_t - \left(\bar{r}^\ddagger - 1\right) \tfrac{\ell^\ddagger - \bar{\ell}}{\ell^\ddagger} \left(\tfrac{\bar{r}^\ddagger}{\bar{r}^\ddagger - 1}\hat{r}_t^\ddagger + \tfrac{\bar{\ell}}{\ell^\ddagger - \bar{\ell}}\hat{\ell}_t\right) + \hat{\ell}_t \left(\bar{r}^\circ - \bar{r} - \bar{r}^\ddagger \tfrac{\ell^\ddagger - \bar{\ell}}{\ell^\ddagger}\right)\right)\end{gathered} \tag{206}$$

$$\frac{\bar{\ell}}{\ell^\ddagger}\hat{\ell}_t = -\frac{\ell^\ddagger}{\Omega_\ell}\frac{(\bar{r}^\ddagger - 1)}{\bar{s}} \left(\frac{\bar{r}^\ddagger}{\bar{r}^\ddagger - 1}\hat{r}_t^\ddagger - \hat{s}_t\right) \tag{207}$$

foreign country

$$\hat{x}_t = \theta^\star \hat{q}_t + \hat{\tilde{x}}_t^\star \tag{208}$$

$$\bar{\Theta}\hat{\Theta}_t = \bar{x}\hat{x}_t - \bar{q}\bar{y}^\star(\hat{q}_t + \hat{y}_t^\star) + \bar{q}\frac{\bar{b}^\star(\bar{r}^\star - 1)}{\bar{\pi}^\star \bar{\psi}} \left(\hat{q}_t + \hat{b}_{t-1}^\star + \frac{\bar{r}^\star}{\bar{r}^\star - 1}\hat{r}_{t-1}^\star - \hat{\pi}_t^\star - \hat{\psi}_t\right) \tag{209}$$

central bank

$$\bar{\Theta}\hat{\Theta}_t = \bar{q}\bar{b}^\star \left(\hat{b}_t^\star + \hat{q}_t \left(1 - \frac{1}{\bar{\pi}^\star \bar{\psi}}\right) - \frac{1}{\bar{\pi}^\star \bar{\psi}} \left(\hat{b}_{t-1}^\star - \hat{\pi}^\star - \hat{\psi}\right)\right) \tag{210}$$

$$\begin{gathered}\bar{q}\bar{b}^\star \left(\hat{b}_t^\star + \hat{q}_t \left(1 - \tfrac{\bar{r}^\star}{\bar{\pi}^\star \bar{\psi}}\right) - \tfrac{\bar{r}^\star}{\bar{\pi}^\star \bar{\psi}} \left(\hat{b}_{t-1}^\star + \hat{r}_{t-1}^\star - \hat{\pi}_t^\star - \hat{\psi}_t\right)\right) \\ = \bar{m}\left(\hat{m}_t - \tfrac{1}{\bar{\pi}\bar{\psi}}\left(\hat{m}_{t-1} - \hat{\pi}_t - \hat{\psi}_t\right)\right) + \bar{g}\left(\hat{g}_t - \tfrac{\bar{r}}{\bar{\pi}\bar{\psi}}\left(\hat{g}_{t-1} + \hat{r}_{t-1} - \hat{\pi}_t - \hat{\psi}_t\right)\right)\end{gathered} \tag{211}$$

$$\hat{m}_t = \hat{m}_{t-1} + \hat{\mu}_t - \hat{\pi}_t - \hat{\psi}_t \tag{212}$$

equilibrium conditions

$$\bar{c}\hat{c}_t = \bar{c}^\bullet \hat{c}_t^\bullet + \bar{c}^\circ \hat{c}_t^\circ \tag{213}$$

$$\hat{g}_t = \hat{s}_t \tag{214}$$

$$\bar{y}\hat{y}_t = \bar{c}\hat{c}_t + \bar{x}\hat{x}_t + \bar{i}\hat{i}_t \tag{215}$$

$$g\bar{d}pg\hat{d}p_t = \bar{c}\hat{c}_t + \bar{x}\hat{x}_t - \bar{q}\bar{y}^\star(\hat{q}_t + \hat{y}_t^\star) + \bar{i}\hat{i}_t \tag{216}$$

