Financial Repression and Liberalisation in China

by

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To my parents

Abstract

This thesis is concerned with the implications of the financial liberalisation of the Chinese economy for savings, investment, monetary policy and the exchange rate, in China.

In the first part, the financial repression hypothesis is tested on savings and investment, with the result that there is some evidence to support the complementarity between money and physical capital in China since 1987, although this effect is shown to have become weaker over the sample period as liberalisation has taken place.

The second issue is to investigate the consequences of interest rate liberalisation in China, using a dynamic stochastic general equilibrium (DSGE) model. There are two main findings. First, raising deposit rates serves to alter the division of production between consumption and investment and to improve the efficiency of the monetary policy transmission mechanism through interest rates. Second, the deregulation of deposit and loan rates leads to less volatility in inflation as interest rates are allowed to partly absorb shocks to the economy. Other monetary policies under financial repression in China are examined as well. The results based on the DSGE model suggest that the interest rate rule is more effective and powerful than the conventional money growth rule and the adjustment of the required reserve ratio helps little to contain inflation. In addition, the administrative window guidance on bank loans contributes to less volatility of inflation and stabilises the deregulation process of deposit and loan rates.

The final part of the thesis examines the sources of the volatility in real exchange rate, which are shown to stem essentially from demand shocks, although up to a quarter of the volatility comes from relative supply disturbances, perhaps reflecting the importance of supply-side reform in China since the early 1990s.

Key words: Financial repression; Interest rate liberalisation; Monetary policy; Exchange rate

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Chapter 1

Introduction

1.1 An overview of China's financial reforms

The reform of China's financial system started in 1978, and according to He (2008) has passed through four stages. The initial stage covered 1978 to 1983 where the objective was to establish the central banking system. In September 1983, the State Council decided to formally designate the People's Bank of China (PBoC) as a central bank. Before that, the PBoC was the only bank in the People's Republic of China, serving the functions of both a central bank and those of commercial banks. The second stage of the reform between 1984 and 1992 focused on the transformation of the function of the central bank. Commercial banks emerged during this period, but the main objective of the monetary policy was still to stimulate economic growth only. The third stage, from 1993 to 2003, saw the development of a modern central banking system. Three policy banks were established in 1994, which had the PBoC focus on the implementation of monetary policy. The PBoC therefore, started to monitor nominal money supply growth in the autumn in 1994. Since then, adjusting the growth of nominal money supply, measured as M1 and M2, has become the official policy to promote economic growth and maintain price stability. Moreover, open market operations were introduced and used by

the PBoC in April 1996. Since 2003, China's financial reform has entered into the fourth stage where the responsibility of financial regulation was taken from the central bank, and moved to the China Banking Regulatory Commission (CBRC), which was opened in April 2003 and takes the role of regulating the banking sector in China.

The objective of China's financial liberalisation is to establish a thorough and effective financial system to promote economic growth, facilitate internal rebalancing and to maintain financial stability. Along with the reform of the economic and financial system, monetary policy in China has been adjusted frequently. Though the PBoC has been transformed and developed into the central bank in China, it is not independent of the central government (Chen *et al.*, 2012). The PBoC and the central government set monetary policy targets every year, as outlined in Table 1.1, along with inflation targets and real GDP growth rate targets. As mentioned above, the nominal money growth target has been the official monetary policy indicator since 1994. The target is published in the People's Banks of China Annual Report and recently it has been announced by the Prime Minister, not the PBoC, in his speech at the National People's Congress every March. For example, the target of M2 growth in 2016, announced by Prime Minister Li Keqiang in March, was set to be "around 13%" in the 2016 Report on the Work of the Government[1]. The objective of the PBoC as a central bank, when implementing monetary policy, is to safeguard price stability and help facilitate economic growth. Open market operations, central bank lending and a required reserve ratio are classified as market-based monetary policy instruments which are widely used by the PBoC and other central banks. Conventional monetary policy theory considers the adjustment of the required reserve ratio to be too sensitive to use and many central banks in advanced economies rarely use it due to the potential huge effects it may have. Nevertheless, it has been actively used by the PBoC in

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[1]The full report in English is available at
http://english.gov.cn/premier/news/2016/03/17/content_281475309417987.htm

Table 1.1: Monetary policy targets (1994-2016)

Year	M2 Growth	Real GDP Growth	Inflation	Year	M2 Growth	Real GDP Growth	Inflation
1994	24%	9%	10%	2006	16%	8%	3%
1995	23%-25%	8%-9%	15%	2007	16%	8%	3%
1996	25%	8%	10%	2008	17%	8%	5%
1997	23%	8%	6%	2009	17%	8%	4%
1998	16%-18%	8%	5%	2010	17%	8%	3%
1999	14%-15%	8%	2%	2011	16%	8%	4%
2000	14%-15%	8%	1%	2012	14%	8%	4%
2001	15%-16%	7%	1%-2%	2013	13%	8%	4%
2002	13%	7%	1%-2%	2014	13%	8%	4%
2003	16%	7%	1%	2015	12%	7%	3%
2004	17%	7%	3%	2016	13%	6.5%-7%	3%
2005	15%	8%	4%				

Note: 1. All the targets above are annualised rates. 2. Data are collected from the People's Bank of China Annual Report and the National People's Congress website. 3. Inflation targets were represented by the growth rate of RPI between 1994 and 1997, and since 1998 the central government has started to publish the inflation targets based on CPI.

China as an important monetary policy instrument, especially since 2007. Table 1.2 summarises the historical adjustment of reserved required ratio since 1984. It shows that the ratio has been adjusted 50 times since 1985, and has been used more frequently since 2006. For example, the ratio was raised 12 times between January 2010 and June 2011, each time by 0.5 percentage points. He (2008) proposes that the frequent adjustments of the required reserve ratio in China helps to control the excess liquidity of banking system, so as to avoid the volatility in the financial markets. In April 2004, the PBoC introduced different required reserve ratios taking account of capital adequacy ratio and asset quality of individual commercial banks, and further developed a dynamic different required reserve ratio in 2011 to allow for monthly variation (Chen *et al.*, 2012). However, the details of financial institutions with different required reserve ratios remain highly confidential.

Meanwhile, some non-market based monetary policy instruments in the presence of financial repression are more frequently used, such as regulated interest rates and the window guidance for bank lending. Interest rate liberalisation has long been proposed in China's financial reform and the objective is to improve the

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Table 1.2: Previous adjustments of required reserve ratio

No.	Effective Date	Before	After	Variation	No.	Effective Date	Before	After	Variation
1	1985	10.0%			26	25-Sep-2008	17.5%	17.5%	0.0%
2	1987	10.0%	12.0%	2.0%	27	15-Oct-2008	17.5%	17.0%	-0.5%
3	Sep-1988	12.0%	13.0%	1.0%	28	05-Dec-2008	17.0%	16.0%	-1.0%
4	21-Mar-1998	13.0%	8.0%	-5.0%	29	25-Dec-2008	16.0%	15.5%	-0.5%
5	21-Nov-1999	8.0%	6.0%	-2.0%	30	18-Jan-2010	15.5%	16.0%	0.5%
6	21-Sep-2003	6.0%	7.0%	1.0%	31	25-Feb-2010	16.0%	16.5%	0.5%
7	25-Apr-2004	7.0%	7.5%	0.5%	32	10-May-2010	16.5%	17.0%	0.5%
8	05-Jul-3006	7.5%	8.0%	0.5%	33	16-Nov-2010	17.0%	17.5%	0.5%
9	15-Aug-2006	8.0%	8.5%	0.5%	34	19-Nov-2010	17.5%	18.0%	0.5%
10	15-Nov-2006	8.5%	9.0%	0.5%	35	20-Dec-2010	18.0%	18.5%	0.5%
11	15-Jan-2007	9.0%	9.5%	0.5%	36	20-Jan-2011	18.5%	19.0%	0.5%
12	25-Feb-2007	9.5%	10.0%	0.5%	37	14-Feb-2011	19.0%	19.5%	0.5%
13	16-Apr-2007	10.0%	10.5%	0.5%	38	25-Mar-2011	19.5%	20.0%	0.5%
14	15-May-2007	10.5%	11.0%	0.5%	39	21-Apr-2011	20.0%	20.5%	0.5%
15	05-Jun-2007	11.0%	11.5%	0.5%	40	18-May-2011	20.5%	21.0%	0.5%
16	15-Aug-2007	11.5%	12.0%	0.5%	41	20-Jun-2011	21.0%	21.5%	0.5%
17	25-Sep-2007	12.0%	12.5%	0.5%	42	05-Dec-2011	21.5%	21.0%	-0.5%
18	25-Oct-2007	12.5%	13.0%	0.5%	43	24-Feb-2012	21.0%	20.5%	-0.5%
19	26-Nov-2007	13.0%	13.5%	0.5%	44	18-May-2012	20.5%	20.0%	-0.5%
20	25-Dec-2007	13.5%	14.5%	1.0%	45	05-Feb-2015	20.0%	19.5%	-0.5%
21	25-Jan-2008	14.5%	15.0%	0.5%	46	20-Apr-2015	19.5%	18.5%	-1.0%
22	25-Mar-2008	15.0%	15.5%	0.5%	47	28-Jun-2015	18.5%	18.0%	-0.5%
23	25-Apr-2008	15.5%	16.0%	0.5%	48	06-Sep-2015	18.0%	17.5%	-0.5%
24	20-May-2008	16.0%	16.5%	0.5%	49	24-Oct-2015	17.5%	17.0%	-0.5%
25	25-Jun-2008	16.5%	17.5%	1.0%	50	01-Mar-2016	17.0%	16.5%	-0.5%

Note: 1. Data are collected from the PBoC's website. 2. The PBoC set the required reserve ratio to be various from different deposit types in 1984, i.e. 20% for enterprise deposits, 25% for rural deposits and 40% for savings deposits. In 1985, the PBoC then adopted the unified required reserve ratio, and set it to be 10%. 3. Since September 2008, required reserve ratio has been different between large financial institutions and medium to small and medium-sized financial institutions. Only the ratios applied to large financial institutions are reported above. 4. On 25-Sep-2008, the adjustment applied to small and medium-sized financial institutions only, by decreasing from 17.5% to 16.5%.

efficiency of capital allocation as well as the monetary policy transmission. Interest rate liberalisation started in the capital market in late 1990s. On the first day of 1996, the China Interbank Offered Rate was introduced and was soon freely determined by the market on 17 May 1996. Following that, the Shanghai Interbank Offered Rate (Shibor) was introduced in April 2007, which is now considered as the benchmark interest rate for asset pricing. In addition, the PBoC has been freeing controls on the interbank bond repurchase rate as well as the bond market rate since 5 June 1997, and the China Development Bank, one of the three policy banks opened in 1994, issued the first market-priced bonds in 1998. One year later, in 1999, government bonds are first issued via an open bid.

Reforms of deposit and lending interest rates are considered as the last and the most difficult step in interest rate liberalisation and are still under way. The reform starts from foreign currency deposit and lending interest rates. On 21 September 2000, the control of foreign exchange lending rates was removed, together with the control of foreign exchange deposit rates for large accounts (3 million dollars equivalently and above). Additionally, the floor of foreign exchange deposit rates for small accounts was removed on 11 November 2003 and following that, the PBoC liberalised the small-account foreign exchange deposit rates with maturity of over one year.

A timeline of deposit and lending rates liberalisation for domestic currency, RMB, is outlined in Table 1.3. The lending interest rates for RMB were allowed to be floating within an interval in 1998. The ceiling of lending interest rates was lifted three times during 1998 to 1999, and was then removed on 29 October 2004 among financial institutions (excluding urban and rural credit cooperatives). The floor of lending interest rates was eventually removed on 20 July 2013, since when the loan rates were allowed to be freely determined by the market. Meanwhile, the floor of deposit rates was also removed in 2004, and the ceiling has been gradually lifted since 2012. The ceiling of deposit rates with maturity of over 1 year was removed on 26 August 2015, and soon in two months the ceiling of 1-year deposit rates

Table 1.3: A timeline of RMB deposit and lending rates liberalisation in China

Date	Deposit rates	Lending rates
1998-1999		The floating interval was extended three times. The floor is 0.9 times the policy benchmark loan rates (0.9×), whilst the ceilings are 1.1× and 1.3× for large enterprises and SMEs, respectively.
01-Jan-2004		The floating interval was set at (0.9×, 1.7×) for commercial banks and urban credit cooperatives, and (0.9×, 2×) for rural credit cooperatives.
29-Oct-2004	Floor was removed.	Ceiling was removed.
08-Jun-2012	Ceiling was raised to 1.1×.	Floor was lowered to 0.8×.
06-Jul-2012		Floor was lowered to 0.6×.
20-Jul-2013		Floor was removed.
28-Feb-2015	Ceiling was raised to 1.3×.	
11-May-2015	Ceiling was raised to 1.5×.	
26-Aug-2015	Ceiling of deposit rates with maturity of over 1 year was removed	
24-Oct-2015	Ceiling of 1-year deposit rates was removed.	

Note: "×" after the numbers in the table means "times the policy benchmark deposit or lending rates".

was eventually removed from the PBoC's control on 24 October 2015. Since then, commercial banks in China have got the opportunity to allow lending and deposit rates to be determined by the market. The PBoC, however, continues publishing the policy lending and deposit rates as a guide, which most commercial banks are still likely to follow due to the absence of full independence in the financial market[2]. The reason why the PBoC announces policy deposit and lending rates is to manage the loan-deposit difference level, which enables commercial banks to acquire monopoly profits and protects their profit margins, but reduces the banks' power of independent pricing. Interest rate liberalisation is not completed, but has just started. In fact, interest rate adjustment has become one of the most actively used and important tools to influence inflation and deflation since 1996. For example, the 1-year deposit rate was adjusted 45 times from 1978 until now, where 5 times of adjustment took place in 2015. The loan-deposit difference however, remained relatively stable at around 3% since 2000. Figure 1.1 plots the 1-year benchmark loan and deposit rates, with the loan-deposit difference being the spread between them. Detailed previous adjustments of benchmark deposit and loan rates are outlined in Tables 1.4 and 1.5, respectively.

Another non-market monetary policy instrument actively used in China is the administrative window guidance for bank lending, through which bank credits are controlled by the PBoC and the CBRC. Although the control of lending rates has been removed, the PBoC could control bank loans by persuading commercial banks to follow its guidance. The guidance includes the appropriate level of loan growth that bank should follow and the sectors to which the bank loans should be directed. This may lower the efficiency of credit allocation and commercial banks could not arrange the bank loans based on the demand and supply in the market. According to the 2015 annual report of the PBoC, bank lending accounts for over 81% of social funding stock for domestic enterprises in 2015, which remains dominant in the

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[2]The last time the PBoC published the policy lending and deposit rates was 24 October 2015. However, no official benchmark policy rate has been proposed and the PBoC has not taken further steps since then.

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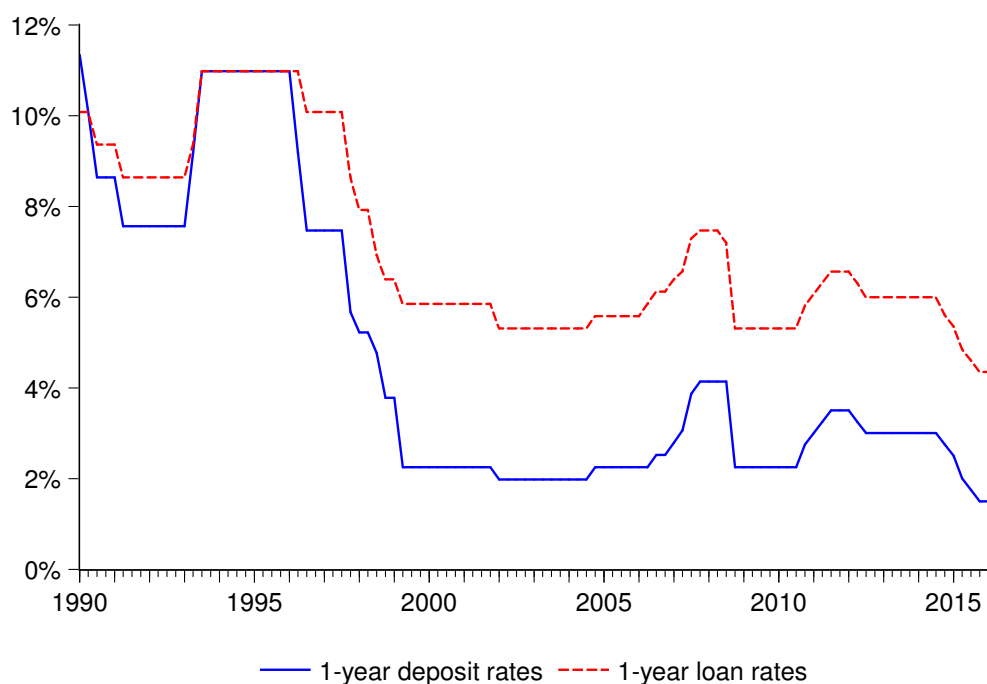
Figure 1.1: 1-year benchmark deposit and loan rates

Table 1.4: Previous adjustments of 1-year benchmark deposit rates

No.	Effective Date	Rate (%)	No.	Effective Date	Rate (%)	No.	Effective Date	Rate (%)
1	15-Sep-1952	14.4	19	15-May-1993	9.18	37	09-Oct-2008	3.87
2	01-Jan-1953	14.4	20	11-Jul-1993	10.98	38	30-Oct-2008	3.6
3	01-Sep-1954	14.4	21	01-May-1996	9.18	39	27-Nov-2008	2.52
4	01-Oct-1955	7.92	22	23-Aug-1996	7.47	40	23-Dec-2008	2.25
5	01-Jan-1959	4.8	23	23-Oct-1997	5.67	41	20-Oct-2010	2.5
6	01-Jul-1959	6.12	24	25-Mar-1998	5.22	42	26-Dec-2010	2.75
7	01-Jun-1965	3.96	25	01-Jul-1998	4.77	43	09-Feb-2011	3
8	01-Oct-1971	3.24	26	07-Dec-1998	3.78	44	06-Apr-2011	3.25
9	01-Apr-1979	3.96	27	10-Jun-1999	2.25	45	07-Jul-2011	3.5
10	01-Apr-1980	5.4	28	21-Feb-2002	1.98	46	08-Jun-2012	3.25
11	01-Apr-1982	5.76	29	29-Oct-2004	2.25	47	06-Jul-2012	3
12	01-Apr-1985	6.84	30	19-Aug-2006	2.52	48	22-Nov-2014	2.75
13	01-Aug-1985	7.2	31	18-Mar-2007	2.79	49	01-Mar-2015	2.5
14	01-Sep-1988	8.64	32	19-May-2007	3.06	50	11-May-2015	2.25
15	01-Feb-1989	11.34	33	21-Jul-2007	3.33	51	28-Jun-2015	2
16	15-Apr-1990	10.08	34	22-Aug-2007	3.6	52	26-Aug-2015	1.75
17	21-Aug-1990	8.64	35	15-Sep-2007	3.87	53	24-Oct-2015	1.5
18	21-Apr-1991	7.56	36	21-Dec-2007	4.14			

Note: Full dataset containing deposit rates with various maturities is available on the PBoC website.

Table 1.5: Previous adjustments of 1-year benchmark loan rates

No.	Effective Date	Rate (%)	No.	Effective Date	Rate (%)	No.	Effective Date	Rate (%)
1	01-Feb-1989	11.34	16	21-Feb-2002	5.31	31	20-Oct-2010	5.56
2	15-Apr-1990	11.34	17	29-Oct-2004	5.58	32	26-Dec-2010	5.81
3	21-Aug-1990	9.36	18	28-Apr-2006	5.85	33	09-Feb-2011	6.06
4	21-Apr-1991	8.64	19	19-Aug-2006	6.12	34	06-Apr-2011	6.31
5	15-May-1993	9.36	20	18-Mar-2007	6.39	35	07-Jul-2011	6.56
6	11-Jul-1993	10.98	21	19-May-2007	6.57	36	08-Jun-2012	6.31
7	01-Jan-1995	10.98	22	21-Jul-2007	6.84	37	06-Jul-2012	6
8	01-Jul-1995	12.06	23	22-Aug-2007	7.02	38	22-Nov-2014	5.6
9	01-May-1996	10.98	24	15-Sep-2007	7.29	39	01-Mar-2015	5.35
10	23-Aug-1996	10.08	25	21-Dec-2007	7.47	40	11-May-2015	5.1
11	23-Oct-1997	8.64	26	16-Sep-2008	7.2	41	28-Jun-2015	4.85
12	25-Mar-1998	7.92	27	09-Oct-2008	6.93	42	26-Aug-2015	4.6
13	01-Jul-1998	6.93	28	30-Oct-2008	6.66	43	24-Oct-2015	4.35
14	07-Dec-1998	6.39	29	27-Nov-2008	5.58			
15	10-Jun-1999	5.85	30	23-Dec-2008	5.31			

Note: Full dataset containing loan rates with various maturities is available on the PBoC website.

source of financing. The loans to small and medium-sized enterprises, according to the 2015 Financial Institutions Loans Directions Report published by the PBoC, account for 31.2% of total loans to domestic enterprises, which is much lower than the loans to large state-owned enterprises. Nevertheless, commercial banks are willing to follow the guidance because it is less risky, and more importantly, it is good for the career of numerous executives and senior personnel in state-owned commercial banks, as they are usually appointed by the central government (Funke & Paetz, 2012).

China still has a long way to go to become a fully financially liberalised economy. Repressive financial policies, contributing to price distortions, are still present and widely used these years, such as high reserve requirements, policy deposit and lending rates and capital account controls. Such repressive financial policies reduce public debt and fill government coffers. In the newly released national 13th five-year plan for 2016-2020, financial reform has been highlighted again, especially the reform of financial system and monetary policy instruments. Future works for China's financial reforms include deepening direct finance market, phasing

out policy guidance for deposit and loan rates and bank lending, exchange rate liberalisation and capital account liberalisation. Capital account liberalisation, according to Funke & Paetz (2012), or referred to as removing the control of capital account to make RMB freely convertible, is achievable provided that all the other financial reforms above have been finalised, otherwise because of China's current immature creditor status it may stimulate hot money inflows and precipitate a currency crisis.

1.2   Research topics and contributions

Although recent years have witnessed the smooth development of financial reform in China, financial repression is never believed to be absent and the role of interest rates as a resource allocation mechanism is widely considered to be distorted. For example, China's commercial banks are still subject to a range of regulations such as the high required reserve ratio and the window guidance on loans. Also, the loan rates were subject to a floor until July 2013 whilst deposit rates were subject to a ceiling until October 2015. Nowadays China still maintains strict capital account controls and the nominal exchange rate of RMB, China's currency, was pegged to the U.S. dollar until July 2005, since when the exchange rate was set to be managed floating with reference to a basket of currencies. According to the latest five-year plan, China's financial liberalisation policies aim to establish a thorough and effective financial system to promote economic growth, facilitate internal rebalancing and to maintain financial stability. In fact, China has achieved financial liberalisation to a certain degree, but it still has a long way to go. Future steps of workable financial liberalisation policies call for large number of investigations and research work. It is therefore worth conducting empirical analysis of financial repression during recent decades in order to evaluate the effects of financial liberalisation and offer evidence to inform future reforms. Building upon the literature to date, this thesis provides a comprehensive empir-

ical analysis of China's financial repression (or inversely financial liberalisation) in some typical areas including savings and investment, monetary policy and the exchange rates. Specifically, it examines McKinnon's complementarity hypothesis between money balances and physical capital, and explores the role of interest rate reform in China's financial reform, as well as the effectiveness of monetary policies implemented in China during the reform period. Besides, the PBoC serves to maintain the balance of international payments, and Chinese government is also undertaking the exchange rate market liberalisation reform. On 21 July 2005, China adopted a managed floating exchange rate regime where exchange rate is determined by the market but adjustable based on a group of currencies (Cheng, 2013). It is therefore important to investigate the sources of the exchange rate fluctuations during this period, which is considered in the thesis. Meanwhile, it makes some methodological contributions to the related empirical literature.

1.2.1 Complementarity hypothesis between money and capital

Financial repression, as was first introduced by McKinnon (1973) and Shaw (1973), is often referred to as distorted prices. For example, it means that interest rates under financial repression are restricted to be under market equilibrium levels, and are inflexible in developing countries. The repressive financial policies consist of various controls by the central bank, from which government could expropriate a large amount of seigniorage. These policies, such as regulated interest rates, high reserve requirements and domestic credit controls, according to McKinnon and Shaw, result in efficiency losses and a lower rate of economic growth. Keynesians, however, suggest low interest rate policies to encourage investment and promote economic growth. Interest rates are considered as part of the cost of investment by Keynesian and neoclassical economists. Investment takes place when the marginal efficiency of capital is greater than the rates of interest in the case of macroeco-

nomic stability. Besides, Keynesians contend that government is able to finance large fiscal deficits by keeping interest rate low, instead of raising taxes and inflation (Ang, 2008). However, McKinnon (1973) and Shaw (1973) challenged the applicability of the Keynesian view in developing countries and proposed that the real interest rates in less developed countries are negative and below the market equilibrium level. Raising interest rates would extend more loans to the investors by attracting more savings and converting them into bank deposits, hence the equilibrium rate of investment increases.

McKinnon (1973) and Shaw (1973) show that direct controls on interest rates lead to negative real interest rates, which lowers both savings and investment and also reduces the efficiency in financial resource allocation. This hypothesis contradicts the neoclassical theories, which assume that money and physical capital are substitutes. For example, in the view of neoclassical economists, economic agents are likely to prefer the real capital assets with higher return so that an increase in the average return on capital raises the demand for physical capital but lowers the money demand. However, McKinnon argues that money and physical capital are not substitutes, but complements in the complementarity hypothesis. Money balances need to be accumulated before investment can be undertaken, provided that all economic units are limited to self-finance and investment is indivisible. According to the survey in Chapter 2, the empirical literature holds different perspectives on the availability of McKinnon's complementarity hypothesis, and there is no consensus with respect to the effects of real interest rate on savings and investment[3]. Moreover, it is noted that few empirical papers have studied financial repression in China.

Chapter 3 tests the credibility of McKinnon's complementarity hypothesis between

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[3]In the financial liberalisation theory by McKinnon (1973) and Shaw (1973), raising real interest rate encourages more savings and investment, whist neo-structuralist economists argue that raising real interest rate inhibits investment, and many empirical literature have detected this negative relationship between real interest rate and investment (see de Melo & Tybout 1986; Greene & Villanueva 1991, etc). Section 2.2.2.1 and 2.2.2.2 in Chapter 2 have included a detailed discussion on this issue.

money and physical capital in China. In addition, the relationship between investment and the actual deposit rates is also examined in this hypothesis. Moreover, following the argument by Fry (1978), this chapter additionally allows the savings equation to enter the complementarity hypothesis model by replacing the investment equation. This chapter is considered as the first empirical analysis of the complementarity hypothesis in China during the period of reform. In addition, in contrast to the existing literature where least squares method or cointegration analysis were employed, this chapter adopts the bounds testing method with autoregressive distributed lags (ARDL) modelling approaches to allow all the underlying variables to be integrated of different orders between 0 and 1.

1.2.2 Interest rate liberalisation

According to McKinnon (1973) and Shaw (1973), interest rates in developing countries like China are below the market equilibrium levels and investment is subject to the shortage of savings. Financial liberalisation thus indicates an increase in the deposit rate. China has removed the ceilings of the deposit rate since October 2015, before that, the floors of the lending rate were removed in July 2013. It is therefore necessary to investigate both the opportunities and the risks of interest rate liberalisation in China's economic development during the period of deregulation. Jin *et al.* (2013) constructed a neoclassical Real Business Cycle (RBC) model with a cash-in-advance constraint proposed by Stockman (1981) and the interest rate liberalisation process was represented by gradually raising the steady state levels of interest rates. Following this method, Chapter 4 simulates China's economy under interest rate liberalisation in a dynamic stochastic general equilibrium (DSGE) modelling framework where interest rate liberalisation is reflected by raising the equilibrium level of deposit rates. It enriches the model of Jin *et al.* (2013) by considering a Taylor-type money growth rule. Also, the new Keynesian DSGE model is considered in this chapter. This research further contributes

to current literature by providing a comparative empirical study among several DSGE model specifications.

Unlike central banks in developed economies that control benchmark interest rates alone, the PBoC sets both benchmark loan rates and deposit rates. In Chapter 5, deposit and loan rates are separated by two types of households and a private bank sector is included in the DSGE model following Gerali *et al.* (2010), Chen *et al.* (2012) and Funke & Paetz (2012). Unlike Funke *et al.* (2015) where the wholesale loan and deposit rates in equilibrium are dependent on the parameters in the management cost function, this model introduces a stochastic elasticity of demand for loans and deposits in the retailing commercial bank section, which is in spirit of Gerali *et al.* (2010). Actual deposit and loan rates are represented by a geometric weighted average between the market-determined rates and the central bank rates. The liberalisation process can thus be illustrated by changing the weighted parameters accordingly, which is a contribution to current research on interest rate liberalisation in China. Although the DSGE model is developed in the spirit of the existing literature on China, this chapter novelly uses Bayesian estimation approach in addition to calibrated parameters when estimating the model.

1.2.3 Monetary policy under financial repression

With nominal money growth target as one of the official monetary policy indicators since 1994, the PBoC has been using the nominal money growth as an instrument when implementing monetary policy in addition to the conventional Taylor-type interest rate rule. However, it is acknowledged that the nominal money supply is difficult to control as the velocity of money has not always been stable in China during the reform period, and the link between nominal money growth and inflation has become weaker due to the volatility of money demand. Nonetheless, the nominal money growth target is published in the People's Banks of China Annual

Report every year, and the target of M2 growth in 2016, for example, is set to be around 13%. This thesis aims to compare the conventional money growth rule and the currently frequently adopted the interest rate rule and seeks to find out which rule is more preferable during the financial liberalisation period. In order to evaluate the effectiveness of the money growth rule and the interest rate rule, Zhang (2009) adopted the new Keynesian money-in-utility DSGE model and the results based on pure calibration showed that the interest rate rule was more effective and powerful.

Chapter 4 compares the two rules in the new Keynesian DSGE model with a cash-in-advance constraint, as well as in the money-in-utility DSGE model. Calibration method and Bayesian estimation method are both employed and the results suggest the interest rate rule to be more effective and powerful, which is consistent with Zhang (2009).

In addition to interest rate adjustment, the PBoC sets targets of nominal broad money growth and sets high required reserve ratios due to the imperfect monetary policy transmission mechanisms. Interest rate adjustment, together with the adjustment of the required reserve ratio, is often employed to maintain the stability of the domestic stock market, so as to maintain social stability and promote economic development. Another non-market monetary policy instrument actively used in China is the administrative window guidance for bank lending, through which bank credits are controlled by the PBoC and the CBRC. Although the direct control of lending rates has been removed, the PBoC could control the quantity of bank loans by persuading commercial banks to follow its guidance. The guidance includes the appropriate level of loan growth that a bank should follow and the sectors to which the bank loan should be directed. This may lower the efficiency of credit allocation and commercial banks could not arrange the bank loans based on the demand and supply in the market. Financial repression can be reflected by implementing those monetary policies above. In recent years, such policies aiming to achieve financial stability are also referred to as macroprudential policies,

and widely recommended to be applied counter-cyclically (Reinhart, 2012; Posen & Véron, 2015). It is therefore important to evaluate the effectiveness of those repressive financial policies and to look into the reason why the PBoC usually intervenes.

In Chapter 5, these typical repressive financial policies are included in the new Keynesian DSGE model to investigate the effects on economy when removing one or all of these policies so as to achieve financial liberalisation. Chen *et al.* (2012) and Funke & Paetz (2012) also considered the required reserve ratios and the window guidance on bank loans in their models, but overlooked the effect of the nominal money growth target. Also, their results were based on pure calibration of the DSGE model, while Chapter 5 uses the Bayesian estimation method when estimating some structural parameters.

1.2.4 Sources of real exchange rate fluctuations

Following the theory of McKinnon and Shaw, many less developed countries have undertaken some form of financial liberalisation, especially liberalising deposit and loan rates. However, the policy of low interest rates in developing countries is, to some extent, determined by the mature industrial economies. According to McKinnon (2013), the world is still on a U.S.-dollar standard at present. McKinnon & Schnabl (2014) point out that developing countries facing the dollar standard are forced to lower the interest rates to avoid volatility given that the U.S. and other principal developed economies adopt near-zero interest rates and put downward pressure on the long-term interest rates via quantitative easing. Besides, McKinnon & Schnabl (2014) suggest keeping the currency pegged to the U.S. dollar and maintaining strict capital controls in the presence of undeveloped capital markets in developing countries, which helps to avoid hot money inflows, as excessive inflows of hot money may lead to a rise in the housing price and contribute to inflation. Moore & Pentecost (2006) propose that an increase in

interest rates as well as rapid economic growth during financial liberalisation may contribute to a dramatic rise in capital inflows, which lifts the money supply and calls for higher aggregate demand given a fixed nominal exchange rate policy, and this in turn leads to an increase in domestic price level, hence a permanent real exchange rate appreciation. If a floating exchange rate regime is adopted, the net capital flow is likely to increase both the nominal and real exchange rate appreciation directly. The demand for domestic products falls in response to a nominal appreciation, so that domestic price level would fall to restore the real exchange rate. This result, however, is subject to change if there is a general price liberalisation process, as suggested by Moore & Pentecost, thus higher domestic prices leads to a continuous real exchange rate appreciation and the effects last long.

In China, the PBoC also serves to maintain the balance of international payments, and Chinese government is also undertaking exchange rate market liberalisation reforms. On 1 January 1994, China officially announced the decision to implement a managed floating exchange rate system with reference to the U.S. dollar. However, the exchange rate of RMB to U.S. dollars was de facto fixed at 8.28 from 1998. On 21 July 2005, China embarked on a managed floating exchange rate regime where exchange rate is tied to a group of currencies, rather than pegging to U.S. dollars only (Cheng, 2013). Prasad *et al.* (2005) suggest that a more flexible exchange rate arrangement is in China's own interest in that China has been more exposed to various types of macroeconomic shocks, and the flexibility helps to better adjust to such shocks and facilitates a more independent monetary policy. According to Huang & Guo (2007), the Chinese RMB has long been regulated during these years, so that identifying a path of exchange rate is challenging and even impossible based on the actual path of the bilateral exchange rate. Moreover, real exchange rate is considered to be related to the export price competitiveness.

Therefore, it is vital to investigate the sources of real exchange rate movements during the reform period and it has important implications for the PBoC to make decisions about the future exchange rate reform, which is done in Chapter 6. To

be specific, Chapter 6 follows the spirit of Blanchard & Quah (1989) by considering nominal and real shocks, but employs a trivariate structural VAR model to investigate fluctuations of real exchange rate. Moreover, this chapter modifies the theoretical model of Clarida & Gali (1994) by allowing for imperfect capital mobility, which is more reliable in China. The long-run restrictions are imposed following Clarida & Gali (1994) in order to estimate the model using both quarterly and monthly data. One contribution of this chapter is to construct a time-varying traded-weighted average of China's major trading partners as the foreign country, rather than using the U.S. data alone. Another contribution is that, in addition to the long-run restrictions when estimating the model, this chapter imposes the sign restrictions to identify supply and nominal shocks, which has been widely used in recent years, as the credibility of imposing long-run restrictions is questioned in finite samples (Faust & Leeper, 1997).

1.3   Structure of the thesis

This thesis consists of seven chapters, and it proceeds as follows. In Chapter 2, a critical survey of major theoretical and empirical analysis is presented on the following issues: a) how savings, investment and economic growth respond to financial liberalisation; b) whether money and physical capital are complementary or substitutable under repressed financial economy; and c) how real and nominal shocks contribute to the fluctuations of nominal and real exchange rates under financial repression.

Chapter 3 examines the credibility of McKinnon's complementarity hypothesis in China between 1987Q1 and 2013Q2 using bounds testing with the ARDL modelling approaches which allow all the underlying variables to be integrated of different orders. The empirical results suggest weak evidence to support the hypothesis but turn out to be fully consistent with the hypothesis when the investment model

is augmented with some additional variables. In addition to testing the two equations of the hypothesis of money and investment, the savings equation is considered as a replacement for the investment equation and the results suggest that raising real deposit rates inhibits the savings in China.

Chapter 4 starts with a simple neoclassical Real Business Cycle (RBC) model with a cash-in-advance constraint to simulate China's money growth rule. The method of undetermined coefficients is used to solve the model. In the spirit of Jin *et al.* (2013), the liberalisation process in this model is represented by raising the steady state levels of deposit rate. It shows that interest rate liberalisation helps reorganise the economic structure between consumption and investment in China, and contributes to a thorough and efficient transmission mechanism of monetary policy. Also, a new Keynesian calibrated closed economy model with a cash-in-advance constraint is built to compare two monetary policy rules, i.e. the interest rate rule and the money growth rule. In addition, a money-in-utility DSGE model is also included to compare with the DSGE model with a cash-in-advance constraint. The results suggest that the interest rate rule is more powerful and effective than the money growth rule.

In Chapter 5, the deregulation of deposit and loan rates is illustrated in a DSGE model, together with some market and non-market monetary policies implemented by the PBoC. Actual deposit and loan rates are represented by a geometric weighted average between market and central bank rates, so that interest rate liberalisation process can be captured by changing the weighted parameters accordingly. Required reserve ratio and the window guidance on bank loans are included in the model. It shows that the liberalisation process is actively affected by the window guidance rule, which helps reduce the inflation volatility. However, although the adjustment of the required reserve ratio helps reduce the quantity of bank loans, it seems not very useful to contain inflation or stabilise the economy. Following that, this model considers the nominal money growth variable in the interest rate Taylor rule. This is important as the PBoC and the central govern-

ment announce and monitor broad money growth target every year. However, the modified Taylor rule brings about more volatility in inflation.

Sources of real exchange rate fluctuations are investigated in Chapter 6, where the real exchange rate movements are broken down and led by structural shocks in the economy. It follows Clarida & Gali (1994) by constructing a trivariate structural VAR model to investigate the movements of real relative output, real exchange rate and relative price level. The long-run restrictions are imposed following Clarida & Gali (1994) in order to estimate the model using quarterly data covering 1995 until recently. To check the robustness of the result, this chapter also looks at a sub-sample period between 2005Q3 until 2015Q2, during which the exchange rate is managed floating with reference of a basket of currencies. Moreover, as the model with quarterly data is subject to insufficient observations, this chapter then selects the monthly data to estimate the model with long-run restrictions for the period after July 2005. Following that, sign restrictions are imposed to identify supply and nominal shocks, instead of the long-run restrictions due to the critique of Faust & Leeper (1997), and the model with monthly data yields similar results as that based on quarterly data. The results overall confirm that demand shocks are the main sources of real exchange rate fluctuations, but supply shocks and nominal shocks play a significant rule as well.

Chapter 7 summarises the main results and implications obtained in the previous chapters.

Chapter 2

Literature review

2.1 Introduction

Financial repression exists extensively among developing countries. The repressive financial policies consist of various controls by the central bank, from which government could expropriate a large amount of seigniorage. A large number of literature have explained the theory of financial repression after it was proposed by McKinnon (1973) and Shaw (1973), together with the empirical analysis among developing countries. This chapter presents a critical survey of major theoretical and empirical analysis on the following issues: a) how savings, investment and economic growth respond to financial liberalisation; b) whether money and physical capital are complementary or substitutable under repressed financial economy and c) how real and nominal shocks contribute to the fluctuations of nominal and real exchange rates under financial repression. The rest of the literature review proceeds along the following lines: Section 2.2 presents a summary of the current literature on McKinnon and Shaw's theory of the behaviour of savings, investment and economic growth under financial liberalisation. McKinnon's complementary hypothesis and empirical tests on the hypothesis are outlined in Section 2.3. Section 2.4 looks at the behaviour of real exchange rate in terms of repressive financial

policies and the sources of fluctuations of nominal and real exchange rates. Some conclusions are drawn in Section 2.5.

2.2 McKinnon-Shaw theory of financial repression

Financial repression was introduced by McKinnon (1973) and Shaw (1973) in their respective works. The repressive financial policies consist of various controls by the central bank, such as direct controls on interest rate, high reserve requirements and domestic credit controls. Government expropriates a large seigniorage from these financial restrictions. According to McKinnon and Shaw, such repressive policies result in efficiency loss and lower the rate of economic growth. They argue that the interest rate liberalisation would contribute to an increase in interest rate and hence savings and investment, and the allocation process of financial resource would be more efficient.

2.2.1 Financial liberalisation theory

Many developing countries adopted the low interest rates policies suggested by Keynesians to encourage investment. However, McKinnon (1973) and Shaw (1973) challenged the applicability of the Keynesian view and proposed that the real interest rates in less developed countries is negative and below the market equilibrium level. Raising interest rates would extend more loans to the investors by attracting more savings and converting them into bank deposits, hence the equilibrium rate of investment increases. They proposed the financial liberalisation theory and concluded that raising interest rates, one of the financial liberalisation policies, would increase savings and investment in a country with rudimentary capital markets.
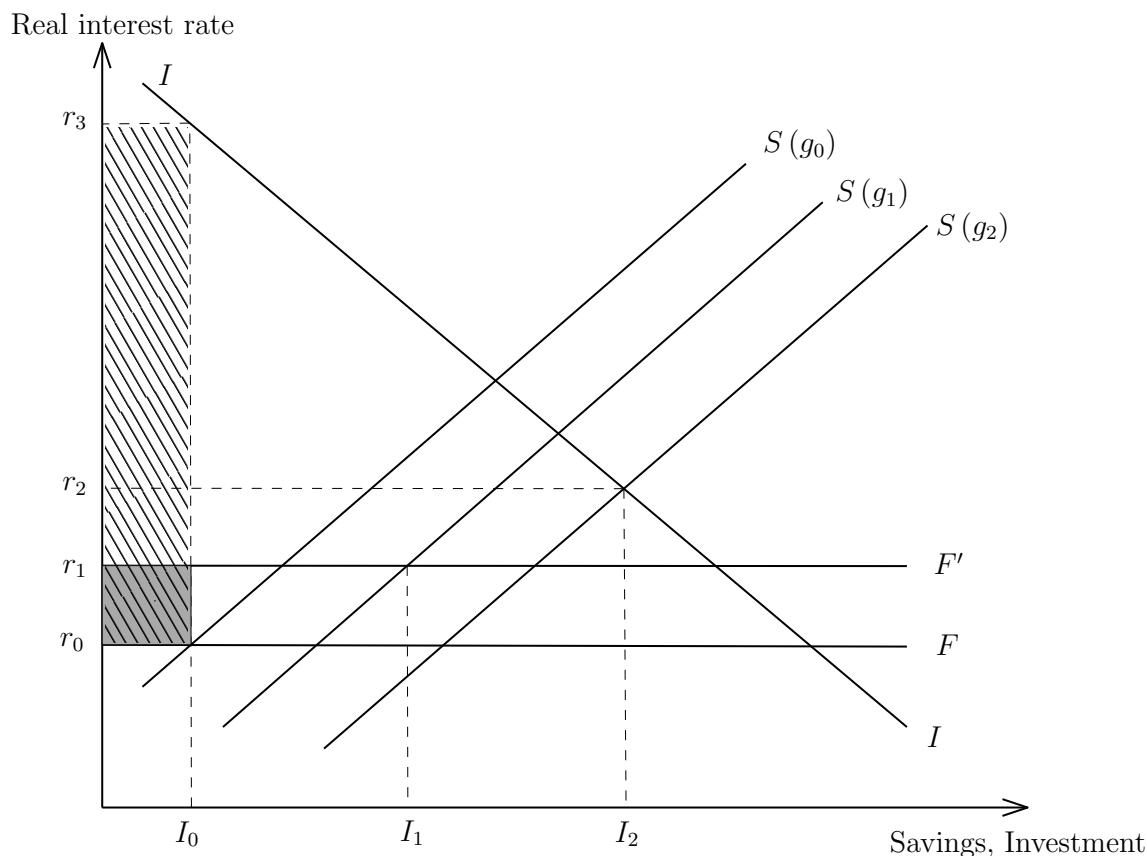
Figure 2.1: Savings and investment under financial repression (Fry, 1978)

Fry (1978) summaries the core elements of the theory, as illustrated in Figure 2.1. Savings and investment are presented in the horizontal axis while real interest rate is measured in the vertical axis. Saving is a function of economic growth. $S(g_0)$ indicates the saving level at a level of economic growth, g_0, and I, represents the level of investment at specific level of real rates of interest, r. F is the financially repressed managed nominal interest rate determined by the government under repressive financial policies, which holds the real rate of interest, r, below its equilibrium level where market clears.

Given the level of r_0 and the growth rate g_0, actual investment is fixed at I_0 due to the limited amount of saving. If the ceiling is applicable to the deposit rates only, investors would confront a market-clearing interest rate, r_3. The spread $r_3 - r_0$, the dashed area, would be spent by financial institutions on non-price competition. In this case, non-price allocation of available funds for investment must take place and it often results in inefficiency, because financial institutions would prefer to

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supply loans to conventional investment projects with low yields, as those projects are less risky and more easily to finance. Hence the interest rate ceiling rations out large amount of investment opportunities. When the interest rate ceiling is raised from F to F', it increases levels of savings and investment, and also rations out the investment of low yields that was financed before, as illustrated by the shaded area in Figure 2.1. The efficiency of investment thus increases as well. The growth rate of economy meanwhile rises to g_1, shifting the saving curve to $S(g_1)$. Actual investment is also increased to I_1. Therefore, raising real interest rates has a positive effect on both saving and investment. One of the goals in financial liberalisation is to remove interest rate controls in a perfectly competitive market by raising the nominal interest rate ceiling or reducing the rate of inflation. This is described in Figure 2.1 by the equilibrium level of I_2, r_2 and a higher growth rate of g_2, where there are abundant investment opportunities and the overall efficiency of investment rises as well.

Following the theory of McKinnon and Shaw, many less developed countries have started the financial liberalisation, but the outcome of the reform has been inconclusive. The critics, or neo-structuralist economists, argue that an increase in the real interest rate leads to a fall in the investment. They assumed that individuals hold "curb market loans" in addition to cash, bank deposits and inflation hedges. Curb markets are often referred to as informal credit markets that are not regulated, but efficient and competitive (Edwards, 1988). The informal credit markets, for example, are not required to hold reserves as commercial banks do. Therefore, a high level of bank savings following an increase in interest rates is only attributed to the transfer of funds away from other asset holdings such as share markets and informal credit markets, thus reducing the stock of loanable funds in the curb market. The investment eventually decreases and so does the economic growth (Taylor, 1983; Edwards, 1988).

However, Bencivenga & Smith (1992) and Kapur (1992) argue that the unregulated curb markets are not necessarily more efficient, and the argument of those neo-

structuralist economists ignores the economic functions served by reserves in terms of liquidity enhancement and seigniorage creation. Therefore, it is not credible to conclude that the efficiency of informal credit market is greater due to the absence of reserve requirement, as the central bank could make proper use of the reserves and thereby yields no additional social costs.

Besides, Beckerman (1988) demonstrates that the argument that the market clearing rate is always positive is not valid. There are some cases when the rate is non-positive, due to the existence of unemployment resources, for example. Policymakers who force up the interest rate to make the real interest rate positive would aggravate financial repression, resulting stagflation and financial system decapitalisation. Therefore, Stiglitz (1993) contends that the "mild financial repression" with the real interest rate to be slightly greater than zero would be optimal (Murdock & Stiglitz, 1993; Agrawal, 2004). Hellmann *et al.* (2000) suggest an interest rate on deposits lower than the market clearing rates, which maintains banks' profits at a satisfactory level. In fact, McKinnon (1973) advocated the so-called "restrained financial liberalisation", with an appropriate ceiling of the real interest rate during financial liberalisation, and suggests the rate to be in the range of 5% to 9%, which is not consistent with Stiglitz's view of "mild financial repression" where the real interest rate is restricted to be around zero. In addition, Clarke (1996) has shown that an instability is induced during financial liberalisation due to portfolio adjustment and therefore a positive but small interest rate, as well as moderate financial regulation, is required to stabilise the economy.

2.2.2 Empirical evidence

2.2.2.1 Savings under financial liberalisation

In recent years, a number of investigators have undertaken empirical studies following the seminal work of McKinnon (1973) and Shaw (1973). The McKinnon-Shaw

financial liberalisation theory suggests the positive effect of real interest rates on savings. According to the financial liberalisation roadmap proposed by McKinnon and Shaw, raising real interest rates encourages more savings, and converts them into the loanable funds. The empirical results, however, are ambiguous. Fry (1978) tested the response of real interest rates to the ratio of aggregate domestic savings to GNP for seven Asian developing countries in 1960s and found a positive link between real interest rates and savings. Yusuf & Peters (1984) employed dummy variables in their model for Korea to capture the second oil shock and its first economic recession. The aggregate savings were positively related to real interest rates during 1965 until 1982. Pentecost & Ramlogan (2000) modelled the private savings to income ratio in Trinidad and Tobago during 1961 to 1991. Real interest rates, according to the Johansen maximum likelihood tests for cointegration, were positively associated with the savings ratio in the long run. Shrestha & Chowdhury (2007) examined the hypothesis by using the ARDL modelling approach to conduct cointegration tests. The result based on Nepalese quarterly data from 1970 to 2003 offered strong evidence of the positive savings-interest rate link.