C Chinese model

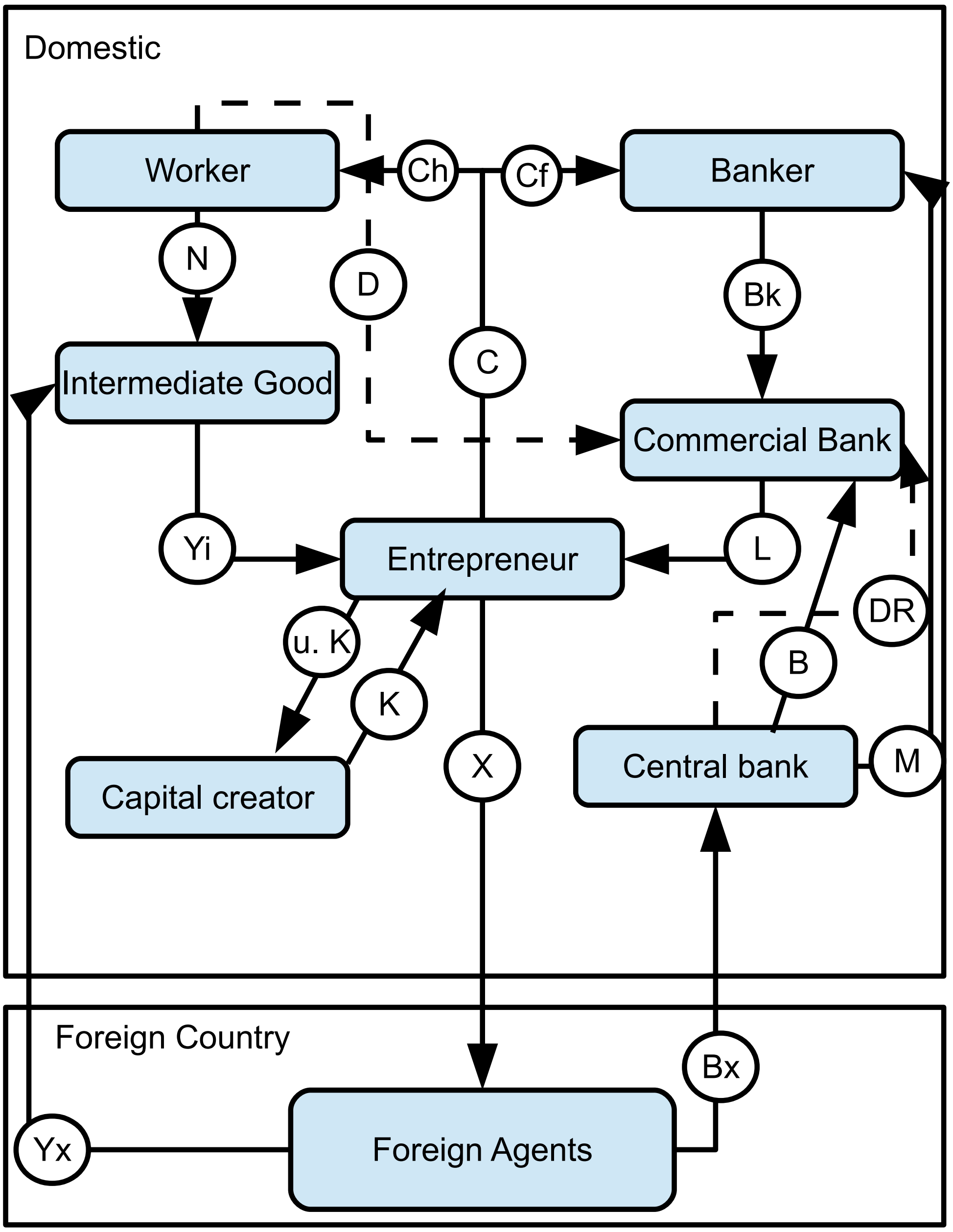

Figure 19: schematic Chinese model

C.1 Log-linear model

worker

$$0 = E_t \left\{ \hat{\lambda}^\bullet_{t+1} - \hat{\lambda}^\bullet_t - \hat{\psi}_{t+1} + \hat{r}^\bullet_t - \hat{\pi}_{t+1} \right\} \tag{217}$$

$$\hat{\lambda}^\bullet_t = -\hat{c}^\bullet_t \tag{218}$$

$$\hat{\pi}^\bullet_t = \frac{\theta_w}{\Omega_w} \phi_n \bar{n}^\eta \bar{c}^\bullet \left(\eta \hat{n}_t + \hat{c}^\bullet_t - \hat{w}_t \right) + \beta E_t \hat{\pi}^\bullet_{t+1} \tag{219}$$

$$\hat{w}_t = \hat{w}_{t-1} + \hat{\pi}^\bullet - \hat{\pi}_t - \hat{\psi}_t \tag{220}$$

banker

$$\hat{\lambda}^\circ = -\hat{c}^\circ_t \tag{221}$$

$$0 = E_t \left\{ \hat{\lambda}^\circ_{t+1} - \hat{\lambda}^\circ_t + \hat{r}_t - \hat{\pi}_t - \hat{\psi}_{t+1} \right\} \tag{222}$$

$$\hat{r}^\circ_t - \hat{r}^\circ_{t-1} = \frac{\theta_f}{\Omega_f} \left(\hat{r} - t - \hat{r}^\circ_t \right) + \beta E_t \left(\hat{r}^\circ_{t+1} - \hat{r}^\circ_t \right) \tag{223}$$

$$\hat{m}_t + \hat{\lambda}^\circ_t = -\frac{1}{\bar{r} - 1} \hat{r}_t \tag{224}$$