Giovannini (1983) reproduced Fry's (1978) estimation over a different sample period. Using instrumental variables regression, he found that the coefficient of real interest rates was either negative or positive but small and insignificant. Giovannini (1985) then estimated a larger sample period spanning from 1962 to 1972 for seven Asian countries in Fry's (1978) model, and the empirical results from TSLS estimation were still not supportive of the hypothesis. Giovannini (1985) concluded that the validity of the financial liberalisation theory is affected by the sample periods selected. Fry (1995) asserted that it was possible that savings could be increased by lifting the interest rate on deposits, provided that there is a significantly negative interest rate of deposits in one country. Schmidt-Hebbel & Serven (2002) documented that financial liberalisation could affect savings via various potential channels, and the effects would be ambiguous. For example, savings could be accumulated by raising interest rates due to a substitution effect,

but on the other side it could be reduced well in the presence of strong income effects.

In addition to aggregate savings, some research considered the private savings in their analysis. de Melo & Tybout (1986) used the data of Uruguay spanning the period 1962 to 1983. They introduced foreign savings and real income growth together with the real interest rate in their savings model. Considering the possibility of endogeneity within the variables, they adopted instrumental variables and the result showed that the real interest rate exhibited a weakly positive correlation with aggregate saving rates during the period before the reform in Uruguay. However, this positive link did not exist when using private savings as the dependant variable. Leite & Makonnen (1986) selected cross-country data to estimate the gross private savings for the six BCEAO countries, and the private savings in each equation was significantly positively affected by the real rate of interest. Warman & Thirlwall (1994) estimated private savings for Mexico, and found a positive but insignificant link between real interest rate and private savings. Loayza *et al.* (2000) showed the negative effect of real rate of interest on private savings. They employed panel data analysis on 150 countries with data ranging from 1965 to 1994. The result suggested that in the short run private savings would decline by 0.25% in response of a 1% rise in the real rate of interest. Morisset (1993) conducted a three-stage least squares estimates for Argentina over the 1961 to 1982 period. Compatible with the Argentine experience, the results revealed that the effects of real rates of interest appeared to be positive on financial savings, but negative on real total savings.

Gupta (1987) argued that it was not credible to assert that the effect of the change in the inflation rate on the real interest rate variations would be indifferent from the effect of the change in the nominal rate of interest. In his aggregate savings model, expected inflation rate and nominal interest rate are both adopted as independent variables for Asia and Latin America. It was suggested that there was some support for the financial liberalisation theory in Asian countries, but not

in Latin America. However, the coefficients of nominal interest rate were positive in both groups, thus providing some evidences that lifting up the interest rate ceilings would be conducive to increasing savings. Leff & Sato (1988) replaced the real interest rate by another two variables, namely, the consumer price index and the expected inflation. The increasing expected inflation was expected to lower the real interest rate so that the savings would decline. The saving model with data for Latin American countries spanning from 1955 to 1983 was estimated, together with the investment model. The results reflected the expected conclusion and the coefficient of the expected inflation was negative and significant. Khatkhate (1988) dropped the regression analysis and classified 64 developing countries into three groups on the basis of the mean of the real interest rate prevailing during the period 1971 to 1980. He stated that the interest rates would be higher in numerical average provided that it had a significant impact on any macroeconomic variable. Therefore, the saving to income ratio in the group with non-negative real interest rate should be the highest due to the highest level of average real interest rates. The results, however, revealed that the group with severely negative real interest rate had the highest saving ratio, which is conflict to the financial liberalisation theory.

Ramlogan (1996) argued that most studies confined the measure of financial repression to the interest rate. In her thesis, five other proxies of financial repression were adopted in addition to the real interest rate, i.e. a dummy variable, reserve requirement ratio, inflation rate, differences between foreign and domestic interest rates and deviations of the actual exchange rate from the equilibrium level. The results were mixed depending on which proxy was selected. For example, when the real interest rate was included in the model, the negative coefficient suggested that isolated increases in the interest rate would not increase savings, which was in conflict with the McKinnon-Shaw hypothesis. The variable representing the deviation of the actual exchange rate from its equilibrium was shown to match the expected results, suggesting that government should relax exchange rate controls.

Bandiera *et al.* (2000) estimated the relationship by considering the ratio of private savings to income to be associated with the real interest rate as well as a financial liberalisation index. The results based on eight developing countries from 1970 to 1994 indicated that the real rate of interest played a small but positive role on driving savings, whilst the financial liberalisation index exerted no positive effect.

2.2.2.2 Investment under financial liberalisation

According to the financial liberalisation theory, raising interest rate also increases investment. Figure 2.1 indicates that a higher interest rate in terms of repressive policies increases savings and hence the equilibrium flow of investment. Seck & El Nil (1993) tested the investment model by including nine African countries covering the annual data from 1974 to 1989. The real deposit rate was shown to positively affect the gross investment to GDP ratio, which was consistent with McKinnon's hypothesis. Shrestha & Chowdhury (2007) used total bank credit to represent investment, and utilised the Nepalese quarterly data during 1970 and 2003. Based on the ARDL approach in cointegration analysis, their result indicated investment increases as interest rate ascends. Some papers focused on the qualitative impact other than the quantitative impact on investment and adopted the capital to output ratio to measure the productivity of investment. According to McKinnon and Shaw, raising interest rate would ration out the lowest yielding investment, thus making the investment more productive. Therefore, raising the interest rate leads to a fall in the capital-output ratio.

On the other hand, most empirical studies refuted the positive effect of interest rate on investment. de Melo & Tybout (1986) found a negative, though weak, response of private investment rate to real interest rate in Uruguay during 1962 and 1983. Besides, they noted that real exchange rate weakly affected investment positively. Edwards (1988) discussed the behaviour of two types of interest rates, namely the officially controlled deposit rates and the unregulated curb market in-

terest rates. A change in the official deposit rates was positively associated with a variation in the interest rates in the curb market. Following that, an aggregate investment function using the Korean data was estimated and it suggested that a rise in the curb market interest rates discourages investment, whilst more investment funds become available when the supply of real credits grows rapidly in the official market. Greene & Villanueva (1991) investigated the effect on private investment during 1975 and 1987 and the results from among 23 developing countries suggested that private investment was significantly negatively associated with the real interest rate. Rittenberg (1991) also failed to support the hypothesis in Turkey. He argued that investment was constrained by savings and was positively responded to an increase in the interest rate given that the interest rate was below the equilibrium level. Once the level of interest rate was higher than that of equilibrium, investment declined with an increase in the rate of interest. Demetriades & Devereux (1992) conducted the panel data analysis on the investment model for 63 less developed countries and suggested that the impact of domestic real interest rate on investment was insignificant. Morisset (1993) demonstrated with a structural model for Argentina that a change in real interest rate is not necessarily responsible for a change in the private investment. He noted the crowding-out effect that financial liberalisation would attract the domestic credit from public sector, thereby restricting the available funds to flow to the private sector. Agrawal (2004) conditioned the investment model by terms of trade, economic growth, foreign capital inflows and the real exchange rate in addition to the real interest rate, but found that the investment ratio increased with the real interest rate by 9% at most among four Asian countries. However, the investment to income ratio in two of the countries started to decline once the interest rate went up to a higher level. This result is supportive of McKinnon's theory of "restrained financial liberalisation".

The effect on the investment is also reflected on the McKinnon's complementarity hypothesis where the real money demand is positively related to the investment to

income ratio. The reason is that investors have to accommodate money balances before investment. Pentecost & Moore (2006) tested the McKinnon's complementarity hypothesis in India and the results from the investment equation indicated that the coefficient of real deposit rate was positive. Similar research papers testing the complementarity hypothesis tend to be supportive of the financial liberalisation theory in terms of the investment (see Fry, 1978; Thornton, 1990; Laumas, 1990; Khan & Hasan, 1998). The investment model is often extended with other variables. For example, Moore (2010) extended the investment equation, and found that the credibility of the complementarity hypothesis remained undetermined when the investment function was augmented with financial development indicators, income level differentials, external inflows, trade barriers and public finance. McKinnon's complementarity hypothesis is questionable in the countries of middle income levels and those that have reached a certain degree of financial liberalisation.

2.2.2.3   Economic growth under financial liberalisation

McKinnon (1973) and Shaw (1973) concluded that financial liberalisation promoted economic growth. In fact, the positive effect on economic growth is the combining effects of financial liberalisation on savings and investment (Ramlogan, 1996). Economic growth follows by the increased savings and the quality and quantity of investment, as stated in Figure 2.1. Seck & El Nil (1993) documented that the economic growth was positively related to the real interest rate on deposit, whilst Warman & Thirlwall (1994) found that raising interest rate would increase the flow of financial savings in Mexico during 1960 and 1990, but the impact of financial liberalisation on economic growth was negative and insignificant.

However, Stiglitz (1993), Hellman *et al.* (1997) and Hellmann *et al.* (2000) argued that under financial repression, developing countries were more able to administrate money supply, and the repressive financial policies would promote economic

growth. Huang & Wang (2011) constructed a composite financial repression index by considering typical repressive policies and controls implemented by government. They conducted a case study of China, and argued that, on average, repressive policies promoted economic growth both at the country and the province level. Besides, they found that financial repression lowered the growth rate in recent years after 2000, but helped the growth in 1980s and 1990s. In fact, their measure of financial repression can be adopted in the validation of McKinnon-Shaw liberalisation theory and other indicators like credit controls, barriers to entry in the financial sector and repression of security markets could also be added to construct the aggregate financial repression index.

2.3   McKinnon's complementarity hypothesis

McKinnon assumes that all economic units are limited to self-finance and investment is indivisible. Money balances have to be accumulated before investment can be undertaken. The more alluring the procedure to accumulate money balances, the stronger the motivation to invest. This leads to the core content of McKinnon's complementarity hypothesis, in which real money balances and physical capital are complementary to each other. The complementarity hypothesis between money and physical capital among the developing countries, summarised by Pentecost & Moore (2006), suggests that the real money demand relies, *inter alia*, on the overall real capital return, while the investment to income ratio increases with the real deposit rates. It postulates demand for money and investment functions, respectively, as follows:

$$M/P = f\left(Y,\ r,\ R\right); \ \ f_Y > 0,\ f_r > 0,\ f_R > 0 \tag{2.1}$$

$$I/Y = g\left(r,\ R\right); \ \ g_r > 0,\ g_R > 0 \tag{2.2}$$

where M/P is the real money balances, Y is the real income, r is the real average return on capital, I/Y is the investment to income ratio, R is the real rate of interest on bank deposits and f_* (or g_*) denote partial derivative of f (or g) with respect to each variable, Y, r or R.

McKinnon's complementarity hypothesis is therefore reflected by $f_r > 0$ and $g_R > 0$. Additionally, Shaw's model assumes that investors are not necessarily confined to self-finance and stresses the role of financial intermediation in borrowing and lending activities. Shaw (1973) constructed the demand for money model function in the debt intermediation view:

$$M/P = f(Y, v, R) \tag{2.3}$$

where v captures opportunity costs of holding money.

The debt intermediation view assumes that the money created as loans to the private sector is based on the internal debt, and it suggests no complementarity between money and physical capital, as non-institutional credits will appear when institutional credits are unavailable. Financial intermediaries thus play an important role in Shaw's model, and the extent of financial intermediation between investors and savers is positively associated with the relationship between money and economic activity. Shaw's debt intermediation hypothesis is reflected by $f_v < 0$. Asset holders may switch their assets from holding money to other assets if the interest rate of other assets increases. This model also suggests $f_R > 0$, i.e. raising real deposit rates will attract more financial savings, and hence enhance the role of financial intermediation between investors and savers. Molho (1986) has shown that McKinnon's complementarity hypothesis and Shaw's debt intermediation hypothesis are compatible. He employed a two-period intertemporal model to suggest that money balances are, during the first period, complements to the physical capital, whilst substitutes in the second period when financing most projects.

It is noted that McKinnon's complementarity hypothesis model is in contrast to the Keynesian and neoclassical economists. In Keynesian model, investment is determined by the market real interest rate only, and the interest rate is negatively related to the real money demand, and hence the investment. The neoclassical approach suggests $f_r < 0$ in equation (2.1) and $g_R < 0$ in equation (2.2). They assume that money and physical capital are substitutes, and capital markets operate perfectly and efficiently, which is unlikely in less developed countries. Burkett & Vogel (1992) enriched the complementarity hypothesis by introducing a firm with credit constrains where the working capital is interpreted using "non-capital asset balances" and the constraint of credit is loosened by increasing its deposits. Their model has shown that the benefit of increasing real interest rates are not restricted to the case of self-financing and indivisible investment. Moreover, increasing the deposit holdings contributes to more efficiency of capital utilisation.

Recent years have witnessed a number of empirical studies on McKinnon's complementarity hypothesis testing. Various econometric techniques are adopted to investigate real money balances, savings, investment and economic growth among different developing countries. The empirical results, however, are ambiguous.

Practically, it is difficult to find an appropriate variable to represent the real capital return, r. McKinnon (1973) suggested the investment to income ratio, I/Y, to replace it in equation (2.1), which varies in the same direction as r. The real money demand equation thus becomes:

$$M/P = f\left(Y,\ I/Y,\ R\right); \ \ f_Y > 0,\ f_{I/Y} > 0,\ f_R > 0 \qquad (2.4)$$

An impressive number of empirical studies have been carried out to test the complementarity hypothesis in developing countries. However, Fry (1978) argued that the investment function must be replaced by the savings function, as explained in Figure 2.1. The demand for investment is plentiful, and it is the supply of savings that contributes to the binding constraint. I/Y in equation (2.4) is re-

placed by the ratio of domestic savings to GNP, thus opting out the investment financed from foreign savings as well. He used pooled data from ten Asian less developed countries to test the demand for money equation during the period of 1962 to 1972. McKinnon's complementarity hypothesis failed to explain the empirical results among these countries. Similarly, Min (1976) and Harris (1979) modelled the real money equation and they both found weak evidence to be supportive of the hypothesis among Asian countries. Following the spirit of Fry's (1978) method, Thornton & Poudyal (1990) tested this hypothesis in the demand for money function for Nepal with the data ranging from 1974 to 1986. The coefficient of the domestic savings to income ratio was positive and statistically significant, which was in sharp contrast to Fry's conclusion. The results tended to show strong evidence to support McKinnon's complementarity hypothesis in Nepal. Additionally, Thornton (1990) applied Fry's demand for money model to India for the period between 1964 and 1984. Both the results of OLS and TSLS estimates were in favour of McKinnon's complementarity hypothesis. Fry (1978) then found that the financial liberalisation of the selected Asian countries had proceeded to a relatively advanced level, therefore alternative financial assets other than broad money might be used to accumulate the supply for investment. In addition, semi-industrial developing countries, like those Asian economies in his study, may have some self-governed effects to develop modern agriculture or achieve industrialisation (McKinnon, 1973).

Khan & Hasan (1998) found that the results in Pakistan during 1959 to 1995 were in favour of McKinnon's complementarity hypothesis. Following Fry (1978), a savings model was introduced to replace the investment in their analysis, and the ratio of savings to GNP was significantly positive in the real money demand equation. Besides, real money demand yielded a positive effect on savings ratio in the savings equation. The results held in the long-run cointegration regressions as well as in the dynamic error correction analysis. Odhiambo (2005) also replaced the investment by domestic savings, and tested the availability of the hypothesis

for South Africa. Unlike the method of testing OLS residuals for cointegration in Khan & Hasan (1998), the maximum likelihood cointegration test was applied to both money and investment equations. Only short-run dynamic error correction models were reported and the results were in favour of the complementarity hypothesis. Another finding of Odhiambo (2005) was that domestic savings and foreign savings[1] were complements rather than substitutes, which is contrary to most research work. Kargbo (2010) recently employed the autoregressive distributed lag (ARDL) model to test the cointegration relationships in the money and savings models, respectively. The one-period lagged per capita real money variable was introduced in the domestic savings function to test the nature of the complementarity hypothesis. In the short run, the result from Sierra Leone during 1977 to 2008 exerted a positive and significant effect of money demand on domestic savings to income ratio.

Laumas (1990) followed McKinnon's initial model for money demand equation and estimated equation (2.4) using annual data for India during 1954-55 to 1974-75. Quite a few studies adopt broad money stock, M2, for the money supply variable, M. Laumas (1990) showed that M2 did not work well in this model. M1, part of M2, must drop if the real interest rate on deposits increases. Therefore, time deposits alone were adopted for M. As to the investment equation, the real return on capital, r, was computed using the data of medium and large-sized Indian enterprises. Gross private investment was used in I/Y. Also, aggregate ratio of public investment to income was added into the explanatory variable, which is expected to negatively affect the private investment. 2SLS estimation procedure was used to estimate both money demand and investment equations simultaneously. The result provided strong support for the complementarity hypothesis in India.

Pentecost & Moore (2006) kept McKinnon's initial money demand function, and

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[1]Domestic savings variable is usually represented by GDP less final consumption expenditure, and foreign savings variable is defined as current account deficits in the balance of payments, according to Odhiambo (2005), because a deficit indicates that a home country absorbs savings abroad to finance domestic investment.

replaced the real capital return, r, by the domestic credit relative to income, DC/Y, in equation (2.2). They argue that McKinnon's initial model overlooked the progress of financial liberalisation. As domestic credit becomes available, investment will increase independently of money demand. The investment equation thus becomes:

$$I/Y = g\left(DC/Y,\ R\right); \ \ g_{DC/Y} > 0,\ g_R > 0 \qquad\qquad (2.5)$$

Pentecost & Moore (2006) looked at the money demand equation and the investment equation as a system and employed the Johansen-Juselius cointegration test. They also argued that the exogenous assumption of the explanatory variables should also be tested. Similarly, they found that money and physical capital were complementary to each other in India from 1951 to 1999, which is in line with Laumas (1990). Following the models developed by Pentecost & Moore (2006), Moore (2010) constructed a panel data framework for 107 developing countries covering the period 1970 to 2006, and ran a simultaneous estimation of money and investment equations using the maximum likelihood estimation (MLE) method. The estimation also concluded that the long-run and dynamic formulations offered significant evidences to be supportive of the complementarity hypothesis.

Ogwumike & Ofoegbu (2012) combined equation (2.4) and equation (2.5) by replacing I/Y in the money demand equation by DC/Y. Following that, the financial liberalisation index was included in the money demand equation as well. They applied the ARDL model to the real money balances in Nigeria spanning from 1970 to 2009. M is represented by the total financial savings. The bounds testing result indicated that, in the long run, the effect of domestic credit to income ratio on real money balances was positive and significant, but the coefficient of the real interest rate was negative. As to the short-run dynamic analysis, changes in the real interest rate and domestic credit both positively affected the change in the money balances. However, this combination of two models rules out the verification of $g_R > 0$ in equation (2.5).

Natke (1999) looked at the complementarity hypothesis in a microeconomic view and investigated the real money demand equation at the firm level. 86 manufacturing firms were chosen during 1972 and 1976 in Brazil. The real money variable is represented by the liquid assets. The revenue of the firm, real interest rate, the planned investment spending and the return on capital are included in the liquid assets model. The study overall found some evidence of McKinnon's hypothesis that the planned spending on investment affects current liquid asset holdings.

2.4 Fluctuations of real exchange rate under financial repression

In McKinnon and Shaw's analysis of financial repression, the behaviours of savings and investment are mostly cited and numerous research studies have examined the impact of financial repression on the savings and investment theoretically and empirically. In fact, the existence of financial repression (or liberalisation) exerts great influence on not only savings, investment and economic growth, but also the behaviour of the real exchange rates. Recent work postulates that financial repression and the less developed financial markets in developing countries are primarily responsible for the movement of real exchange rates. The suggestion of financial liberalisation, proposed by McKinnon and Shaw, contributes to a dramatic increase in capital inflows and real exchange rate appreciation. This section begins with the definition of real exchange rate, and the theoretical framework and empirical studies on the sources of real exchange rate fluctuations follow.

2.4.1 Concept of real exchange rate

Real exchange rate is defined as a relative price which reflects the external competitiveness of a country. Also, it is often interpreted as the nominal exchange

rate considering the inflation inequality in different countries. Traditionally, the real exchange rate, q, is defined in line with the purchasing power parity (PPP) in the long run. :

$$q = \varepsilon \frac{P^*}{P}$$

where ε is nominal exchange rate, P^* and P are price levels of foreign and home countries, respectively. A decline in the real exchange rate can be interpreted as a real exchange rate appreciation. Another definition considers the price of tradable goods in one country relative to the price of nontradable goods, which can also represent the level of external competitiveness in one country (see Dornbusch, 1974; Dornbusch, 1980; Frenkel & Mussa, 1985 and Neary & Purvis, 1983). Assuming that the law of one price holds for the tradables and that no taxes are imposed on trade, the real exchange rate can be defined as follows:

$$q = \varepsilon \frac{P_T^*}{P_N}$$

where P_T^* is the world price of the tradable goods, and P_N denotes the domestic price of the nontradable goods.

In this case, an increase of q represents a real depreciation of the domestic currency. This definition, however, confronts the measurement problem as no countries formulate price statistics on the basis of the tradable and nontradable goods. Harberger (1986) suggested using the domestic consumer price index to represent the price of the tradables, and the foreign wholesale or producer price index as the proxy for the international price of the tradables. He also proposed another alternative definition of real exchange rate and it is defined by the general domestic price index, P_d:

$$q = \frac{\varepsilon}{P_d}$$

All the definitions above are built on the assumption that there is only one trading partner for the home country, which is unrealistic in most cases. The real effective

exchange rate (REER) is introduced to incorporate both the nominal exchange rate and the price levels of other countries. In this case, a trade-weighted criteria is included in order to define the multilateral real exchange rates in terms of the trading partners of a country and the REER in country i is defined as:

$$REER_i = \prod_{j=1}^{n} \left(\varepsilon_{ij} \frac{P_j^*}{P_i} \right)^{w_{ij}}$$

where ε_{ij} is the nominal exchange rate between i and j, P_j^* is the price level for foreign country j, P_i is the domestic price level for country i, and the weighting pattern, w_{ij}, is time-varying and represented by the trade allocation of each trading partner of a country such that $\sum_{i \neq j} w_{ij} = 1$. The REER data, together with the time-varying weights data, are often calculated and published by the Bank for International Settlements.

2.4.2 Real exchange rate fluctuations

An increase in interest rate during financial liberalisation contributes to a rise in the capital inflow, which lifts the money supply and higher aggregate demand given a fixed nominal exchange rate policy, and boosts domestic price level, and hence a real appreciation. If a flexible exchange rate regime takes effect, the net capital flow is likely to increase both nominal and real exchange rate appreciation directly (Moore & Pentecost, 2006). Kohli & Kletzer (2001) studied the function of financial repression in exchange rate management in presence of capital controls in India. Government could intervene by adopting policy tools of financial repression to manage exchange rate under the managed floating exchange rate regime in India. Using a stylized model based on optimizing the behaviour of households and firms in a monetary economy, they revealed how financial liberalisation without fiscal policy reforms would bring about the balance of payments crisis in an economy where capital account was non-convertible. Besides, given the existence of

rising capital inflows, government borrowing from the domestic financial sector played a crucial role in managing exchange rate. In addition, many methods were proposed and used to pinpoint the sources of real exchange rate movements, which is summarised as follows.

2.4.2.1 Monetary approach with sticky prices

Based on the concept of PPP, one popular way to measure fluctuations of real exchange rate is the monetary approach with sticky prices. In line with this disequilibrium approach, changes in real exchange rate respond to changes in nominal exchange rate due to the slow adjustment of nominal price. Dornbusch (1976) models this approach and explains that the interaction of monetary shocks with sticky prices contributes to movements in real exchange rate. Frankel (1979) constructed a general monetary model of exchange rate where flexible and sticky price monetarists are included and considered as special cases. Hooper & Morton (1982) extended the Dornbusch-Frankel model by allowing for large and sustained changes in real exchange rate.

Many empirical analyses seek to investigate movements of real exchange rate using this approach. Hooper & Morton (1982) related real exchange rate to the balance of current account. Using the quarter data in the U.S, during 1973 and 1978, they suggested that the cumulative first difference of current account balance affected negatively on the U.S. real exchange rate, and the real dollar appreciation would be caused by a rise in the current balances. Kletzer & Kohli (2000) argued that the monetary approach with sticky prices offered a reasonable description for the Indian real exchange rate under the managed floating regime. Junttila & Korhonen (2011) analysed the nonlinear relationships between macroeconomic fundamentals and exchange rate among five industrial countries. They developed Frenkel's (1976) model of exchange rate with flexible prices and modified the error correction model with time-varying parameters. Their estimation concluded that

it was the inflation rate differentials that drove exchange rates in the long run.

2.4.2.2   General equilibrium approach

Another approach to determine fluctuations of real exchange rate is to generate a general equilibrium model where the nominal prices are flexible. Stockman (1980, 1983 and 1987) consider real exchange rate as endogenous which is determined in the general equilibrium approach. Stockman rejects the direct effect of nominal exchange rate on real exchange rate, but regards nominal exchange rate as part of the monetary equilibrium. The real exchange rate is then represented by the terms of trade, defined as the relative price of foreign to domestic goods. Fluctuations of real exchange rate hence are responses to the disequilibrium in output markets raised by real variables such as productivity, labour supply and government spending. Neary (1988) further adds the optimising behaviour of consumers and producers to Stockman's model with regard to an objective function. In the spirit of this, Edwards (1991) developed a dynamic intertemporal general equilibrium model to capture the behaviour of real exchange rate. The real exchange rate in his model was defined as the relative price of tradables to nontradables. In the empirical analysis, he estimated the dynamic equations using the pooled data for twelve developing countries, showing that real exchange rate in the short run responded to both nominal and real disturbances. Moreover, expansive policies tended to bring about real overvaluation.

Jang (1995) extended Edwards's optimising intertemporal general equilibrium model by including the analysis of a duality theory as in Kähkönen (1987). In this model, three types of goods were incorporated, i.e. exportables, importables and nontradables, and financial repression in the domestic market, for example, was reflected by lowering the domestic interest rate on deposit. Jang built the intertemporal general equilibrium model by optimising the behaviour of households, firms, banking sector and the government, and undertook the comparative static

analysis to explore the reaction of the real exchange rates to financial repression and other governmental policies. One conclusion from the theoretical analysis was that financial repression would contribute to a real exchange rate appreciation in the short run, provided that there was no initial distortion. Also, under financial repression, trade liberalisation might not result in a real depreciation.

2.4.2.3   Structural vector autoregression approach

Policy-makers have long expressed concern about the sources of nominal and real exchange rate fluctuations in order to stabilise exchange rates. The structural vector autoregression (VAR) model treats exchange rates, together with some other variables, as endogenous variables so that movements of exchange rate can be decomposed into parts due to various types of shocks in the economy. Also, shocks need to be identified in the structural VAR model, and most empirical research works have followed the pioneering work of Blanchard & Quah (1989) where structural shocks are identified by applying the long-run relationships from the theory to the model estimation procedure. Lastrapes (1992) employed the bivariate VAR model to have nominal and real exchange rates included as endogenous variables, and the structural shocks were defined as nominal shocks (money supply) and real shocks (technology, preferences and resource endowments, etc.). Following Blanchard & Quah (1989) and assuming nominal shocks have no persistent effect on the real exchange rate, Lastrapes found that fluctuations of both nominal and real exchange rates during 1973 to 1989 were dominated by real shocks in five developed countries with flexible exchange rate regimes. Enders & Lee (1997) also looked at the real and nominal exchange rates, and confirmed the role of real shocks in dominating movements of exchange rates in Japan, Canada and Germany during the post-Bretton Woods period. An investigation in real exchange rate fluctuations in the Euro between 1999 and 2006 was conducted by Hamori & Hamori (2007), and various methods to measure prices and nominal exchange rates were compared for the purpose of robustness checks. The results suggested

that real shocks played a key rule in the variation of real exchange rate in the long run. Nominal shocks, however, showed no long-run effects on real exchange rate because of the restriction imposed, but reduced nominal exchange rate at a significant level. In addition, several studies look at transition economies and less developed economies. For example, Dibooglu & Kutan (2001) investigated the sources of real exchange rate movements in Hungary and Poland, both of which were considered as transition economies during the sample period, i.e. January 1990 to March 1999. Hungary, with low-inflation, had similar results to advanced economies that real shocks dominated in the long run. However, the sources of real exchange rate fluctuations in Poland were mainly caused by nominal shocks in the short horizon. Morales-Zumaquero (2006) also obtained mixed results among transition economies in the Europe, but suggested different results in advanced economies. According to Morales-Zumaquero, real shocks were the predominant sources of real exchange rate fluctuations between 1973 and 1990, whilst nominal shocks took the rule during 1991 and 2000. Moreover, nominal shocks dominate among Euro-zone countries between 1991 and 2000. Moore & Pentecost (2006) examined the rules of two shocks in India since its financial liberalisation in 1990s, and the results suggested that real shocks dominate variations in real exchange rate, which is consistent with most advanced economies.

Clarida & Gali (1994) constructed a trivariate structural VAR model where output, price level and real exchange rate are considered as endogenous. The model can be interpreted as a stochastic model of Obstfeld *et al.* (1985). Three types of structural shocks, namely demand shocks, supply shocks and nominal shocks, are introduced into the model. The first two shocks are real shocks in Lastrapes (1992), whilst the nominal shocks capture exogenous changes of monetary policy as well as money demand. The identification of three shocks is motivated by imposing long-run restrictions following Blanchard & Quah (1989). To be specific, it is assumed that long-run level of real exchange rate is not driven by nominal shocks, and that long-run level of output is not driven by both nominal shocks

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and real demand shocks. Detken *et al.* (2002) applied the model proposed by Clarida & Gali (1994) to the Euro area, and found that real demand shocks were the main factor to drive exchange rate fluctuations in the long run. A study on the transition economies among Central and Eastern Europe during 1995 and 2005 by Stazka (2006) provided mixed results. According to Stazka, the results were dependent of whether a country had joined Exchange Rate Mechanism II (ERM II). For example, nominal shocks overall accounted for most of exchange rate movements for those economies who had not jointed ERM II, whilst real demand shocks dominated for others. Besides, a number of empirical literature have looked at less developed countries following the approach proposed by Clarida & Gali (1994). Wang (2005), for example, showed that real demand shocks were the main sources of real exchange rate fluctuations in China between 1980 and 2003. However, nominal shocks reported unusual results where real exchange rate initially depreciates in response of a positive nominal shock. One possible defect of Wang (2005) is that annual data should be avoided, as Faust & Leeper (1997) argued that the estimates are likely to be unreliable in finite samples. The number of observations when using annual data in this model was only 24, making the results much questionable. However, due to the scarcity of data among most less developed countries, it is far difficult or even impossible to obtain monthly data. Ahmad & Pentecost (2009) chose quarterly data between 1980 and 2005 to examine the sources of real exchange rate fluctuations in nine African countries, and found that nominal shocks accounted for a small part of real exchange rate movements, but real demand shocks were the main sources driving real exchange rate fluctuations in the long run. Inoue & Hamori (2009) also found a persistent effect of real demand shocks in India the long run, which is in favour of Moore & Pentecost (2006) during the similar sample periods. The result from Pakistan, however, provided contrary results. According to Khan *et al.* (2010) and based on quarterly data from 1982 to 2007, nominal shocks played a significant role in the short run, and supply shocks were predominant sources over the long horizon.

Similarly, Apergis & Karfakis (1996) showed that supply shocks accounted for most of real exchange rate variations in Greece since 1975, when Greece adopted a managed floating regime. Their results were robust by repeatedly choosing foreign price levels from six different industrial and developed countries.

In addition to a bivariate or trivariate structural VAR model, multivariate structural VAR model is adopted with general equilibrium models to incorporate more shocks in the estimation, and the results varies from countries. Huang & Guo (2007) used a four-dimensional structural VAR model with an additional oil shock, and suggested that the oil shocks accounted for a little degree of long-run real exchange rate fluctuations in China, and real shocks accounted for most of the variation. According to a two-sector two-factor small open economy model with a multivariate structural VAR approach, Jakab & Kovács (2000) found a real supply shock dominated for Hungary during 1991 to 1998, whilst nominal policy shock made little effect. However, nominal shocks in Australia played a key role in real exchange rate movements, based on a model containing nine endogenous variables constructed by Dennis (2003).

As mentioned above, Faust & Leeper (1997) criticised the credibility of the long-run restrictions imposed in the structural VAR model in terms of finite samples. Recently, an alternative method was used to impose sign restrictions, rather than long-run restrictions, to identify shocks in the structural VAR model (see Uhlig, 2005; Peersman, 2005; Fry & Pagan, 2007 and Mountford & Uhlig, 2009). Juvenal (2011) imposes the sign restrictions in the structural VAR model, and the result based on the U.S. data during 1976 until 2007 was in favour of most previous empirical work on developed economies, i.e. it is demand shocks that drove about 37% of real exchange rate fluctuations in a 20-quarter horizon, and monetary shocks played a limited role. Enders *et al.* (2011) considered a quantitative business cycle model with sign restrictions, and their results from the U.S. data suggested that real exchange rate appreciates in response to a negative shock of government expenditure and a positive technology shock. Huh & Kwon (2015)

looked at real exchange rate fluctuations as well as trade balances in the G7 country groups. He imposed long-run restrictions on relative output level, but a set of sign restrictions on real exchange rate and trade balances, and found that nominal shocks account for 20% to 50% of real exchange rate fluctuations in the long run among these countries, and demand shocks are less important in five countries except Germany and Italy. This finding is in sharp contrast with many results based on pure long-run restrictions, where demand shocks are main sources of real exchange rate variations. The empirical results using sign restrictions on structural VAR models for transition or less developed economies, however, are still scarce.

2.5 Conclusion

To summarise, empirical literature holds different perspectives on the credibility of McKinnon's complementary hypothesis. Moreover, there is no consensus with respect to the impacts of the real interest rate on savings as well as investment. Although recent years have witnessed smooth development in financial liberalisation in China, it is believed that financial repression still exists within China. Nonetheless, it is noted that very few empirical papers have studied this potential financial repression. The credibility of the complementarity hypothesis in China, however, needs to be tested by empirical work. To test the cointegration relationships between money and physical capital, the maximum likelihood based reduced rank regression test by Johansen & Juselius (1990), Johansen (1991) and Johansen (1995) rests on the assumption that all the underlying variables are integrated of order one, $I(1)$, which is sometimes unlikely in practical analysis. In order to solve this potential problem, Pesaran *et al.* (2001) then proposed the bound testing approach to the cointegration analysis where the variables can be a group of $I(0)$ and $I(1)$. This study employs the bound testing method using the autoregression distributed lag (ARDL) model to investigate the complementary hypothesis. Also,

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savings equation is considered so as to assess the argument by Fry (1978), who suggested that the investment function be replaced by the savings function.

In addition to the analysis based on the partial equilibrium above, this thesis considers alternative DSGE model specification to investigate the effects of financial repression and deregulation. Firstly, deposit rate deregulation is measured by gradually increasing the long-run deposit rate. Also, as the control of money supply in China has long been a vital instrument of monetary policy to meet inflation targets and stabilise economy, but it is far more difficult to control the money supply, it is believed that an interest rate rule has been more frequently used. This study then compares the efficiency of the two monetary policy instruments during financial liberalisation process. Following that, a new Keynesian model with patient and impatient households and commercial banks sector is constructed following Iacoviello (2005) and Gerali *et al.* (2010), with several types of repressive financial policies proposed by Chen *et al.* (2012) and Funke & Paetz (2012). This model considers the effect of the window guidance for bank loans on the process of deposit and loan rate deregulation. Another typical repressive policy, high required reserve ratio in China, is also captured in the model.

Lastly, fluctuations of real exchange rate have generated increasing interest in policy-makers aiming to maintain the stability of exchange rate, especially for those transition countries experiencing financial liberalisation. The empirical literature on detecting the sources of real exchange rates based on structural VAR models yield mixed results, though the argument that real shocks are main sources to drive movements of real exchange rate is preferred in most cases. The sources of real exchange rate variations in China, however, call for an empirical re-examination, especially for recent decades.

Chapter 3

Testing McKinnon's complementarity hypothesis

3.1 Introduction

According to Keynesians, reducing interest rates lowers the cost of capital, which induces more capital formation, but inhibits savings. McKinnon (1973) also suggests a negative effect on savings from lowering the interest rate. However, reducing the real interest rate on deposits in China is not related to a decrease in the savings to income ratio, as illustrated in Figure 3.1. Data for some years even suggest a possible negative link between them. One possible reason that the saving ratio is not sensitive to the real interest rate is the limitation of investment opportunities. In addition, households tend to save more to guarantee their basic living due to the absence of the well developed social welfare system.

McKinnon (1973) and Shaw (1973) suggest that raising the level of interest rates induces more savings, and hence increases the quantity and quality of investment. The effect can be partly reflected by the bank's ability to transform savings into investment. Figure 3.2 shows the difference between bank loans and bank savings
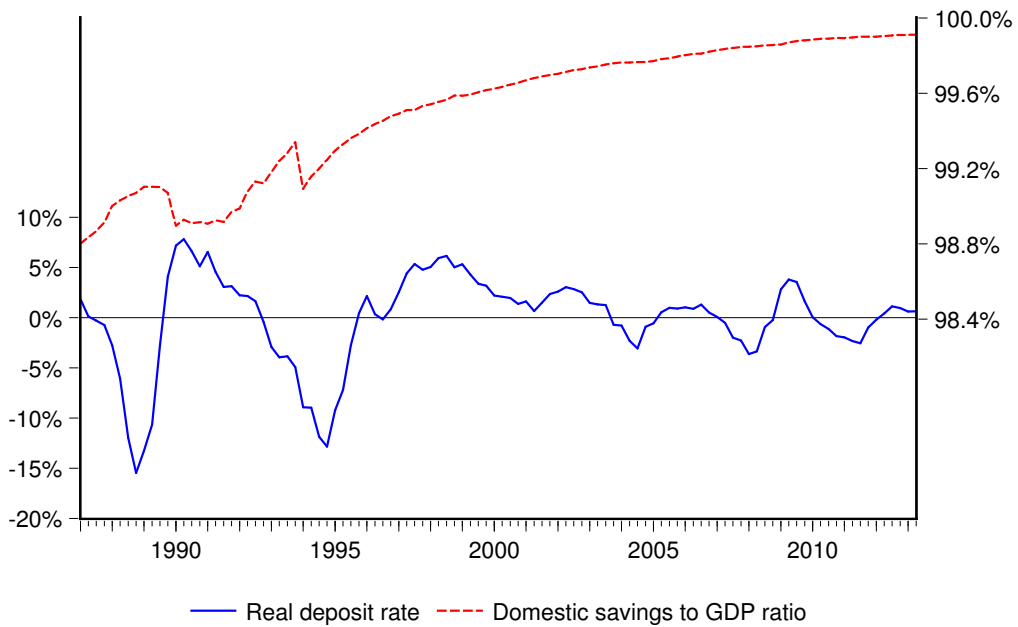
Figure 3.1: Real deposit rates and savings to income ratio in China
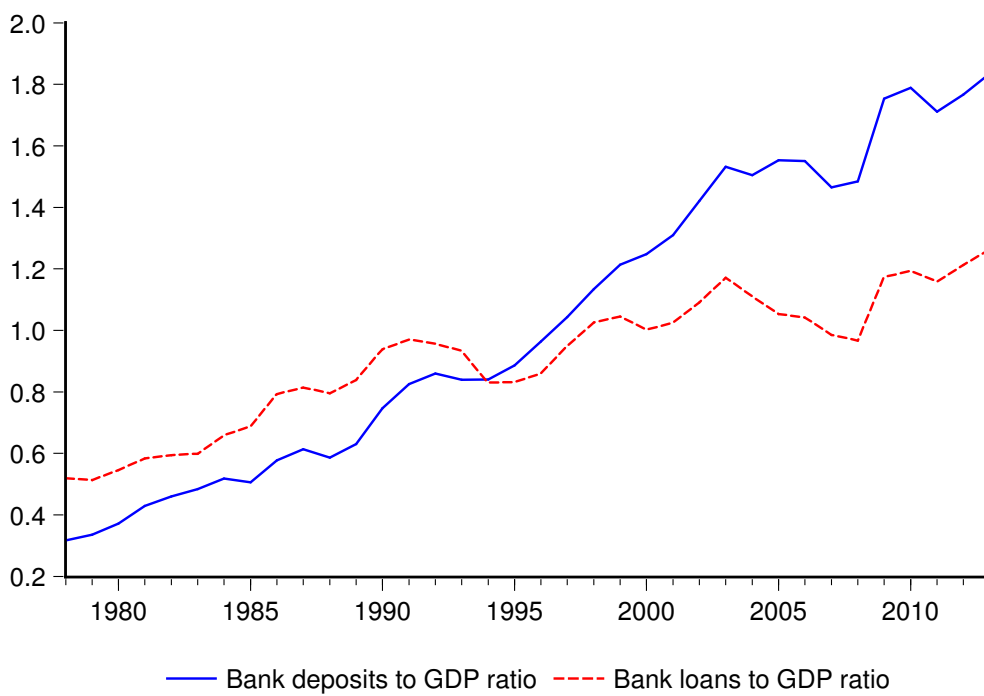
Figure 3.2: Bank loans and deposits relative to GDP in China

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relative to GDP in China since 1978. The ratio of deposits to GDP started to take the lead after 1995, indicating potential difficulties banks are confronted with when transforming deposits into loans. The difference became even larger in recent years. In addition, the imperfect bank supervision mechanism may also work to reduce the bank's ability of transforming savings. Finally, the profitability of financial intermediation in one country can be measured by the spread between the interest rates on bank loans and bank deposits. The spread remained at around 3% in the interest rate reform period after 1996, as illustrated in Figure 1.1.

This chapter conducts an empirical study to examine the credibility of the complementarity hypothesis between money and physical capital in China. Due to the availability of quarterly data, the period considered covers 1987 until 2013 when China started a transformation from a centrally planned economy to a market oriented economy. The bounds testing with ARDL modelling approaches are employed in the study to allow all the underlying variables to be integrated of different orders. Moreover, the unit root test developed by Perron (1997) is used in addition to the augmented Dickey-Fuller (ADF) test, as the latter has low power in the presence of a structural break in the data. The empirical results from the money and investment models following Pentecost & Moore (2006) offer weak evidence to support the hypothesis, as the real interest rate on bank deposits has no effects on capital formation. The result, however, turns out to be in favour of McKinnon's complementarity hypothesis by indicating a significant positive relationship when extending the investment model with variables such as income growth, real exchange rates and the terms of trade, and when the domestic credit to income ratio is removed. Finally, following Fry (1978), the savings equation enters the complementarity hypothesis testing model framework to replace the investment equation. The negative relationship between money and savings is in sharp contrast to the complementarity hypothesis.

This chapter is organised as follows. Section 3.2 briefly outlines McKinnon's complementarity hypothesis and the theoretical framework of the model. The empir-

ical models, methodology of cointegration analysis and data selections are illustrated in Section 3.3. Following that, Section 3.4 shows the main empirical results. Lastly, Section 3.5 concludes and proposes future research work.

3.2 The complementarity hypothesis and framework

McKinnon's model rests on some vital assumptions, i.e. household firms and small enterprises in less developed countries are limited to self-finance and have no access to credit. Also, investment is indivisible. Money balances have to be accumulated before investment can be undertaken. The more alluring the procedure to accumulate money balances, the stronger the motivation to invest. This leads to the core content of McKinnon's complementarity hypothesis, in which real money balances and physical capital are complementary to each other. The complementarity hypothesis between money and physical capital among less developed countries suggests that the real money demand relies directly, *inter alia*, on the real capital return, while the ratio of investment to income increases with the real deposit rate. It postulates the money demand and investment functions as follows:

$$M/P = f\left(Y,\ r,\ R\right);\ \ f_Y > 0,\ f_r > 0,\ f_R > 0 \tag{3.1}$$

$$I/Y = g\left(r,\ R\right);\ \ g_r > 0,\ g_R > 0 \tag{3.2}$$

where M/P is the real money balances, Y is the real income, I/Y is the investment to income ratio, r is the real average return on capital, R is the real rate of interest on bank deposits and f_* (or g_*) denote partial derivative of f (or g) with respect to each variable, Y, r or R.

McKinnon's complementarity hypothesis is therefore reflected by $f_r > 0$ and $g_R > 0$ in equation (3.1) and (3.4). Practically, it is difficult to find an appropriate

variable to represent the real capital return, r. McKinnon (1973) suggested the investment to income ratio, I/Y, to replace r in equation (3.1), which varies in the same direction as r. The real money demand equation thus becomes:

$$M/P = f\left(Y,\ I/Y,\ R\right);\ \ f_Y > 0,\ f_{I/Y} > 0,\ f_R > 0 \tag{3.3}$$

An impressive number of empirical studies have been carried out to test the complementarity hypothesis in developing countries, as discussed in Section 2.3 in Chapter 2. However, Fry (1978) argued that the investment function must be replaced by the savings function, as the demand for investment is plentiful and it is the supply of savings that contributes to the binding constraint. I/Y in equation (3.3) is replaced by the ratio of domestic savings to GNP, thus opting out the investment financed from foreign savings as well. Pentecost & Moore (2006) kept McKinnon's initial money demand function, and replaced the real capital return, r, by the domestic credit relative to income, DC/Y, in equation (3.2). They argue that McKinnon's initial model overlooked the progress of financial liberalisation. As domestic credit becomes available, investment will increase independently of money demand. The investment equation thus becomes:

$$I/Y = g\left(DC/Y,\ R\right);\ \ g_{DC/Y} > 0,\ g_R > 0 \tag{3.4}$$

The link between the two equations above is derived from goods market and money market equilibrium conditions as described in Pentecost & Ramlogan (2000) and Pentecost & Moore (2006). To be specific, goods market equilibrium indicates that:

$$S - I = G - T + CA \tag{3.5}$$

where S and I are aggregated private savings and investment, respectively, G denotes government expenditure, T is tax income and CA is the current account on the balance of payments at current price level, and is known as foreign savings.

On the other hand, money market equilibrium yields:

$$M^s = DC + F \tag{3.6}$$

$$M^d = P \times f(Y, \; r, \; R) \tag{3.7}$$

$$M^d = M^s \tag{3.8}$$

where DC is domestic credit, F denotes the foreign exchange reserve kept by the central bank, M^d and M^s are money demand and supply, respectively, and P denotes price level.

As Pentecost & Moore (2006) suggest, if there is no net international lending outstanding, and the capital is prevented from international mobility, then $\Delta F = CA$. Furthermore, assuming a balanced budget constraint of the government, $T = G$, yields the following relationship:

$$S - I(r, \; R) = \Delta f(Y, \; r, \; R) - \Delta(DC/P) \tag{3.9}$$

which means that the real excess supply of private savings without banks equals to the excess real money demand. In the presence of money market equilibrium, i.e. $\Delta f(Y, \; r, \; R) = \Delta(DC/P)$, the stock equilibrium can be defined as $S = I(r, \; R)$.

3.3   Methodologies and data

3.3.1   Models

This section starts from the model developed by Pentecost & Moore (2006), as indicated in equation (3.3) and equation (3.4). The investment to income ratio enters the money demand function to be a proxy of the real return on capital, whilst the domestic credit to income ratio is included in the investment equation.

McKinnon's complementarity hypothesis between money and physical capital is tested by specifying the real money demand equation and the investment equation respectively:

$$m = f\left(y,\ i,\ R\right) \tag{3.10}$$

$$i = g\left(dc,\ R\right) \tag{3.11}$$

where $m = ln\left(M/P\right)$ is the log of real money demand, $y = ln\left(Y\right)$ is the log of real income level, $i = I/Y$ is the investment to income ratio, R is the real interest rate on bank deposits, and $dc = DC/Y$ is the domestic credit relative to income. McKinnon's complementarity hypothesis hence indicates $f_i > 0$ and $g_R > 0$.

The investment equation (3.11) can be conditioned by some additional variables (see Agrawal, 2004; Shrestha & Chowdhury, 2007; Moore, 2010). The following augmented investment model is constructed:

$$i = g\left(dc,\ R,\ \nu\right) \tag{3.12}$$

where ν is a vector of variables that are considered to affect the investment to income ratio. For example, the real growth rate of income, GR, is expected to positively affect the investment ratio, since higher economic growth rate induces more requirements for capital formation, and hence raising the investment to income ratio. The terms of trade, TOT, calculated as the ratio between export and import price index, denotes the relative export price in terms of import price. An improvement of TOT therefore would expect a decrease in the relative price of the importable goods, i.e. usually capital goods in developing countries, and hence increasing the investment. Also, TOT would influence investment by affecting real income (Cardoso, 1993). Additionally, the real exchange rate, RER, can also be included in ν.