intermediate good

$$\hat{y}^\dagger_t = \alpha \hat{n}_t + (1 - \alpha) \hat{y}^\star_t \tag{225}$$

$$\hat{v}^\dagger = \alpha \hat{w}_t + (1 - \alpha) \hat{q}_t \tag{226}$$

$$\hat{q}_t = \hat{q}_{(t-1)} + \hat{\pi}^\star_t - \hat{\pi}_t - \hat{\psi}_t \tag{227}$$

$$\hat{w}_t + \hat{n}_t = \hat{q}_t \hat{y}^\star_t \tag{228}$$

capital creator

$$\hat{k}_t = \frac{\bar{i}}{\bar{k}} \hat{i}_t + \frac{(1 - \delta)}{\bar{\psi}} \left(\hat{k}_{t-1} - \hat{\psi}_t \right) \tag{229}$$

$$\hat{i}_t - \hat{i}_{t-1} = \frac{\hat{p}^\diamond_t}{\Omega_k} + \beta E_t \left(\hat{i}_{t+1} - \hat{i}_t \right) \tag{230}$$

entrepreneur

$$\hat{y}_t = \hat{A}_{m,t} + \gamma \left(\hat{k}_{t-1} - \hat{\psi}_t \right) + (1 - \gamma) \hat{y}^\dagger_t \tag{231}$$

$$\hat{v}_t = \gamma \hat{z}_t + (1 - \gamma) \hat{v}^\dagger_t - \hat{A}_{m,t} \tag{232}$$

$$\hat{z}_t + \hat{k}_{t-1} - \hat{\psi}_t = \hat{y}^\dagger_t + \hat{v}^\dagger_t \tag{233}$$

$$\hat{\pi}_t = \frac{\theta_y - 1}{\Omega_y} \hat{v}_t + \beta E_t \hat{\pi}_{t+1} \tag{234}$$