Fry (1978) has argued that the investment equation must be taken over by the savings equation due to the shortage of savings as the supply of loanable funds,

as illustrated in Figure 2.1, so here the following equations are tested as well:

$$m = f\left(y,\ sd,\ R\right) \tag{3.13}$$

$$sd = h\left(R,\ y,\ sf\right) \tag{3.14}$$

where sd, the domestic savings to income ratio, is included in the money demand equation to replace the investment to income ratio. sf is the foreign savings to income ratio, which is considered as substitutes for domestic savings. The complementarity hypothesis thus suggests $f_{sd} > 0$ and $h_R > 0$.

3.3.2   Bounds testing approach

To test the cointegration relationships in time series analysis, several approaches are used in the empirical studies. Engle & Granger (1987) developed a two-step test based on the OLS residual for the null of no cointegration. Johansen & Juselius (1990), Johansen (1991) and Johansen (1995) introduced the maximum likelihood based reduced rank regression test for cointegration. All of the tests rest on the assumption that all the underlying variables are integrated of order one, i.e. $I\left(1\right)$ which is sometimes unlikely in practical analysis. Pesaran *et al.* (2001) then proposed the bounds testing approach to the cointegration analysis where the variables can be a mix of I(0) and I(1). This test reduces the degree of pre-testing problems by allowing sufficient numbers of lags to describe the data generating process (Shrestha & Chowdhury, 2007). This paper thus considers using the bounds testing approach in the empirical studies.

The bounds testing approach is based on the conditional error correction model (ECM) taking the following specification:

$$\Delta s_t = c + b_{ss} s_{t-1} + \boldsymbol{b}_{sx} \boldsymbol{x}_{t-1} + \sum_{j=1}^{p} \boldsymbol{\delta}_j' \Delta \boldsymbol{z}_{t-j} + \boldsymbol{\varphi}' \Delta \boldsymbol{x}_t + \varepsilon_t \tag{3.15}$$

where $z_t = \left(s_t, x'_t\right)'$ is a vector of underlying variables, which can be either $I(0)$ or $I(1)$. The error term, ε_t, is assumed to be serially uncorrelated.

The null hypothesis of no cointegration for the bounds testing approach is therefore, $H_0 : b_{ss} = 0$ and $b_{sx} = 0'$. The long-run level model and the short-run dynamic error correction model then can be specified given that H_0 is rejected.

For example, to test the cointegration relationships in equation (3.10) and equation (3.11), the bounds testing frameworks are as follows:

$$\Delta m_t = c_0 + b_{mm}m_{t-1} + b_{my}y_{t-1} + b_{mi}i_{t-1} + b_{mr}r_{t-1} + \sum_{j=1}^{p}\delta_{m,j}\Delta m_{t-j}$$

$$+ \sum_{j=0}^{p}\delta_{y,j}\Delta y_{t-j} + \sum_{j=0}^{p}\delta_{i,j}\Delta i_{t-j} + \sum_{j=0}^{p}\delta_{r,j}\Delta r_{t-j} + \varepsilon_{m,t} \qquad (3.16)$$

$$\Delta i_t = c_1 + b_{ii}i_{t-1} + b_{idc}dc_{t-1} + b_{ir}r_{t-1} + \sum_{k=1}^{p}\delta_{i,k}\Delta i_{t-k}$$

$$+ \sum_{k=0}^{p}\delta_{dc,k}\Delta dc_{t-k} + \sum_{k=0}^{p}\delta_{r,k}\Delta r_{t-k} + \varepsilon_{i,t} \qquad (3.17)$$

The null hypotheses in equation (3.16) and equation (3.17) are $H_0 : b_{mm} = b_{my} = b_{mi} = b_{mr} = 0$ and $H_0 : b_{ii} = b_{idc} = b_{ir} = 0$, respectively. To conduct the bounds test, OLS technique is used to estimate equation (3.16) and equation (3.17), respectively. Following that, given each H_0, compare the conventional F statistics with the critical values, as reported in Pesaran *et al.* (2001). It is noted that two critical values are provided. The lower bound is obtained when x_t is purely $I(0)$, whilst the upper bound is calculated under the condition that the underlying variables are all $I(1)$. The null hypothesis of no cointegration is rejected at certain significance level provided that F exceeds the upper-bound critical value, and it cannot be rejected when F is below the lower-bound critical value. However, if F falls within the interval between the lower and upper bounds, the bounds testing result is inconclusive.

The coefficients, bs, indicate the long-run level effects whilst δs are the short-run dynamic coefficients. Shrestha & Chowdhury (2007), Kargbo (2010) and Ogwumike & Ofoegbu (2012) also employed the bounds testing approach, but they estimated the appropriate ARDL models for the bounds testing procedure, rather than using the unrestricted models such as equation (3.16) and equation (3.17). Pesaran *et al.* (2001) content that the coefficients of δs should remain unrestrained when conducting the bounds tests, otherwise the tests are likely to be subject to the pre-testing problem. Given that the null hypothesis is rejected at certain significance level, the ARDL model is considered to estimate the long-run effects and the short-run dynamics, as is a more parsimonious specification. This means that the ARDL model is selected by looking at $q * (q+1)^k$ models in equation (3.15), where k is the number of the variables in $\boldsymbol{x}$, and q is the maximum order of p.

3.3.3 Data selection

The quarterly data used in this study cover the period starting from Quarter 1, 1987 until Quarter 2, 2013 in China. This is a remarkable period in China's economic and financial reform, as it started a transformation from a centrally planned economy to a market oriented one in 1987. The nominal money demand, M, is the M2 end-period stock including cash and time deposits. The income level, Y, is nominal GDP. The real money stock and real GDP are both obtained by deflating the CPI. The investment variable, I, given the availability of data, is indicated by the gross fixed capital formation. DC is measured by the domestic credit to private non-financial sector. Inflation rate is calculated as the annual difference of CPI, i.e. $log\,(CPI_t/CPI_{t-4}) * 100$. The real deposit rate, R, is the the nominal 1-year deposit rate less the expected inflation rate.

Additional variables in equation (3.12) include the growth of income level, GR, the terms of trade, TOT, and the real exchange rate RER. GR is calculated as the growth of real GDP at the annual rate, i.e. $GR = log\,(GDP_t/GDP_{t-4}) *$

100. TOT is defined as the export to import price index ratio, and the real exchange rate is specified as $RER = \frac{e \cdot P^*}{P}$, where e is the exchange rate and is defined as the domestic price per U.S. dollar; P^* is the foreign price level, which is represented by the U.S. CPI; the price level of domestic country, P is the CPI data in China. As to the savings model, domestic savings are nominal GDP less the final consumption expenditure, whilst foreign savings are defined as the balance on current account with the sign reversed. The foreign savings to GDP ratio, sf, during the period reports negative results, which means that net foreign savings were negative accordingly.

The Chinese data are obtained from the People's Bank of China, the National Bureau of Statistics of China and the Oxford Economics database. The U.S. CPI data is from the Bureau of Labour Statistics, U.S.. All the data are seasonally adjusted where applicable. The trends in the three dependent variables, m, i, and sd, are plotted in Figure 3.3. All these variables show an upward trend during the 27 years.

3.4 Empirical findings

3.4.1 Unit root tests

Although the bounds testing procedure allows the underlying variables to be integrated of a mix of $I(0)$ and $I(1)$, it is vital that no series is $I(2)$ or integrated of higher orders. The ADF test is widely employed to test the stationarity of the data. However, the ADF test is criticised to have poor power when structural breaks are present, and the non-stationary data suggested by the ADF may be actually stationary given that a structural break exists in the series. Perron (1989) proposed a new stationary test by considering the structural break as known in the series, and Perron (1997) developed this test by allowing the structural break
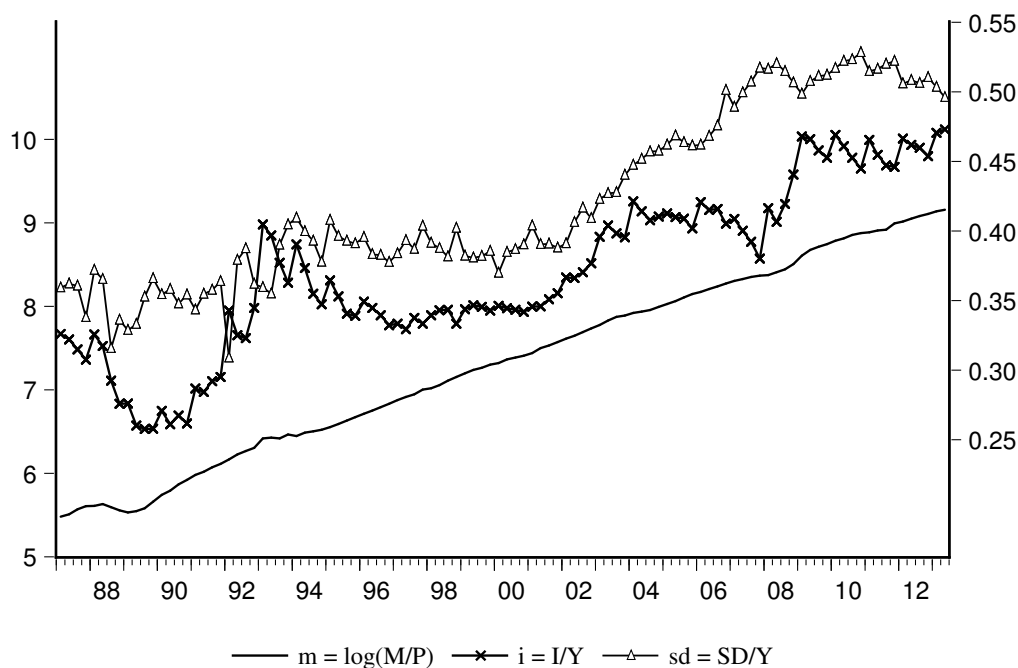
Note that *m* is measured on the left vertical axis, whilst *i* and *sd* are measured on the right axis.

Figure 3.3: Real money in logarithms, investment to income ratio and domestic savings to income ratio

to be endogenously determined. This section also reports the results of the Perron test of unit roots, of which the null hypothesis is that a unit root is found with a structural break in the series. Table 3.1 outlines the results of unit root tests from the ADF as well as the Perron test. The two approaches yield inconsistent results. m and y, according to the ADF, are integrated of order two. i and r in the ADF test are considered as stationary variables and the remaining six variables are $I(1)$. The Perron results show a mixture of $I(0)$ and $I(1)$ variables. In particular m is stationary in the presence of a structural break in the spring of 1993. The test results from Perron meet the requirement of the bounds testing approach.

Table 3.1: Unit root tests

Variable	ADF			Perron			
	Level	1st Diff	Result	Break	Level	1st Diff	Result
m	-2.110	-1.860	I(2)	1993Q1	-7.049*		I(0)
y	-2.364	-1.313	I(2)	1998Q4	-5.279	-9.201*	I(1)
i	-4.947*		I(0)	1996Q3	-4.730	-6.177*	I(1)
R	-4.401*		I(0)	1996Q2	-5.402*		I(0)
dc	-0.592	-7.699*	I(1)	2006Q3	-3.026	-9.796*	I(1)
GR	-2.937	-9.084*	I(1)	2005Q3	-4.801	-6.504*	I(1)
TOT	-3.043	-9.917*	I(1)	2005Q2	-2.565	-12.265*	I(1)
RER	-1.580	-10.034*	I(1)	2001Q3	-3.228	-14.744*	I(1)
sd	-2.825	-13.872*	I(1)	1994Q1	-2.551	-14.923*	I(1)
sf	-2.471	-4.550*	I(1)	2006Q1	-4.774	-13.732*	I(1)

Note: A superscript * hereafter in this chapter indicates statistically significant at the 5% level. The t-statistics in the ADF test for the second difference of m and y are -10.033 and -8.163, respectively, both significant at the 5% level.

3.4.2 Cointegration analysis

3.4.2.1 Money and investment model

The bounds testing approach is conducted on equation (3.10) and equation (3.11) respectively to descry the long-run relationships. The choice of the lag order p in equation (3.16) and equation (3.17) is subject to the requirement of non-serial correlation, as well as the need to avoid the problem of over parametrization. The maximum lag is set to be 8 based on the nature of quarterly data. The test results are outlined in Table 3.2. The lag order is chosen to be 1 in the money demand equation and is 4 in the investment equation. F statistics in both equations are greater than the upper-bound critical values at the 10% level, thus confirming the existence the cointegration.[1]

Once the cointegration relationship is confirmed, it is advisable to employ a more

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[1]In the investment equation, F is slightly less than the upper-bound critical value at the 5% level, resulting the cointegration testing result inconclusive. However this section considers a cointegration relationship at this stage, at the 10% level, and will check F again in the following ARDL models. In addition, Narayan (2005) has argued that the critical values reported above are based on large sample sizes and produced the adjusted critical values when the sample size is between 30 and 80. The F statistics here in fact are greater than Narayan's upper-bound critical values as well, which are 3.885 and 4.247 (when $n = 80$) for the two equations above.

Table 3.2: Bounds testing results for money and investment model

Equation	Lag p	F Stat.	C.V. I(0)	C.V. I(1)	$\chi^2_{SC}(1)$	$\chi^2_{SC}(4)$
(3.10)	1	6.571	3.23 (5%)	4.35 (5%)	0.062	2.788
			2.72 (10%)	3.77 (10%)		
(3.11)	4	4.511	3.79 (5%)	4.85 (5%)	0.105	10.975
			3.17 (10%)	4.14 (10%)		

Note: The lag order, p, is selected by AIC or SBC depending on the presence of serial correlation. The numbers in the parentheses after the C.V., the critical values, represent the significance level. $\chi^2_{SC}(1)$ and $\chi^2_{SC}(4)$ are the LM statistics for testing the null hypothesis of no serial correlation against the orders 1 and 4, respectively, and are insignificant at the 1% level.

Table 3.3: Long-run estimation results for money and investment model

	Money Equation: ARDL(1,0,0,0)		Investment Equation: ARDL(4,4,0)	
Constant	0.965	(1.048)	0.141*	(3.343)
y	0.760*	(2.205)		
i	7.967**	(1.780)		
dc			0.058*	(5.559)
R	0.119*	(2.270)	0.004	(0.892)

Note: t-statistics are reported in the parentheses. A superscript ** hereafter in this chapter indicates statistically significant at the 10% level. The method used by Shrestha & Chowdhury (2007), Kargbo (2010) and Ogwumike & Ofoegbu (2012) also suggests the existence of cointegration, as the F statistic is 8.123 for ARDL(1,0,0,0), and 5.495 for ARDL(4,4,0), both of which are beyond the upper bounds of the critical values at the 5% level.

parsimonious ARDL specification to estimate both long-run and short-run dynamic equations. For a maximum lag order $p = 8$, $8 \times (8+1)^3 = 5832$ regressions of the ARDL model in equation (3.16) are looked at to select the most appropriate specification based on SBC or AIC. Similarly, 648 regressions are considered for the investment equation (3.17). Finally, the model selected is ARDL(1,0,0,0) for the money demand equation, and ARDL(4,4,0) for the investment equation. The long-run estimation results for both equations are outlined in Table 3.3. The coefficient of i in the money equation is 7.967, positive but only significant at the 10% level, whilst the coefficient of the real interest rate, R, is small and positive but statistically insignificant in the investment equation. The results show weak evidence to endorse McKinnon's complementarity hypothesis in the long run.

The results of short-run dynamic error correction models are outlined in Table 3.4 and Table 3.5. The lagged error correction terms in both equations show the

Table 3.4: Short-run ECM results for money equation ARDL(1,0,0,0)

Regressor	Coefficient	t-Stat	Regressor	Coefficient	t-Stat
ecm_{t-1}	-0.033*	-8.179	Δi_t	0.519*	4.394
Δm_{t-1}	-0.064	-0.679	ΔR_t	0.007*	7.271
Δy_t	0.152**	1.732			

$\bar{R}^2 = 0.519$, $SBC = -5.295$, $AIC = -5.422$, $LL = 286.943$
$\chi^2_{SC}(4) = 3.491[0.479]$, $\chi^2_H(4) = 8.035[0.090]$
$F_{FF}(1,98) = 0.379[0.540]$, $JB = 20.367[0.000]$

Note: ecm is the error correction term and $ecm = m - 0.965 - 0.760*y - 7.967*i - 0.119*R$ in this case. The dependent variable is Δm_t. Some diagnostic statistics are also reported in the table. χ^2_{SC}, χ^2_H, F_{FF} and JB are the test statistics for no residual serial correlation, heteroscedasticity, function misspecification and normal errors. The associated p values are in [*].

expected negative sign, and are significant as well. The coefficient of ecm_{t-1} in the investment ECM equation is -0.101, implying a somewhat high speed of recovering to equilibrium compared to that in the money ECM equation. Table 3.4 indicates that the effect of the lagged variable of investment to income ratio is positive and statistically significant. Given one shot increase in the investment to income ratio brings about 0.519% increase in the real money demand, suggesting a positive relationship between money and investment in the short run. The effect of the first-difference real deposit rate, ΔR_t, as indicated in Table 3.5, has a positive effect on Δi_t, but insignificant, offering weak evidence to support McKinnon's complementarity hypothesis.

3.4.2.2 Augmented investment model

The investment equation discussed above can be conditioned by some other variables which may affect fixed capital formation. The augmented investment model is outlined in equation (3.12), i.e. $i = g(dc,\ R,\ \nu)$, where ν is a vector of underlying variables in addition to dc and R. This section considers $\nu = (GR,\ TOT,\ RER)$ in the investment model. Moreover, Agrawal (2004) argued that the domestic credit to income ratio, dc, has already captured the effect of raising interest rate, because an increase in the availability of the domestic credit is partly due to a

Table 3.5: Short-run ECM results for investment equation ARDL(4,4,0)

Regressor	Coefficient	t-Stat	Regressor	Coefficient	t-Stat
ecm_{t-1}	-0.101*	-4.138	Δdc_{t-1}	-0.005	-0.582
Δi_{t-1}	0.024	0.309	Δdc_{t-2}	-0.013	-1.516
Δi_{t-2}	0.012	0.158	Δdc_{t-3}	-0.022*	-2.626
Δi_{t-3}	0.002	0.026	Δdc_{t-4}	-0.015*	-1.769
Δi_{t-4}	0.654*	8.388	ΔR_t	0.001	0.993
Δdc_t	0.029*	3.855			

$\bar{R}^2 = 0.574$, $SBC = -6.198$, $AIC = -6.483$, $LL = 338.370$
$\chi^2_{SC}(4) = 10.201[0.037]$, $\chi^2_H(4) = 8.975[0.062]$
$F_{FF}(1, 89) = 1.428[0.235]$, $JB = 56.913[0.000]$

Note: ecm is the error correction term and $ecm = i - 0.141 - 0.058 * dc + 0.004 * R$ in this case. The dependent variable is Δi_t. Some diagnostic statistics are also reported in the table. χ^2_{SC}, χ^2_H, F_{FF} and JB are the test statistics for no residual serial correction, heteroscedasticity, function misspecification and normal errors. The associated p values are in [*].

rise of real deposit rate. Therefore it is not surprised that the coefficient of R in equation (3.11) is insignificant given that domestic credit is the main constraint on investment, which was shown in Table 3.3 as well. Therefore, the following empirical analysis drops dc in the investment model:

$$i = g\left(R,\ GR,\ TOT,\ RER\right) \tag{3.18}$$

The conventional F test in the bounds testing approach is 4.198 in terms of $p = 8$, which surpasses the upper-bound critical value, 4.01. Therefore the bounds testing result confirms the existence of the cointegration relationships in equation (3.18). The ARDL(4,0,0,0,0) model is then selected among $8 \times (8+1)^4 = 52488$ models based on SBC. The long-run level effects and short-run ECM dynamics are both reported in Table 3.6. The real interest rate positively affects the investment to income ratio in the long run, as the coefficient of R is positive and significant at the 10% level. In addition, improving the growth rate of GDP brings more opportunities to invest in the long run, as the coefficient of GR is positive. The real exchange rate turns out to be negatively related to investment, though it is insignificant. A real appreciation of exchange rates indicates a depreciation of Chinese RMB, and produces a negative effect of importing capital goods from

Table 3.6: Long-run and short-run ECM results for augmented investment model

Long-run level effect (Dependent variable: i)

Regressor	Coefficient	t-Stat
Constant	0.299	0.465
R	0.017**	1.793
GR	0.018*	2.908
TOT	0.109	0.172
RER	-0.026	-1.341

Short-run ECM effect (Dependent variable: Δi_t)

Regressor	Coefficient	t-Stat	Regressor	Coefficient	t-Stat
ecm_{t-1}	-0.054*	-5.450	ΔR_t	0.004*	5.234
Δi_{t-1}	-0.007	-0.107	ΔGR_t	-0.001*	-3.311
Δi_{t-2}	-0.068	-0.992	ΔTOT_t	0.015	0.250
Δi_{t-3}	-0.080	-1.169	ΔRER_t	-0.003	-1.086
Δi_{t-4}	0.710*	9.612			

$\bar{R}^2 = 0.575$, $SBC = -6.268$, $AIC = -6.501$, $LL = 337.317$
$\chi^2_{SC}(4) = 5.863[0.210]$, $\chi^2_H(4) = 11.435[0.022]$
$F_{FF}(1,91) = 0.236[0.628]$, $JB = 39.308[0.000]$

Note: ecm is the error correction term and $ecm = i - 0.299 - 0.017 * R - 0.018 * GR - 0.109 * TOT + 0.026 * RER$ in this case. The dependent variable is Δi_t. Some diagnostic statistics are also reported in the table. χ^2_{SC}, χ^2_H, F_{FF} and JB are the test statistics for no residual serial correlation, heteroscedasticity, function misspecification and normal errors. The associated p values are in [*].

abroad. The terms of trade variable is not significant as well, which is partly because of the presence of RER in the model. As to the ECM in the short run, the speed of adjustment is 5.4%, and the lagged real interest rate yields a significantly positive effect on the dependent variable, Δi_t, and the coefficient is 0.004. Compared to equation (3.11), the augmented investment model is slightly improved according to the adjusted R-square. Moreover, the results are in favour of McKinnon's complementarity hypothesis in both the long period and short run.

3.4.2.3 Money and savings model

Fry (1978) proposed the model indicated by equation (3.13) and equation (3.14). According to Fry, the domestic savings variable is the key constraint for the capital formation and therefore should be included to replace the investment variable.

Table 3.7: Bounds testing results for money and savings model

Equation	Lag p	F Stat.	C.V. I(0)	C.V. I(1)	$\chi^2_{SC}(1)$	$\chi^2_{SC}(4)$
(3.13)	1	7.146	3.23	4.35	0.857	4.126
(3.14)	1	5.340	3.23	4.35	3.289	5.755

Note: The critical values at the 5% level are reported above.

Table 3.8: Long-run estimation results for money and savings model

	Money Equation: ARDL(1,1,8,0)		Savings Equation: ARDL(1,6,0,0)	
Constant	0.851	(0.558)	0.003	(0.095)
y	1.245*	(2.257)	0.067*	(13.443)
sd	0.383	(0.062)		
R	0.072	(1.189)	-0.005*	(-4.239)
sf			-0.262*	(-2.075)

Note: t-statistics are reported in the parentheses. The bounds testing statistic F is 6.233 in the money equation and 5.069 in the savings equation.

McKinnon's complementarity hypothesis is thus tested by $f_{sd} > 0$ and $h_R > 0$. In addition, the financial liberalisation theory suggests $h_R > 0$ as well. The bounds tests indicate the existence of long-run cointegration relationships in both equations at the 5% level, as both of the F statistics in Table 3.7 are greater than the critical values of the upper bounds, 4.35.

To estimate the long-run relationships, ARDL modelling specifications are selected respectively among the $8 \times (8+1)^3 = 5832$ models based on SBC after considering no serial correlation in the model, respectively. Table 3.8 outlines the long-run level effects. The domestic savings to income ratio in the money equation is insignificantly positively associated with the real money demand, while the real interest rate in the savings model shows a significant and negative sign. The result, however, suggests a strong evidence to reject the complementarity hypothesis in the long run.

The error correction model captures the short-run dynamics and the estimation results are shown in Table 3.9 and 3.10, together with some diagnostic checks. The speed of adjustment in the savings equation is 31.4%, which means that the disequilibrium occurring due to a shock is corrected at 31.4% each quarter, whilst

Table 3.9: Short-run ECM results for money equation ARDL(1,1,8,0)

Regressor	Coefficient	t-Stat	Regressor	Coefficient	t-Stat
ecm_{t-1}	-0.042*	-7.482	Δsd_{t-3}	0.371*	2.667
Δm_{t-1}	0.011	0.109	Δsd_{t-4}	0.056	0.380
Δy_t	0.092	0.698	Δsd_{t-5}	0.196	1.397
Δy_{t-1}	-0.238**	-1.957	Δsd_{t-6}	0.275*	2.011
Δsd_t	-0.156	-0.939	Δsd_{t-7}	0.153	1.154
Δsd_{t-1}	0.042	0.249	Δsd_{t-8}	0.127	0.989
Δsd_{t-2}	0.115	0.786	ΔR_t	0.005*	4.062

$\bar{R}^2 = 0.366$, $SBC = -4.998$, $AIC = -5.369$, $LL = 274.407$
$\chi^2_{SC}(4) = 6.351[0.174]$, $\chi^2_H(4) = 1.432[0.839]$
$F_{FF}(1,82) = 0.253[0.616]$, $JB = 24.480[0.000]$

Note: ecm is the error correction term and $ecm = m - 0.851 - 1.245*y - 0.383*sd - 0.072*R$ in this case. The dependent variable is Δm_t. Some diagnostic statistics are also reported in the table. χ^2_{SC}, χ^2_H, F_{FF} and JB are the test statistics for no residual serial correction, heteroscedasticity, function misspecification and normal errors. The associated p values are in [*].

the speed is slower in the money equation, which is 4.2% per quarter. In the money equation, all the lagged variables of Δsd show the positive sign, except that Δsd_t itself is negative, though insignificant, meaning a change in the domestic savings is weakly negatively related to a variation of the money demand. The negative sign is also found in the coefficient of ΔR_t in the savings equation. The result overall fails to support the complementarity hypothesis in the short run.

3.5 Conclusion

Recent years have witnessed rapid financial development and fast economic growth in China, but repressive financial policies still exist. The People's Bank of China removed the floors for loan rates of interest in the third quarter of 2013, whilst the ceilings of the interest rates on bank deposits were remained under control until October 2015. This study employed the bounds testing approach and constructed ARDL models to verify the complementarity hypothesis between money and physical capital in China during a 27-year period from 1987 to 2013, and found some evidence to endorse the hypothesis. In the long run, money demand is posit-

Table 3.10: Short-run ECM results for savings equation ARDL(1,6,0,0)

Regressor	Coefficient	t-Stat	Regressor	Coefficient	t-Stat
ecm_{t-1}	-0.314*	-6.389	ΔR_{t-4}	-0.003*	-3.612
Δsd_{t-1}	-0.220*	-3.025	ΔR_{t-5}	0.001	0.925
ΔR_t	-0.002*	-2.442	ΔR_{t-6}	0.002*	2.100
ΔR_{t-1}	0.002**	1.690	Δy_t	0.417*	8.919
ΔR_{t-2}	0.002*	2.184	Δsf_t	-0.122*	-2.562
ΔR_{t-3}	0.001	1.429			

$\bar{R}^2 = 0.571, SBC = -6.192, AIC = -6.480, LL = 331.755$
$\chi^2_{SC}(4) = 8.215[0.084], \chi^2_H(4) = 3.072[0.546]$
$F_{FF}(1, 87) = 2.937[0.090], JB = 2.760[0.252]$

Note: ecm is the error correction term and $ecm = sd - 0.003 + 0.005*R - 0.067*y + 0.262*sf$ in this case. The dependent variable is Δsd_t. Some diagnostic statistics are also reported in the table. χ^2_{SC}, χ^2_H, F_{FF} and JB are the test statistics for no residual serial correlation, heteroscedasticity, function misspecification and normal errors. The associated p values are in [*].

ively associated with the investment to income ratio and the long-run relationship between fixed capital formation and the real deposit rate is positive but insignificant. Following Agrawal's (2004) argument that the real interest rate may be insignificant in the presence of the domestic credit to income ratio, and that the investment ratio is affected by some additional variables besides the interest rate, this study also considers the augmented investment model and the results tend to be in favour of the complementarity hypothesis. Additionally, Fry (1978) replaced the investment ratio by the domestic savings ratio when conducting the empirical studies. The model following this suggestion in this study yields an insignificantly positive relationship between money and savings, and improving the real deposit rate inhibits savings, which is in contradiction with McKinnon's complementarity hypothesis and McKinnon-Shaw financial liberalisation theory. The result of a negative relationship between the real deposit rate and the savings ratio in China is captured in Figure 3.1 at the beginning, indicating that domestic savings are not sensitive to the real deposit rate.

The result that there is no strong evidence to support the complementarity hypothesis in China in the long run may be partly due to the certain degree of financial liberalisation in China, which is consistent with the suggestion by Fry

(1978) that McKinnon's hypothesis was valid only when a country is yet to start the progress of financial reform. Further study should also consider the effects from additional financial repression variables, such as reserve requirements, capital account controls and managed exchange rates, on the financial development in China.

Chapter 4

Evaluating interest rate liberalisation and two monetary policy rules

4.1 Introduction

Interest rate adjustment has long been one of the most commonly used monetary policies by central banks. In China, for example, interest rate adjustment has become one of the most important tools to restrict inflation and deflation since 1996. For example, the 1-year deposit rate has been adjusted 45 times since 1978. Additionally, the objective of the PBoC when considering various monetary policy tools appears more complicated than that in some developed countries, as it does not only aim to maintain price stability, but also to help create job opportunities and maintain balance of international payments (Zhang, 2009). Consequently, interest rate adjustment is often employed to maintain the stability of the domestic stock market, so as to maintain social stability and promote economic development. McKinnon (1973) and Shaw (1973) have argued that interest rates in developing countries under financial repression like China are below the market equilibrium

level and investment is subject to the shortage of savings. In order to capture the degree of interest rate liberalisation, Jin *et al.* (2013) assumed different steady state levels of interest rates, and the interest rate liberalisation process was represented by gradually raising the steady state levels. Using this method, this chapter constructs several variations of DSGE models and investigates the effects of raising interest rates under financial liberalisation.

In addition to interest rate adjustment, China imposes controls on broad money supply growth due to the imperfect monetary policy transmission mechanism. However, it is well known that controlling money supply has become far more challenging given that the velocity of money does not remain stable in China. Nevertheless, China announces the target of M2 growth every year and the target in 2016, for example, is set to be around 13%. In order to evaluate the effectiveness of the money growth rule and the interest rate rule, this chapter then compares them in the new Keynesian DSGE model with a cash-in-advance constraint, and check the robustness in terms of a money-in-utility DSGE model. Calibration method and Bayesian estimation method are both employed and the results suggest the interest rate rule to be more effective and powerful.

The DSGE model has become widely used in the mainstream macroeconomic analysis for the transmission mechanisms of monetary policy (see Monacelli, 2005; Galí & Monacelli, 2005; Zhang, 2009; Gerali *et al.*, 2010; Justiniano & Preston, 2010), and even for fiscal policy in recent years (Galí & Monacelli, 2008). DSGE was initially proposed by Kydland & Prescott (1982) to be used in the Real Business Cycle (RBC) analysis. The RBC model is built in the context of neoclassical framework of micro-founded optimising problem with flexible prices. Fluctuations of real variables in the RBC model, according to the neoclassical assumptions, are caused by real shocks only, such as government spending shocks and technology shocks. However, new-Keynesian economists have introduced nominal rigidities in the DSGE model. For example, Taylor (1980) considered staggered wage contacts as the source of rigidity and Calvo (1983) developed a model with staggered prices

in the price setting behaviour. This allows for a number of short-run macroeconomic frictions to be present in the DSGE model (see Smets & Wouters, 2003, 2005).

The transmission channels of monetary policy, according to Mishkin (1996), can be classified as traditional interest rate channels, money growth channels, credit channels and exchange rate channels. A large number of investigators have undertaken empirical studies on China's monetary policy in the framework of DSGE models. Jin *et al.* (2013) used a simple closed economy neoclassical Cash-in-Advance model with the money growth rule only, whilst Carlstrom & Fuerst (1995) compared two main monetary policy rules, namely the money growth rule and the interest rate rule, in terms of welfare gains in the Cash-in-Advance model and they concluded that according to the simulations, the interest rate rule was preferable as there was a more efficient response of households to real supply and demand shocks. Bhattacharjee & Thoenissen (2007) also studied the two rules above in the DSGE model, but the models they used were a money-in-utility model and a cash-in-advance model. Their results based on the U.S. data suggested that the money supply rule with Cash-in-Advance model best matched the real data. Zhang (2009) compared the two monetary policy rules for China in a new-Keynesian DSGE model with sticky wages and staggered prices. Zhang adopted nominal money growth to be linked to output gap and inflation for the money supply rule, and computed a modified Taylor rule to capture China's interest rates in the interest rate rule. The method of undetermined coefficients developed by Uhlig (1999) was employed to solve the model after calibration. The result suggested that the interest rate rule was more effective than the money supply rule. Liu & Zhang (2010) built a new-Keynesian model containing four equations from the DSGE model regarding to the Phillips curve, the IS curve, the interest rate Taylor rule and the money growth rule, respectively. Their results suggested using two monetary policy rules together would be superior to the use of one single rule.

This chapter first investigates the effects of interest rate liberalisation on China's

economy in the DSGE model. It starts from introducing a simple neoclassical Real Business Cycle (RBC) model with a cash-in-advance constraint proposed by Stockman (1981) to simulate China's money growth rule. The model is solved by the method of undetermined coefficients proposed and developed by Uhlig (1999). In the spirit of Jin *et al.* (2013), the liberalisation process in this model is reflected by raising the steady state levels of deposit rates. Then, a new Keynesian closed economy model with a cash-in-advance constraint is built to compare two monetary policy rules, i.e. the interest rate rule and the money growth rule. To check the robustness of the results, the chapter also validates Zhang's (2009) results based on the money-in-utility DSGE model. The result suggests that the interest rate rule is more efficient and powerful. Zhang (2009) and Liu & Zhang (2010) compared the money supply rule and the interest rate rule for China, but few have compared them in terms of the interest rate liberalisation process. It is therefore vital to understand which rule is more effective when implementing the liberalisation process in China. Following that and assuming the interest rate rule is used by the PBoC, it investigates the effects of interest rate liberalisation on China's economy. As a result, interest rate liberalisation contributes to a thorough and efficient transmission mechanism of monetary policy. Moreover, to check the robustness of the results from the DSGE model with a cash-in-advance constraint, this chapter also constructs a money-in-utility DSGE model where the variable referring to real money balances enters the utility function of households. Bayesian estimation method is employed to estimate the parameters of the central bank's monetary policy and the results are in favour of that in the DSGE model with a cash-in-advance constraint.

This chapter is organised as follows. Section 4.2 outlines the neoclassical model with a cash-in-advance constraint, together with data, calibration, solving method and the impulse response functions. The new Keynesian model with a cash-in-advance constraint is interpreted in Section 4.3, where two monetary policy rules are also compared. Section 4.4 presents the robustness check in terms of a money-

in-utility model with Bayesian estimation methods, and presents the impulse responses results. Section 4.5 concludes.

4.2 A neoclassical model with a cash-in-advance constraint

4.2.1 Model structure

The neoclassical school holds the idea that money is neutral based on the assumptions of rational expectations and market clearing. However, this argument is interrupted by imposing a cash-in-advance constraint in the simple RBC model. a variable reflecting nominal money balances affects real variables in the economy, resulting in the non-neutrality of money. Households in this model deposit and hold money balances to consume and invest. In addition, a money variable is included in the cash-in-advance constraint faced by the households. Firms produce goods in line with a Cobb-Douglas production function for a given technology. The central bank uses nominal money growth as the monetary policy tool. Unlike Baharumshah *et al.* (2009) and Jin *et al.* (2013) who assume that money growth follows an $AR(1)$ process, this section adopts endogenous money growth lag also taking inflation and output gap into consideration.

4.2.1.1 Households

The representative household chooses real consumption, C_t, and labour supply, N_t, to maximise her utility function:[1]

$$\max \mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left(\frac{1}{1-\sigma} C_t^{1-\sigma} - \psi^N \frac{1}{1+\phi} N_t^{1+\phi} \right) \right\}$$

where $\beta \in (0,1)$ is the intertemporal discount factor, σ is the coefficient of relative risk aversion of households, ϕ denotes the inverse of wage elasticity of labour supply, also known as the inverse of Frisch elasticity, and ψ^N captures the substitution between labour supply and consumption.

The representative patient household's choice is subject to the following budget constraint (in real terms hereafter):

$$C_t + D_t + M_t + I_t = \frac{R_{t-1} D_{t-1}}{\Pi_t} + W_t N_t + \frac{M_{t-1}}{\Pi_t} + \tilde{r}_t^K K_{t-1} + F_t^R \qquad (4.1)$$

where D_t is the private deposits held in the commercial banks, M_t is the real money balances held at the end of period t, R_t is the gross interest rate on deposits[2], $\Pi_t = \frac{P_t}{P_{t-1}}$ is the gross inflation where P_t is the price level denoted by the Consumer Price Index, W_t denotes the real wage rate, $\tilde{r}_t^K$ is the real rental rate of capital and F_t^R is the lump-sum profits received from firms. I_t is investment defined as $I_t = K_t - (1-\delta) K_{t-1}$, where δ is the deprecation rate for capital.

The cash-in-advance constraint imposed in households reads:

$$C_t \leq \frac{M_{t-1}}{\Pi_t} \qquad (4.2)$$

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[1] Recent studies with DSGE models have seen a household utility function that is compatible with a balanced-growth steady state, hence the utility function is non-separable (Smets & Wouters, 2007; Cantore *et al.*, 2015) and the growth of population is considered. Nevertheless, a separable utility function, as in this chapter, is still widely used by, for example, Smets & Wouters (2003), Smets & Wouters (2005) and Gerali *et al.* (2010).

[2] In this chapter, R_t refers to nominal interest rate as well, as there is no lending rate in the model.

As in Svensson (1985), the timing assumption in this model is that households have available for consumption only the cash carried over from the previous period, so that cash balances must be chosen before they know how much spending they will wish to undertake.

In equilibrium, the dynamics of consumption, bank deposits, real money balances, labour supply and capital are determined by equation (4.1) and equation (4.2). The first order conditions (FOCs) are outlined below:

$$C_t^{-\sigma} = \tilde{\lambda}_t + \tilde{\mu}_t \tag{4.3}$$

$$\tilde{\lambda}_t = \beta R_t \mathbb{E}_t \frac{\tilde{\lambda}_{t+1}}{\Pi_{t+1}} \tag{4.4}$$

$$\tilde{\lambda}_t W_t = \psi^N N_t^\phi \tag{4.5}$$

$$\tilde{\lambda}_t = \beta \mathbb{E}_t \left(\frac{\tilde{\lambda}_{t+1} + \tilde{\mu}_{t+1}}{\Pi_{t+1}} \right) \tag{4.6}$$

$$\tilde{\lambda}_t = \beta \mathbb{E}_t \left(\tilde{\lambda}_{t+1} \left(1 - \delta + \tilde{r}_{t+1}^K \right) \right) \tag{4.7}$$

where $\tilde{\lambda}_t$ and $\tilde{\mu}_t$ denote the Lagrange multipliers with respect to the budget constraint (4.1) and the cash in advance constraint (4.2), respectively.

4.2.1.2 Firms

Firms produce goods according to the Cobb-Douglas function:

$$Y_t = A_t K_{t-1}^\alpha N_t^{1-\alpha}, \quad 0 < \alpha < 1 \tag{4.8}$$

where $A_t = \exp(u_t^a)$ is the total factor productivity with u_t^a representing the productivity shock, and α is the output elasticity of capital.

Firms minimise the cost $W_t N_t + \tilde{r}_t^K K_{t-1}$, and it yields the following conditions:

$$W_t = (1-\alpha)\frac{Y_t}{N_t} \tag{4.9}$$

$$\tilde{r}_t^K = \alpha\frac{Y_t}{K_{t-1}} \tag{4.10}$$

4.2.1.3 Central bank

Every year at the National People's Congress, China's Prime Minister releases the target growth of M2. Also, this target is published at the People's Bank of China Annual Report. The money growth rule, therefore, remains dominant when implementing monetary policy in China. The nominal money growth gross rate, $G_t = 1 + \tilde{g}_t$, is defined as $\mathcal{M}_t = (1 + \tilde{g}_t)\mathcal{M}_{t-1}$, where $\mathcal{M}_t = P_t M_t$ is the nominal money supply. Therefore,

$$M_t = (1 + \tilde{g}_t)\frac{M_{t-1}}{\Pi_t} \tag{4.11}$$

Bhattacharjee & Thoenissen (2007) assume that the growth rate follows an $AR(1)$ process and Burdekin & Siklos (2008) suggest a McCallum rule where the target growth of nominal GDP is taken into consideration. Following Zhang (2009) and considering that money supply is used to constrain inflation in China, this model sets the money growth rule to be a Taylor-type equation that is similar to the interest rate rule:

$$G_t = G_{t-1}^{\phi_g^g}\left(G\left(\frac{\bar{\Pi}}{\Pi_t}\right)^{\phi_g^\pi}\left(\frac{Y}{Y_t}\right)^{\phi_g^y}\right)^{\left(1-\phi_g^g\right)}\exp\left(u_t^g\right) \tag{4.12}$$

where G is the target gross growth rate, u_t^g denotes the external shock, and ϕs, again, reflect the preferences of the central bank.

4.2.1.4   Shocks

To close the model, the productivity shock and the money-growth shock, are set to follow $AR(1)$ processes as described below:

$$u_t^a = \rho_a u_{t-1}^a + \epsilon_t^a \tag{4.13}$$

$$u_t^g = \rho_g u_{t-1}^g + \epsilon_t^g \tag{4.14}$$

where ϵ_t^a and ϵ_t^g are exogenous driving forces that are assumed to be identically independently distributed with zero means and standard deviations, σ^a and σ^g.

4.2.1.5   Log linearised equations

With goods market clearing condition $Y_t = C_t + I_t$, general equilibrium dynamics around the steady state levels can be derived from the equations above. The cash-in-advance constraint must be binding. Assuming inflation in the steady state equals the inflation target, $\Pi = \bar{\Pi}$, the steady states of the variables can be computed. For example, the steady state from equation (4.4) yields $R = \dfrac{\bar{\Pi}}{\beta}$. Also, the lower-case variables except interest rate, inflation and money growth rate, hereafter denote the percentage derivations from the steady states. For interest rate, inflation and money growth, the lower-case letters represent absolute derivations. Assuming the upper-case variables without a time subscript t refer to the levels of steady states, one could log-linearise the model around the steady states.

Firstly, the capital formation of households is log-linearised:

$$k_t = (1 - \delta) k_{t-1} + \delta i_t \tag{4.15}$$

An approximation of the binding cash-in-advance constraint yields:

$$m_{t-1} - \pi_t = c_t \tag{4.16}$$

Then, the FOCs of households are log-linearised as follows:

$$-\sigma c_t = \frac{\beta}{\Pi}\lambda_t + \left(1 - \frac{\beta}{\Pi}\right)\mu_t \tag{4.17}$$

$$\lambda_t = \mathbb{E}_t\lambda_{t+1} - \mathbb{E}_t\pi_{t+1} + r_t \tag{4.18}$$

$$\lambda_t + w_t = \phi n_t \tag{4.19}$$

$$\lambda_t + \sigma\mathbb{E}_t c_{t+1} + \mathbb{E}_t\pi_{t+1} = 0 \tag{4.20}$$

$$\lambda_t = \mathbb{E}_t\lambda_{t+1} + [1 - \beta(1-\delta)]r_{t+1}^K \tag{4.21}$$

Production function of firms is log-linearised as:

$$y_t = u_t^a + \alpha k_{t-1} + (1-\alpha)n_t \tag{4.22}$$

The real wage and real return on capital in equations (4.9) and (4.10) are log-linearised as follows:

$$w_t = y_t - n_t \tag{4.23}$$

$$\tilde{r}_t^K = y_t - k_{t-1} \tag{4.24}$$

Money growth function and the Taylor-type rule are log-linearised as:

$$m_t = m_{t-1} - \pi_t + \frac{g_t}{\Pi} \tag{4.25}$$

$$g_t = \phi_g^g g_{t-1} - \left(1 - \phi_g^g\right)\left(\phi_g^\pi \pi_t + \phi_g^y y_t\right) + u_t^g \tag{4.26}$$

In addition, the productivity shock and the money-growth shock mentioned above

are outlined again as follows:

$$u_t^a = \rho_a u_{t-1}^a + \epsilon_t^a \tag{4.27}$$

$$u_t^g = \rho_g u_{t-1}^g + \epsilon_t^g \tag{4.28}$$

Equations (4.15) to (4.28) constitute a system of linear rational expectations difference equations containing 15 endogenous variables, plus 2 exogenous driving forces.

4.2.2 Calibration

Parameters of DSGE models are determined using different estimation approaches. For example, pure calibration is used by Kydland & Prescott (1982) in the neoclassical model. Numerous research works employ this method due to its strong robustness (see Monacelli, 2005; Zhang, 2009; Chen *et al.*, 2012; Funke & Paetz, 2012; Jin *et al.*, 2013; Funke *et al.*, 2015), but it is also criticised for the absence of theory foundation. Calibration is widely used as the estimation method of DSGE models for China. Zhang (2009) argues that estimating DSGE models for China is difficult and challenging due to the absence of detailed datasets and potential structural changes since 1978. Jin *et al.* (2013) also note that the calibration method makes little difference from other methods like maximum likelihood estimation and Bayesian estimation, as long as the data are stable. Therefore, in this section, a calibrated model is considered. To be specific, some parameters are set following the related model in the literature or according to the steady state equations with the mean of real data, whilst others are estimated in separate equations, depending on the availability of data. Table 4.1 summarises all the parameters used in this section. The period this chapter focuses covers 1996Q1 until 2015Q4[3], which has seen the progress of interest rate liberalisation as well as

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[3]In case that only annual data are available, quarterly data are generated in EViews using 'quadratic-match sum' method based on annual data.

Table 4.1: Model calibration

Description	Calibrated value
Annual inflation rate	2.07%
Annual deposit rate	3.28%
Intertemporal discount factor	$\beta = \dfrac{\Pi}{R} = 0.997$
Capital depreciation rate	$\delta = 4\%$
Output elasticity of capital	$\alpha = 0.53$
Inverse of Frisch elasticity	$\phi = 1/3$
Relative risk aversion of households	$\sigma = 2$
Money growth rule	$\phi_g^g = 0.88,\ \phi_g^\pi = 0.5,\ \phi_g^y = 1.33$
Productivity shock	$\rho_a = 0.8,\ \sigma^a = 2.5\%$
money-growth shock	$\rho_g = 0.8,\ \sigma^g = 0.4\%$

sustainable economic growth in China.

The depreciation rate of capital, δ, in China is set to be 0.04 according to Zhang (2009). The average annual net deposit rate during this period is 3.28%, and the average quarterly inflation rate is 2.07% at the annual rate. Hence, the intertemporal discount factor, β, is 0.997 according to $\beta = \dfrac{\Pi}{R}$ in the steady state[4]. The data for the income approach of GDP are not available in China at national level, but provincial levels of GDP using the income approach are published every year. Summing up the data of individual provinces yields the approximation of national level of GDP, where labour income accounts for 47% of total income, meaning $\alpha = 1 - 0.47 = 0.53$. This value is consistent with the model estimation result of equation (4.22), which yields 0.58. The inverse of Frisch elasticity, ϕ, is set to be 1/3, following Chen *et al.* (2012). $\sigma = 2$ according to Xiao *et al.* (2015).