$$\bar{r}^\dagger \hat{r}^\dagger_t = \bar{z} \hat{z}_t + (1 - \delta) \bar{p}^\diamond \hat{p}^\diamond_t \tag{235}$$

$$\hat{\xi}_t = \psi_e(\hat{p}_t^{\diamond} + \hat{k}_t - \hat{\Upsilon}_t) \tag{236}$$

$$\begin{gathered} \frac{1}{\nu}\bar{\Upsilon}\hat{\Upsilon}_t = \\ \frac{\bar{r}^{\dagger}\bar{k}}{\bar{\psi}}\left(\hat{r}_t^{\dagger} + \hat{k}_{t-1} - \hat{\psi}_t\right) - \frac{\bar{r}^{\ddagger}}{\bar{\pi}}\overline{\xi b}\left(\hat{r}_t^{\ddagger} + \hat{\xi}_t + \hat{b}_t - \hat{\pi}_t\right) \end{gathered} \tag{237}$$

$$\bar{b}\hat{b}_t = \bar{p}^{\diamond}\bar{k}(\hat{p}_t^{\diamond} + \hat{k}_t) - \bar{\Upsilon}\hat{\Upsilon}_t \tag{238}$$

commercial bank

$$\hat{b}_t = \hat{d}_t \tag{239}$$

$$\hat{b} = \hat{\ell}_t + \hat{s}_t \tag{240}$$

$$\hat{r}_t^{\bullet} = \theta_m\hat{\Xi}_t + (1-\theta_m)\left(\bar{r}\hat{r}_t - \chi\bar{d}\hat{d}_t\right) \tag{241}$$

$$\hat{r}_t^{\ddagger} - \hat{r}_{t-1}^{\ddagger} = \frac{\theta_j}{\Omega_j}(\hat{v}_t^{\ddagger} - \hat{r}_t^{\ddagger}) + \beta E_t(\hat{r}_{t+1}^{\ddagger} - \hat{r}_t^{\ddagger}) \tag{242}$$

$$\begin{gathered} \bar{v}^{\ddagger}\hat{v}_t^{\ddagger} = \bar{r}^{\bullet}\hat{r}_t^{\bullet} - \theta_\zeta\bar{\zeta}\hat{\zeta}_t \\ +\frac{1}{\bar{\ell}}\left(\bar{r}^{\circ}\hat{r}_t^{\circ} - \bar{r}\hat{r}_t - \left(\bar{r}^{\ddagger}-1\right)\frac{\ell^{\ddagger}-\bar{\ell}}{\ell^{\ddagger}}\left(\frac{\bar{r}^{\ddagger}}{\bar{r}^{\ddagger}-1}\hat{r}_t^{\ddagger} + \frac{\bar{\ell}}{\ell^{\ddagger}-\bar{\ell}}\hat{\ell}_t\right) + \hat{\ell}_t\left(\bar{r}^{\circ} - \bar{r} - \bar{r}^{\ddagger}\frac{\ell^{\ddagger}-\bar{\ell}}{\ell^{\ddagger}}\right)\right) \end{gathered} \tag{243}$$

$$\frac{\bar{\ell}}{\ell^{\ddagger}}\hat{\ell}_t = -\frac{\ell^{\ddagger}}{\Omega_\ell}\frac{(\bar{r}^{\ddagger}-1)}{\bar{s}}\left(\frac{\bar{r}^{\ddagger}}{\bar{r}^{\ddagger}-1}\hat{r}_t^{\ddagger} - \hat{s}_t\right) \tag{244}$$