The steady state equations of (4.4)(4.7)(4.8)(4.9)(4.10) indicate that

$$\frac{I}{Y} = \frac{\delta\alpha}{\left(\dfrac{1}{\beta} - 1 + \delta\right)}$$

which means that the share of investment in total output, $\dfrac{I}{Y}$, is 0.49 given α, β

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[4]Note that $\beta = (1 - 2.07\%/400\%) / (1 - 3.28\%/400\%)$.
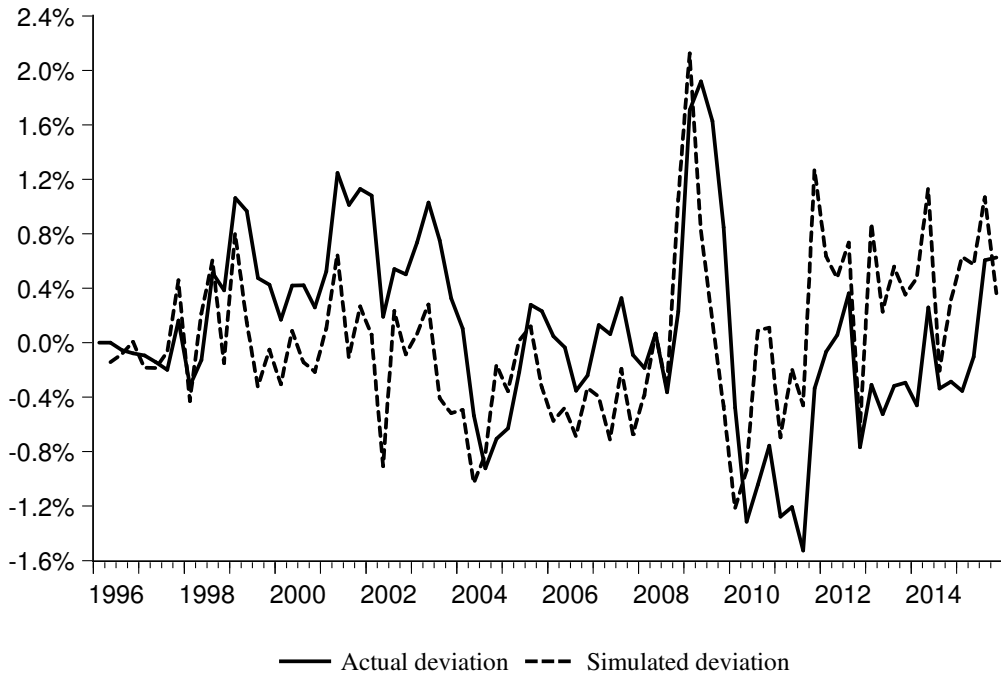
Figure 4.1: Actual and simulated nominal money growth deviations

and δ. Hence, the consumption to income ratio $\frac{C}{Y} = 1 - \frac{I}{Y}$, is equal to 0.51, which is consistent with the data.

The reaction parameters from the money growth rule in equation (4.26) are taken from Liu & Zhang (2010) with $\phi_g^g = 0.88$, $\phi_g^\pi = 0.5$ and $\phi_g^y = 1.33$. The simulated money growth deviation seems to capture the data at a satisfactory level, as shown in Figure 4.1. The differential between actual and simulated money growth deviations is 1.6% at most, and the simulated result captures the huge increase after 2008, when the government decided to release a 4-trillion yuan (approx. 570 billion U.S. dollars) stimulus package to boost economy.

Lastly, measuring the residuals from the equation of the money growth rule gives the $AR(1)$ parameter $\rho_g = 0.8$, with the standard deviation $\sigma^g = 0.4\%$. Also, the $AR(1)$ parameter of total productivity is estimated from the Cobb-Douglas equation, with $\rho_a = 0.8$ and $\sigma^a = 2.5\%$.

4.2.3 Method of undetermined coefficients

To solve the log-linearised model above, this section employs the method of undetermined coefficients proposed by Uhlig (1999). To use this method, the variables in the model are written as linear functions of a vector of endogenous variables (or state variables) $\mathbf{X}_{t-1}$ and exogenous variables $\mathbf{Z}_t$ which are determined at time t. In the model above, $\mathbf{X}_t = [k_t, m_t, g_t]'$ is a vector containing three state variables and $\mathbf{Z}_t = [u_t^a, u_t^g]'$ contains the stochastic processes. In fact, all the other endogenous variables in the model can be "eliminated" after simplification. However, Uhlig (1999) keeps those variables in the linear functions and defines them as "jump variables". In this case, $\mathbf{Y}_t = \left[r_t, i_t, c_t, \pi_t, \lambda_t, \mu_t, w_t, n_t, r_t^K, y_t \right]'$ is a list of jump variables. Uhlig (1999) then constructed the following equations for the three vectors:

$$0 = \mathbf{A} \cdot \mathbf{X}_t + \mathbf{B} \cdot \mathbf{X}_{t-1} + \mathbf{C} \cdot \mathbf{Y}_t + \mathbf{D} \cdot \mathbf{Z}_t \tag{4.29}$$

$$0 = \mathbb{E}_t \left[\mathbf{F} \cdot \mathbf{X}_{t+1} + \mathbf{G} \cdot \mathbf{X}_t + \mathbf{H} \cdot \mathbf{X}_{t-1} + \mathbf{J} \cdot \mathbf{Y}_{t+1} + \mathbf{K} \cdot \mathbf{Y}_t + \mathbf{L} \cdot \mathbf{Z}_{t+1} + \mathbf{M} \cdot \mathbf{Z}_t \right] \tag{4.30}$$

$$\mathbf{Z}_{t+1} = \mathbf{N} \cdot \mathbf{Z}_t + \epsilon_{z,t+1} \tag{4.31}$$

where matrices $\mathbf{A}$, $\mathbf{B}$, ..., $\mathbf{N}$ contain the coefficients of the model.

In general, suppose that the endogenous state vector $\mathbf{X}_t$ is of size $m \times 1$, the vector containing jump variables $\mathbf{Y}_t$ is of size $n \times 1$ and the vector of exogenous stochastic processes $\mathbf{Z}_t$ is of size $k \times 1$, this method thus requires $l \geq n$ for the coefficient matrix $\mathbf{C}$, size $l \times n$, and the rank of $\mathbf{C}$ is n. However, in the model above, $l = 9$ and $n = 10$ and the rank of $\mathbf{C}$ is 9, which fails to meet the requirements to use the method. Nonetheless, Uhlig (1999) proposes that the case $l < n$ can be treated by simply "redeclare" some other endogenous variables (or jump variables) to be state variables instead, i.e. to reduce n and thus increase m until $l = n$. This does not affect the results. Following this idea, the interest rate variable r_t in $\mathbf{Y}_t$ is taken out and redeclared to be state variables in $\mathbf{X}_t$ so that $m = 4$ and $n = l = 9$.

Given those equations above, one could compute the following relationships:

$$\mathbf{X}_t = \mathbf{S_1} \cdot \mathbf{X}_{t-1} + \mathbf{S_2} \cdot \mathbf{Z}_t \tag{4.32}$$

$$\mathbf{Y}_t = \mathbf{S_3} \cdot \mathbf{Y}_{t-1} + \mathbf{S_4} \cdot \mathbf{Z}_t \tag{4.33}$$

where $\mathbf{S_i}$ are response coefficients to the endogenous state and jump variables. Details of how to calculate the solution can be found in Uhlig (1999). In this chapter, the Matlab programmes performing this method are used and the programmes are provided by Uhlig (1999)[5].

4.2.4   Impulse response analysis

The impulse responses of output, consumption, investment and interest rate to one-standard-deviation sized positive shocks[6] in productivity are outlined in Figure 4.2. Output increases by approximately 1.5% due to a productivity shock, with a 2.8% point upturn in investment. Consumption increases continuously by 0.4% in the first 4 years, whilst inflation declines by 0.6% due to the increase of supply in terms of an improvement in productivity. Those responses are in line with economic theory. Figure 4.3 outlines the impulse responses of output, consumption, investment and interest rate to shocks in money growth, and it indicates that a money-growth shock leads to a 2.2% increase in inflation in the first year because of money expansion, with a decline in consumption by 1% in the first year. Investment sees a decline at the beginning, but increases by 0.7% during the first two years. Consequently, output initially drops by 0.2% in response to a money-growth shock, and then increases around its steady path. Those effects will last for 7 or 8 years.

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[5]The Matlab toolkit programme, with the latest version 4.1, is available at https://www.wiwi.hu-berlin.de/de/professuren/vwl/wipo/research/MATLAB_Toolkit

[6]Impulse responses analysis hereafter in this chapter, unless otherwise specified, indicates the impulse responses to positive shocks with the size of one standard deviation.
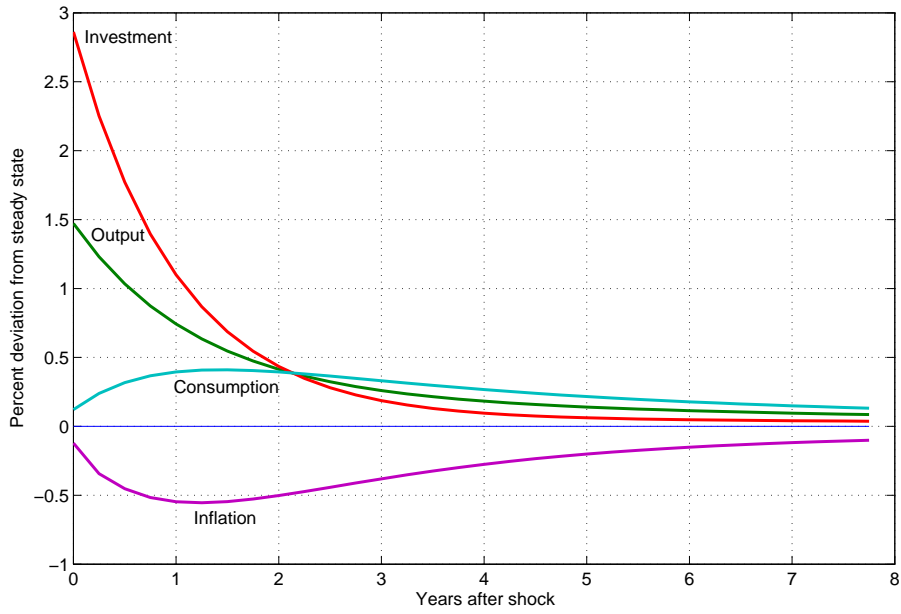
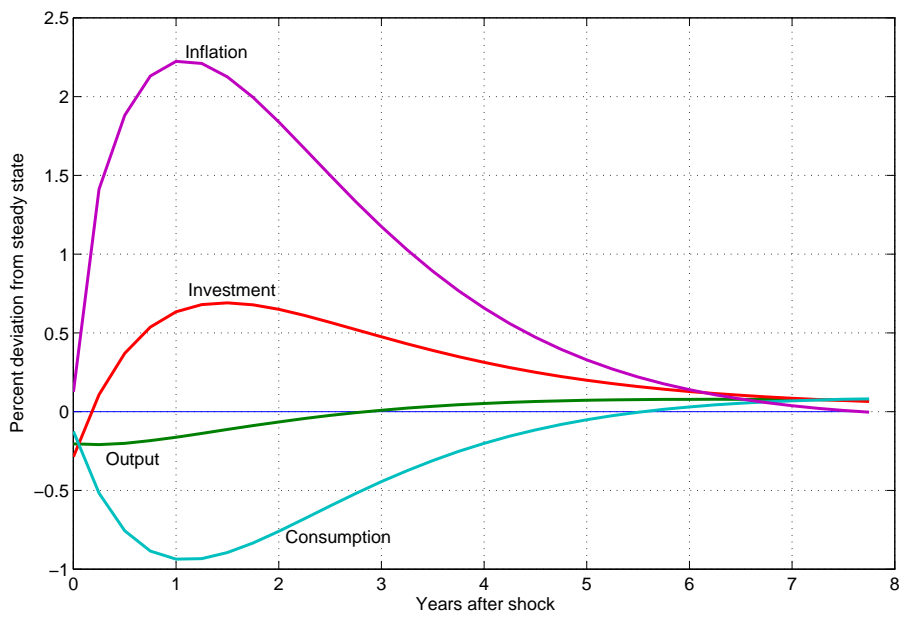Figure 4.2: Impulse responses to a productivity shock

Figure 4.3: Impulse responses to a money-growth shock

4.2.5 Steady state analysis of interest rate liberalisation

Jin *et al.* (2013) interpret the potential effects of interest rate liberalisation in the steady state model, in which interest rate liberalisation is reflected by raising the level of nominal interest rate on deposits in the steady state. To begin with, the steady state of equation (4.11) is $1 + \tilde{g} = \Pi$, indicating that nominal money growth in the steady state is equal to inflation. The steady state equations of (4.4) and (4.7) read $\beta = \dfrac{\Pi}{R}$ and $r^K = \dfrac{1}{\beta} - 1 + \delta$. The intertemporal discount factor, β, goes down due to increasing R, and the real return on capital stock, r^K increases. Moreover, the representative firm's equations of (4.8)(4.9) and (4.10), together with $I = \delta K$, produce the following steady state equations:

$$W = (1 - \alpha) \left(\frac{r^K}{\alpha} \right)^{-\frac{\alpha}{1-\alpha}} \tag{4.34}$$

$$K = \frac{\alpha}{1 - \alpha} \frac{WN}{r^K} \tag{4.35}$$

$$Y = \frac{r^K K}{\alpha} \tag{4.36}$$

Equation (4.34) shows a negative relationship between real wage W and capital return r^K in the steady state. Interest rate liberalisation, hence reduces real wage through raising r^K and lowering W would reduce capital stock, K, and investment, I, as well. However, as to output, Y, the positive effects from increasing r^K would be offset by the negative effects of lowering K, which stabilises the real output level in the steady state. Consequently, the investment to income ratio falls, which is consistent with the equation $\dfrac{I}{Y} = \dfrac{\delta \alpha}{\left(\dfrac{1}{\beta} - 1 + \delta \right)}$, where lowering β reduces the ratio. The consumption to income ratio, $\dfrac{C}{Y} = 1 - \dfrac{I}{Y}$, would increase accordingly. Therefore, raising nominal interest rate in the steady state readjusts the investment-consumption structure in an economy. To illustrate the process of interest rate liberalisation, Jin *et al.* (2013) simulated various situations with

Table 4.2: Different steady state levels under different nominal interest rates, R

Nominal Interest Rate Level	β	I/Y	C/Y
$R = 1\%$	1.011	0.568	0.432
$R = 3.28\%$	0.988	0.492	0.508
$R = 6\%$	0.960	0.420	0.580
$R = 9\%$	0.929	0.359	0.641

Note: β in this table denotes the annualised discount factor.

different levels of R, where interest rate and inflation rate were transformed into the annual rates, hence β denoted the annualised parameter. This section follows this method and chooses the steady state levels of interest rate, R, to be 1%, 6% and 9% in addition to the current level, 3.28%. The steady state levels of I/Y and C/Y, together with the annualised discount factor, β, is summarised in Table 4.2. According to the table, the discount factor can be greater than 1 when the nominal interest rate is smaller than the inflation level, indicating a negative real interest rate. Annualised inflation and interest rate are adopted to calculate the discount factor, β.

The impulse responses to shocks in productivity and money growth are presented in Figure 4.4 and 4.5, respectively. The numbers on the horizontal axis indicate quarters after each shock. With different levels of R, output shows little difference, according to Figure 4.4, but the initial response of output is slightly lower when $R = 9\%$, this is due to the decline of the investment to income ratio and the increase of the consumption to income ratio in the steady state level. The initial responses of consumption and investment are stronger with higher level of R, but the responses converge more quickly. Consumption increases in the first several years, and declines afterwards due to income and substitution effects, which are contrary to each other. Inflation responses almost identically, with an upturn following a decline in the first few years. Therefore, on the completion of interest rate liberalisation, raising the steady state levels of nominal interest rate helps to adjust the structure of the economy between consumption and investment, whilst maintaining output at a stable stage. Figure 4.5 describes the impulse
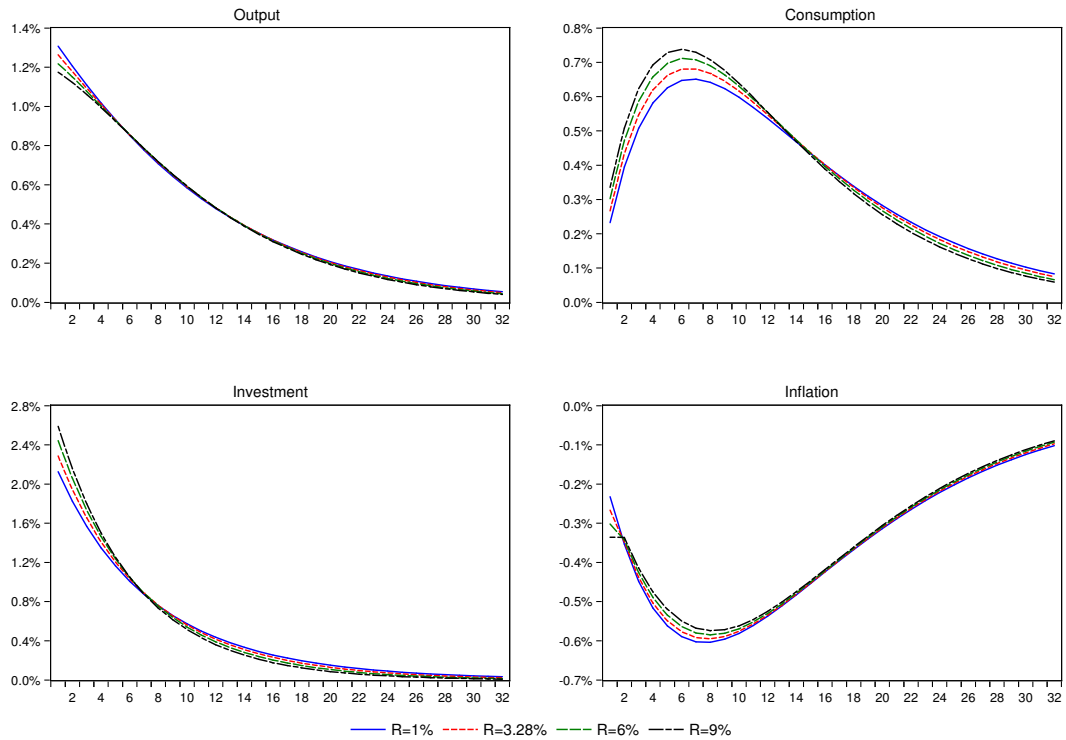
Figure 4.4: Impulse responses to a productivity shock with different R

responses to a money-growth shock. Similar to Figure 4.3, the initial response of output decreases by 0.3% to 0.5% with different levels of R. In other words, increasing the steady state levels of interest rate contributes to stronger response of output, and the effect remains longer than that with lower degree of interest rate liberalisation, i.e. lower R. The longer effects can be observed in investment as well. The initial response of consumption remains little different given different levels of R. Lastly, inflation yields almost identical responses to a money-growth shock at the beginning, and not many differences afterwards. Above all, it can be concluded that interest rate liberalisation, when measured by increasing the steady state levels of nominal interest rate, contributes to a more powerful and efficient transmission channel of monetary policy in presence of a money-growth shock.

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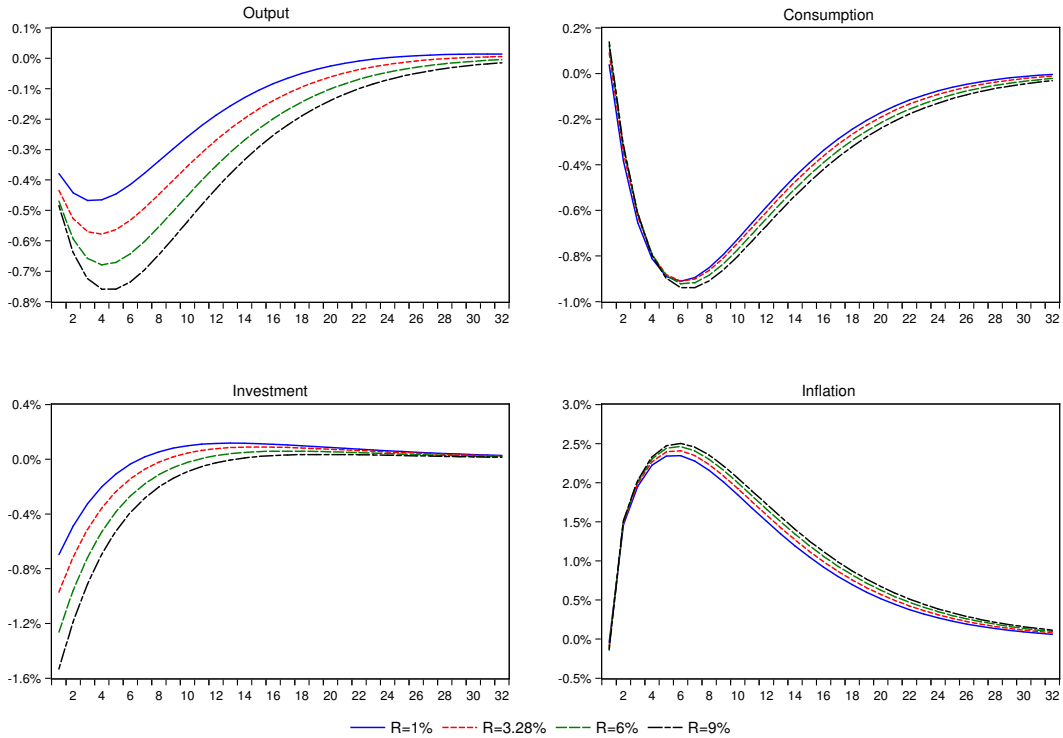
Figure 4.5: Impulse responses to a money-growth shock with different R

4.3 A new Keynesian closed economy model with a cash-in-advance constraint

4.3.1 Model structure

In order to compare the efficiency between the interest rate rule and the money growth rule, this section constructs a standard new Keynesian model with monopolistic competition and sticky prices, as is widely used in most empirical work. Households deposit at financial intermediates and hold money balances to consume, invest during her unlimited lifetime. The money variable is included in the model by imposing a cash-in-advance constraint, as suggested by Bhattacharjee & Thoenissen (2007). Firms employ labour and utilise capital to produce intermediate goods and retailers buy intermediate goods from firms in a competitive market, and differentiate them at no costs. Retailers then sell them in a monopolistic competitive market and therefore have some monopoly power when setting prices.

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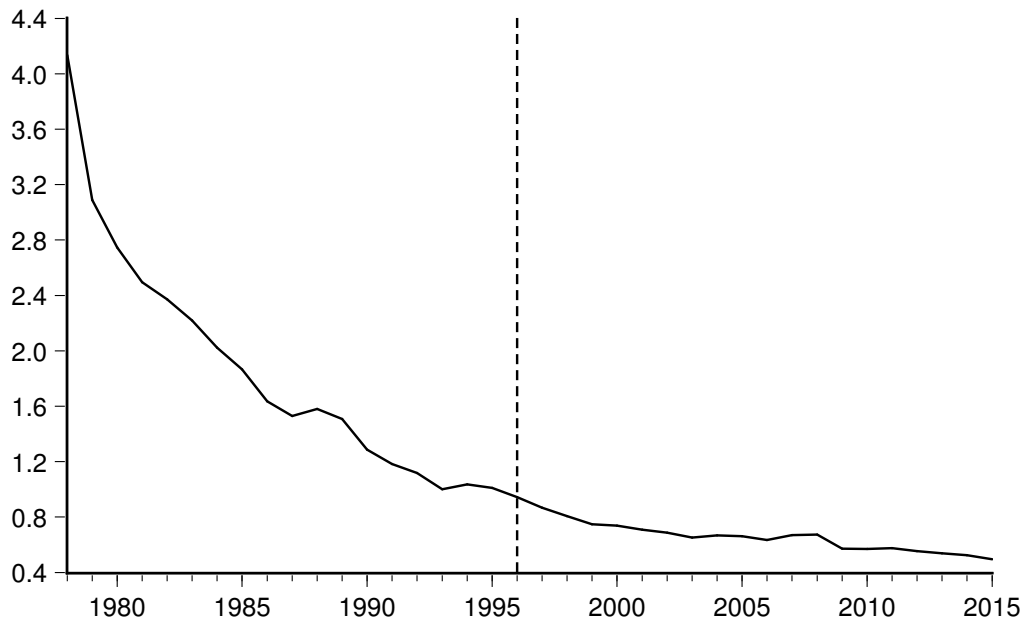
Note that the velocity is defined here as the ratio of nominal GDP to nominal broad money supply (M2).

Figure 4.6: M2 velocity in China: 1978-2015

The prices are set in a Calvo-type fashion. Lastly, timing is vital in the presence of a cash-in-advance constraint. Unlike Bhattacharjee & Thoenissen (2007), this model follows the timing assumption of Svensson (1985), assuming that goods market open before asset market, so that consumers have to decide the amount of cash to hold before they are aware of the real state of the world, hence the velocity of money is allowed to be non-constant. This assumption is more appropriate because the velocity of money in China, defined as nominal GDP to money supply ratio, has been far from invariable, as depicted in Figure 4.6. The velocity was above 4 in 1978 but saw a sharp decline to less than 0.5 in 2015. Although the velocity has become less volatile since 1996 (after the vertical dash line), it is still more appropriate to assume that the velocity of money is non-constant.