foreign country

$$\hat{x}_t = \theta_\star\hat{q}_t + \hat{\tilde{x}}_t^{\star} \tag{245}$$

$$\bar{\Theta}\hat{\Theta}_t = \bar{x}\hat{x}_t - \bar{q}\bar{y}^{\star}\left(\hat{q}_t + \hat{y}_t^{\star}\right) + \bar{q}\frac{\bar{b}^{\star}(\bar{r}^{\star}-1)}{\bar{\pi}^{\star}\bar{\psi}}\left(\hat{q}_t + \hat{b}_{t-1}^{\star} + \frac{\bar{r}^{\star}}{\bar{r}^{\star}-1}\hat{r}_{t-1}^{\star} - \hat{\pi}_t^{\star} - \hat{\psi}_t\right) \tag{246}$$

central bank

$$\bar{\Theta}\hat{\Theta}_t = \bar{q}\bar{b}^{\star}\left(\hat{b}_t^{\star} + \hat{q}_t\left(1 - \frac{1}{\bar{\pi}^{\star}\bar{\psi}}\right) - \frac{1}{\bar{\pi}^{\star}\bar{\psi}}\left(\hat{b}_{t-1}^{\star} - \hat{\pi}^{\star} - \hat{\psi}\right)\right) \tag{247}$$

$$\begin{gathered} \bar{q}\bar{b}^{\star}\left(\hat{b}_t^{\star} + \hat{q}_t\left(1 - \frac{\bar{r}^{\star}}{\bar{\pi}^{\star}\bar{\psi}}\right) - \frac{\bar{r}^{\star}}{\bar{\pi}^{\star}\bar{\psi}}\left(\hat{b}_{t-1}^{\star} + \hat{r}_{t-1}^{\star} - \hat{\pi}_t^{\star} - \hat{\psi}_t\right)\right) \\ = \bar{m}\left(\hat{m}_t - \frac{1}{\bar{\pi}\bar{\psi}}\left(\hat{m}_{t-1} - \hat{\pi}_t - \hat{\psi}_t\right)\right) + \bar{g}\left(\hat{g}_t - \frac{\bar{r}}{\bar{\pi}\bar{\psi}}\left(\hat{g}_{t-1} + \hat{r}_{t-1} - \hat{\pi}_t - \hat{\psi}_t\right)\right) \\ +\theta_\zeta\bar{d}\left(\hat{d}_t - \frac{\bar{\zeta}}{\bar{\pi}\bar{\psi}}\left(\hat{\zeta}_{t-1} + \hat{d}_{t-1} - \hat{\pi}_t - \hat{\psi}_t\right)\right) \end{gathered} \tag{248}$$

$$\hat{m}_t = \hat{m}_{t-1} + \hat{\mu}_t - \hat{\pi}_t - \hat{\psi}_t \tag{249}$$

$$\hat{\Xi} = \rho_d\hat{r}_{t-1}^{\bullet} + (1-\rho_d)\left(\frac{\bar{r}^{\bullet}}{\bar{r}}\right)^{(1-\rho_d)}\hat{r}_t \tag{250}$$

$$\hat{\zeta}_t = \rho_\zeta\hat{\zeta}_{t-1} + (1-\rho_\zeta)(\hat{r} - \hat{r}_{t-1}) \tag{251}$$

equilibrium conditions

$$\bar{c}\hat{c}_t = \bar{c}^{\bullet}\hat{c}_t^{\bullet} + \bar{c}^{\circ}\hat{c}_t^{\circ} \tag{252}$$

$$\hat{g}_t = \hat{s}_t \tag{253}$$

$$\bar{y}\hat{y}_t = \bar{c}\hat{c}_t + \bar{x}\hat{x}_t + \bar{i}\hat{i}_t \tag{254}$$

$$g\bar{d}pg\hat{d}p_t = \bar{c}\hat{c}_t + \bar{x}\hat{x}_t - \bar{q}\bar{y}^{\star}(\hat{q}_t + \hat{y}_t^{\star}) + \bar{i}\hat{i}_t \tag{255}$$

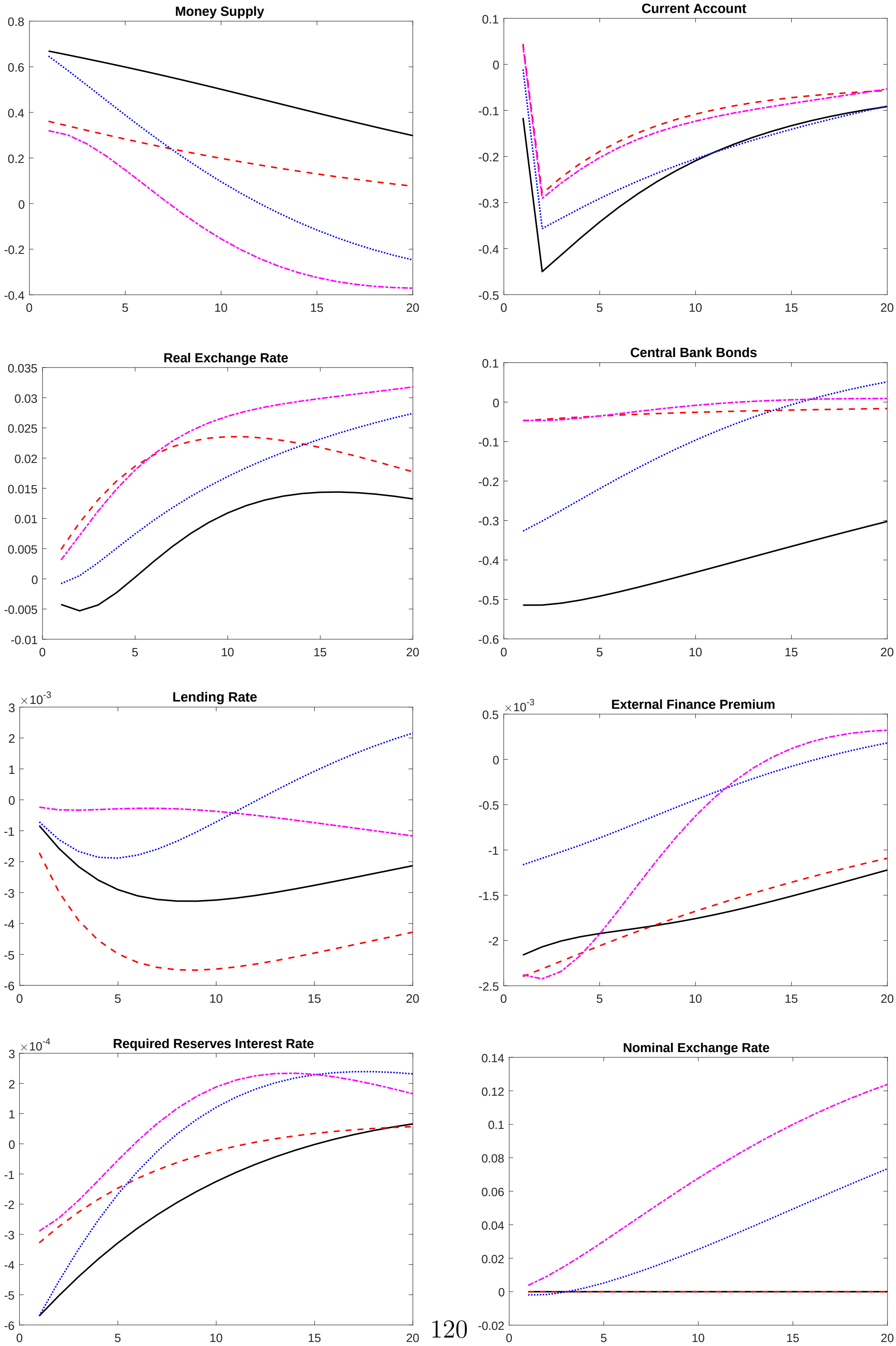

Figure 20: IRF of other variables after a persistent foreign interest rate shock, Chinese model (black), open capital account (red), floating exchange rate (blue) and complete liberalization(violet)