4.3.1.1 Households

The representative household behaves identically as in previous neoclassical model, by choosing C_t and N_t to maximise her utility subject to the budget constraint in equation (4.1), where F_t^R indicates the lump-sum profits received from retailers. Also, a cash-in-advance constraint is included, as in equation (4.2). The FOCs are same as previous, and are outlined in equations (4.3) to (4.7).

4.3.1.2 Firms

Firms produce intermediate goods that are assumed to follow the Cobb-Douglas function:

$$Y_t = A_t K_{t-1}^\alpha N_t^{1-\alpha}, \quad 0 < \alpha < 1 \tag{4.37}$$

where $A_t = \exp(u_t^a)$ is the total factor productivity with u_t^a representing the productivity shock.

Firms minimise the cost function $W_t N_t + \tilde{r}_t^K K_{t-1}$ and the FOCs with respect to N_t and K_{t-1} yield the optimal labour and capital inputs. The real marginal cost, MC_t, is then derived as follow:

$$MC_t = \frac{1}{A_t} \left(\frac{\tilde{r}_t^K}{\alpha} \right)^\alpha \left(\frac{W_t}{1-\alpha} \right)^{1-\alpha} \tag{4.38}$$

In addition,

$$W_t = \frac{1-\alpha}{\alpha} \frac{K_{t-1}}{N_t} \tilde{r}_t^K \tag{4.39}$$

4.3.1.3 Retailers

In the presence of sticky prices, Bernanke *et al.* (1999) and Iacoviello (2005) assume that retailers have some monopoly power and set the price in a Calvo-type staggered fashion. A continuum of retailers of mass 1, indexed by j, purchase intermediate goods from firms and differentiate the goods into $Y_t(j)$ at no cost and sell

them at $P_t(j)$. Final goods, Y_t^f is assumed to follow $Y_t^f = \left(\int_0^1 Y_t(j)^{\frac{\epsilon-1}{\epsilon}} dj\right)^{\frac{\epsilon}{\epsilon-1}}$, where $\epsilon > 1$ is the elasticity of substitution between differentiated goods. The price index is defined as $P_t = \left(\int_0^1 P_t(j)^{1-\epsilon} dj\right)^{\frac{1}{1-\epsilon}}$. Therefore, the demand curve of each retailer at time t follows a CES function and reads $Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon} Y_t^f$. Each retailer chooses a sale price $P_t(j)$. In this chapter, following Bäurle & Menz (2008) and Justiniano & Preston (2010), it is assumed that $(1-\theta)$ of retailers can reset their price optimally in every period, whilst the remaining θ of retailers cannot, but adjust the price according to the indexation rule in the following manner:

$$P_t(j) = P_{t-1}(j)(\Pi_{t-1})^\tau \tag{4.40}$$

where $\Pi_{t-1} = \dfrac{P_{t-1}}{P_{t-2}}$ is gross inflation of last period, and τ captures the degree of indexation to previous inflation.

Retailers in this chapter are assumed to behave identically and therefore the index j can be omitted in what follows. Let P_t^n denote the price set by the retailers that are able to reset their price optimally in period t, the aggregate price index can then be defined as:

$$P_t = \left[(1-\theta)(P_t^n)^{1-\epsilon} + \theta\left(P_{t-1}\left(\frac{P_{t-1}}{P_{t-2}}\right)^\tau\right)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} \tag{4.41}$$

For the $(1-\theta)$ of retailers who re-optimise their price in period t, the following present discount value of profits is maximised with respect to P_t^n:

$$\max \mathbb{E}_t \sum_{k=0}^\infty \theta^k \left\{ \Lambda_{t,t+k}\left(P_t^n\left(\frac{P_{t+k-1}}{P_{t-1}}\right)^\tau - P_{t+k}MC_{t+k}\right)Y_{t+k|t}\right\} \tag{4.42}$$

where $\Lambda_{t,t+k} = \beta^k\left(\dfrac{C_{t+k}}{C_t}\right)^{-\sigma}\dfrac{P_t}{P_{t+k}}$ is the discount factor retrieved from households.

Accordingly, the demand function in period $t + k$ for retailers who reset their price at time t and adjust the price according to the indexation rule henceforth is

specified as follows:

$$Y_{t+k|t} = \left(\frac{P_t^n}{P_{t+k}} \left(\frac{P_{t+k-1}}{P_{t-1}} \right)^{\tau} \right)^{-\epsilon} Y_{t+k} \qquad (4.43)$$

The first order condition takes the form:

$$0 = \sum_{k=0}^{\infty} \theta^k \mathbb{E}_t \left\{ \Lambda_{t,t+k} Y_{t+k|t} \left(\frac{P_t^n}{P_{t-1}} \left(\frac{P_{t+k-1}}{P_{t-1}} \right)^{\tau} - \frac{\epsilon}{\epsilon-1} MC_{t+k} \left(\frac{P_{t+k}}{P_{t-1}} \right) \right) \right\} \qquad (4.44)$$

Lastly, the lump-sum profits, $F_t^R = (1 - MC_t) Y_t$, are rebated to households.

4.3.1.4 Monetary Policy

Monetary policy is implemented by the PBoC. The control of money supply (or nominal money growth) by the PBoC has long been an important tool of monetary policy to meet inflation targets and stabilise the economy. However, as the velocity of money in China has been increasing significantly in the past years, it is far more difficult to control the money supply, which further weakens the link between money growth and inflation. Recently, the interest rate rule has been more frequently used by the PBoC. This model aims to compare the efficiency of the two monetary policy instruments during the financial liberalisation process, therefore both the interest rate rule and the money growth rule are outlined below.

Interest rate rule   The central bank sets the benchmark interest rate following a standard Taylor-type rule:

$$R_t = R_{t-1}^{\phi_r} \left(R \left(\frac{\Pi_t}{\bar{\Pi}} \right)^{\phi_\pi} \left(\frac{Y_t}{Y} \right)^{\phi_y} \right)^{(1-\phi_r)} \exp\left(u_t^r \right) \qquad (4.45)$$

where R_t is the policy interest rate set by the central bank, $\bar{\Pi}$ denotes the inflation target and u_t^r captures the interest-rate shock. The parameters, ϕs, measure the

preferences with respect to lagged policy rate, inflation and output gap, respectively.

Money growth rule   The rule is same as that in the neoclassical RBC model. The nominal money growth gross rate, $G_t = 1 + \tilde{g}_t$, is defined as $\mathcal{M}_t = (1 + \tilde{g}_t) \mathcal{M}_{t-1}$, where $\mathcal{M}_t = P_t M_t$ is the nominal money supply. Therefore,

$$M_t = (1 + \tilde{g}_t) \frac{M_{t-1}}{\Pi_t} \tag{4.46}$$

As in previous section, the central bank sets money growth according to a Taylor-type equation that is similar to the interest rate rule:

$$G_t = G_{t-1}^{\phi_g^g} \left(G \left(\frac{\bar{\Pi}}{\Pi_t} \right)^{\phi_g^\pi} \left(\frac{Y}{Y_t} \right)^{\phi_g^y} \right)^{\left(1 - \phi_g^g \right)} \exp \left(u_t^g \right) \tag{4.47}$$

where G is the target gross growth rate, u_t^g denotes the external shock, and ϕs, again, reflect the preferences of the central bank.

4.3.1.5   Shocks

To close the model, a productivity shock, an interest-rate shock and a money-growth shock, are all set to follow an $AR(1)$ process and are described below:

$$u_t^a = \rho_a u_{t-1}^a + \epsilon_t^a \tag{4.48}$$

$$u_t^r = \rho_r u_{t-1}^r + \epsilon_t^r \tag{4.49}$$

$$u_t^g = \rho_g u_{t-1}^g + \epsilon_t^g \tag{4.50}$$

where the autoregressive parameters $0 < \rho_j < 1$. ϵ_t^a, ϵ_t^r and ϵ_t^g are exogenous driving forces that are assumed to be identically independently distributed with zero means and specific standard deviations.

4.3.1.6 Log-linearised equations

With the goods market clearing condition $Y_t = C_t + I_t$, general equilibrium dynamics around the steady state levels can be derived from the equations above. Assuming inflation in the steady state equals the inflation target, $\Pi = \bar{\Pi}$, the steady states of the variables can be computed. For example, the steady state from equation (4.4) yields $R = \dfrac{\bar{\Pi}}{\beta}$. The model is then log-linearised around the steady state, as shown in the Appendix.

4.3.2 Calibration

The calibration process is same as before. All the parameters in previous neoclassical model will be used in this model, as outlined in Table 4.1. In addition, assuming retailers adjust prices once a year indicates that $\theta = 0.75$. τ is considered to be equal to θ, i.e. $\tau = 0.75$, as the Phillips curve in the long run is vertical in the presence of full employment. Also, the elasticity of substitution between differentiated goods, ϵ, is set to be 11, indicating a 10% net markup of final over intermediate goods. The investment to income share in steady state, $\dfrac{I}{Y}$, is calculated as $\dfrac{I}{Y} = \dfrac{\epsilon - 1}{\epsilon} \dfrac{\delta \alpha}{\frac{1}{\beta} - 1 + \delta}$.

The log-linearised equation of the interest rate rule, equation (4.67), are estimated by the Generalised Method of Moments (GMM) using quarterly data from 1996Q1 to 2015Q4. The result is shown as below, with standard errors in the parentheses[7].

$$
\begin{aligned}
r_t = \quad & 0.93 \quad r_{t-1} + \quad 0.18 \quad \pi_t + \quad 0.003 \quad y_t + \epsilon_t^r \\
& (0.02) \qquad\quad (0.03) \qquad\quad (0.01)
\end{aligned}
$$

where three variables, r_t, π_t and y_t are deviations from individual steady states. y_t is also defined as the output gap. The result shows that $\phi_r = 0.93$, $\phi_\pi =$

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[7] The instrument variables used in the GMM estimation are lagged variables of interest rate, inflation and output gap.
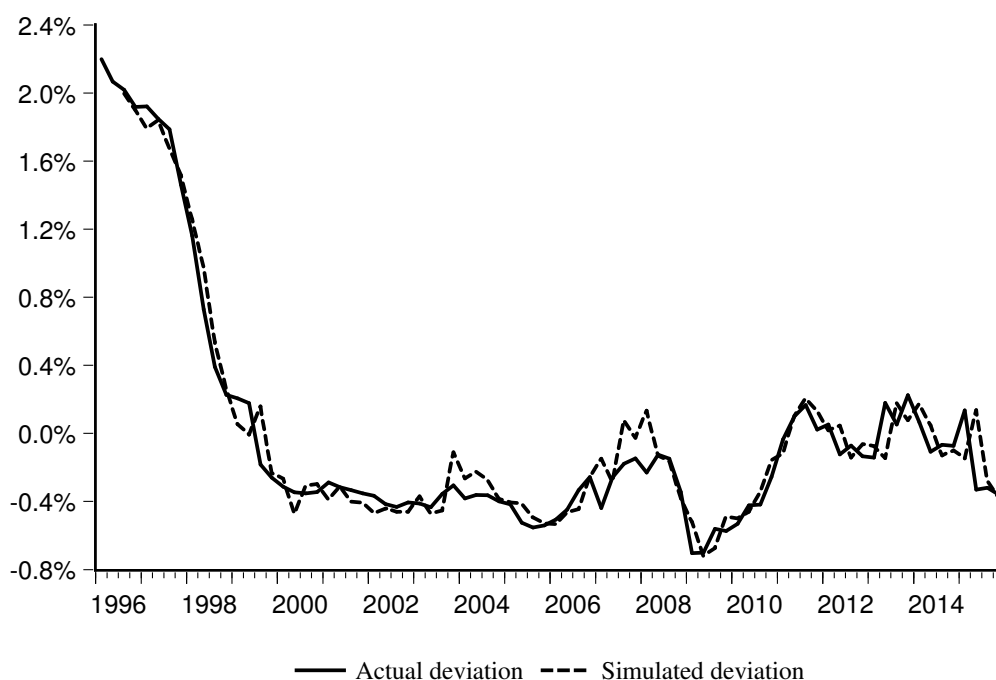
Figure 4.7: Actual and simulated interest rate deviations

$0.18/\left(1 - 0.93\right) = 2.57$, and $\phi_y = 0.05$, though ϕ_y is not significant in the model, meaning the PBoC does not care much about output gap when implementing the interest rate rule. Also, $\phi_\pi > 1$ means the interest rate responses more aggressively with respect to inflation, which is the case in China, as one of the objectives that the PBoC sets interest rates is to secure low inflation. The actual and simulated r_t is plotted in Figure 4.7. However, when measuring the error term in the above equation, the $AR\left(1\right)$ parameter in the interest rate rule, ρ_r, is insignificant, i.e. $\rho_r = 0$, thus resulting $u_t^r = \epsilon_t^r$, which is a white-noise error with a standard deviation $\sigma^r = 0.14\%$.

4.3.3 Impulse response analysis and simulations

The model is solved by the method of undetermined coefficients for the recursive equilibrium law of motion in general. The impulse responses to one standard deviation productivity shock and money-growth shock under the money growth

rule are outlined in Figure 4.8. The numbers on the horizontal axis represent quarters after each shock. The result from the new Keynesian model with the cash-in-advance constraint is similar to that in previous neoclassical model. To be specific, the impulse responses to a productivity shock, as in Figure 4.8a, remain the same as in Figure 4.4. Following this shock, output goes up by 1.6% and declines to the steady state in more than 10 years. Consumption increases by less than 0.5% during the first 2 years, and declines afterwards. Investment lifts more than 3% at the beginning, and is gradually reduced to its steady state. Inflation enters the period with 0.15% below the steady state level, and decreases to 0.55% within 2 years before returning to the steady state. The impulse responses to a money-growth shock in Figure 4.8b suggest a decline of 1.4% in output, but with a quick 1.2% point upturn in the next 2 or 3 quarters. A similar response is found in investment, with an initial 2.5% decrease, followed by a 0.4% increase within the first half year. Also, inflation is raised to 0.3% above the steady state due to a money-growth shock, and increases by 2% before declining in about one year. Consumption declines at first, and grows rapidly over the next 5 years.

To compare the effects of the two monetary policy instruments, Figure 4.9 plots the impulse responses to productivity shocks and interest-rate shocks when the interest rate rule takes effect in the model. It shows that when facing identical productivity shocks, the economy experiences smaller fluctuations when using the interest rate rule. For example, inflation in Figure 4.9a faces smaller fluctuations, and converges to its steady state more quickly than that in Figure 4.8a. Consumption also experiences 0.5% smaller fluctuations, whilst the responses of output and investment tend to be weaker as well in terms of the interest rate rule, and converges to the steady states as quickly as in the money growth rule. Thus, the interest rate rule is more favourable when considering the desire to restrict inflation and stabilise economy along with the development of productivity. Moreover, comparing Figure 4.8b and 4.9b suggests that the interest rate rule is more powerful and effective. For example, an interest-rate shock reduces output by nearly

8%, whilst a money-growth shock leads to a decline of output of only 1.4%. Also, inflation declines by 5% in response of an interest-rate shock, but with an initial increase of 0.3% in terms of a money-growth shock. Similar results can be found in the paths of consumption and investment as well. The economy tends to converge to steady state more quickly when implementing the interest rate rule.

To further evaluate the interest rate and the money growth rules, the model is simulated corresponding to a random draw of shocks. In this case, the model is simulated for 1200 periods and the simulation paths of output and inflation for 1000 quarters after dropping the first 200 periods is plotted in Figure 4.10. The left figure indicates the similar dynamics of output under two rules, and the interest rate rule is more powerful with slightly higher volatility of output. The dynamics of inflation on the right differ substantially, with smaller fluctuations in presence of the interest rate rule. These findings are consistent with the impulse responses analysis above.

The results above are in favour of Zhang (2009), where two monetary policy rules are compared in a new Keynesian framework with money-in-utility model. Following the method of Jin et $al.$ (2013) using a neoclassical model and assuming that the interest rate rule is adopted by the PBoC, the process of interest rate liberalisation is measured by raising the steady state levels of annualised nominal interest rates, R. The discount factor, β, is obtained by annualised inflation and interest rate. Figure 4.11 and 4.12 plot the impulse responses to productivity shocks and interest-rate shocks when the steady state level of interest rate, R, is selected to be 1%, 3.28%, 6% or 9%. In terms of a productivity shock, as in Figure 4.11, output initially increases less when facing higher R, whilst consumption responses with no difference at the beginning, but peaks at 0.58% when $R = 9\%$, compared to 0.5% or so when $R = 3.28\%$. Investment increases by more in response to the interest rate liberalisation, whilst inflation responses more strongly negative at first, and increases more afterwards, and converges to steady state more quickly in presence of higher R. Thus, increasing R boosts consumption and investment in the short
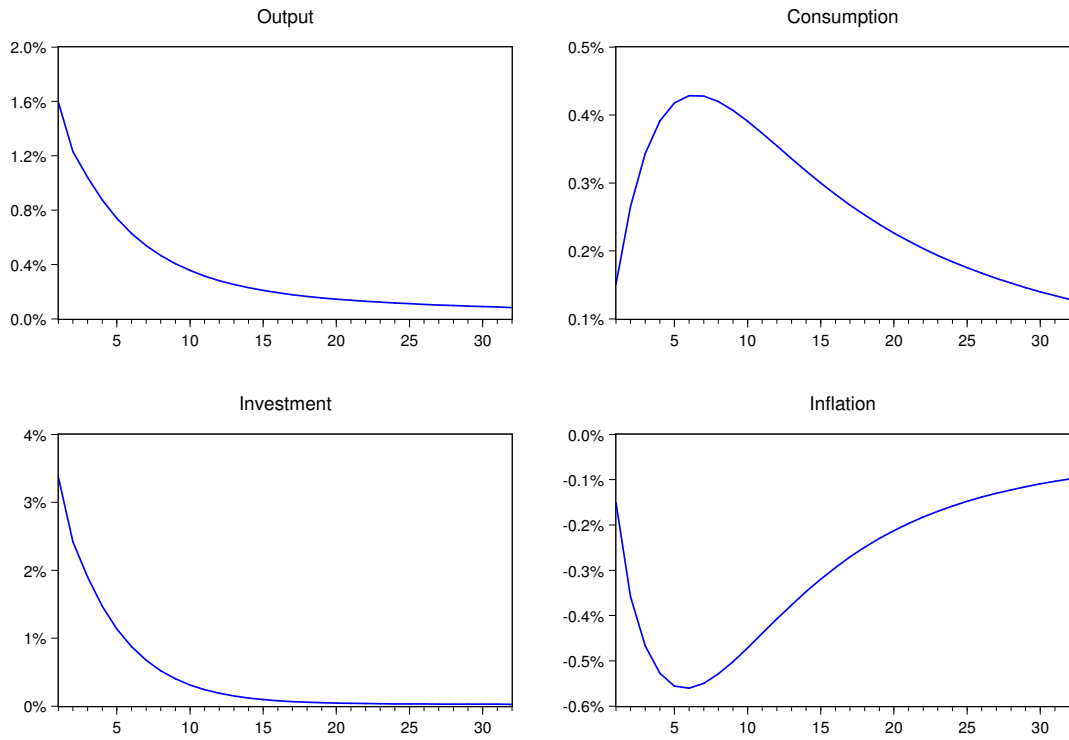
(a) Impulse responses to a productivity shock
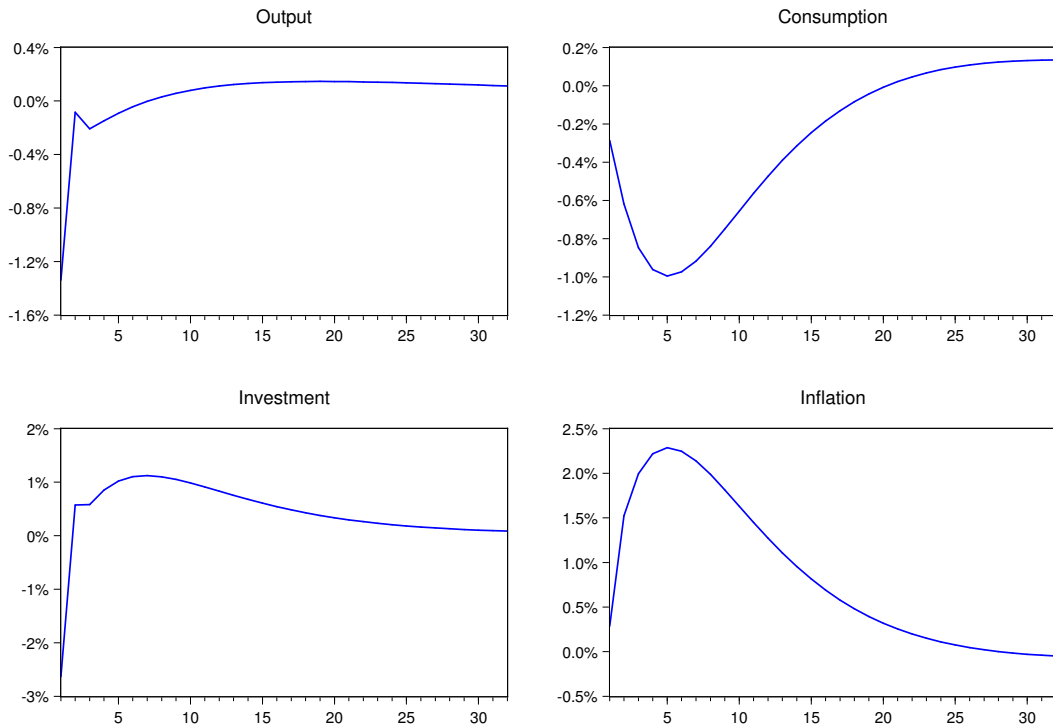
(b) Impulse responses to a money-growth shock

Figure 4.8: Impulse responses to shocks under money growth rule
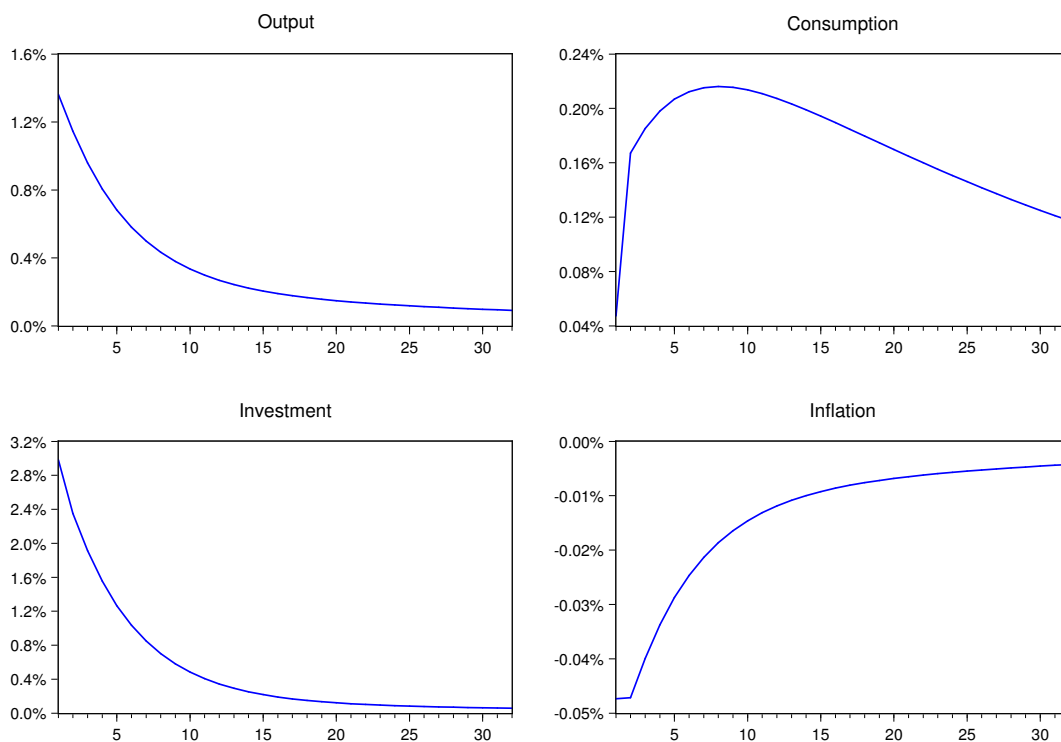
(a) Impulse responses to a productivity shock
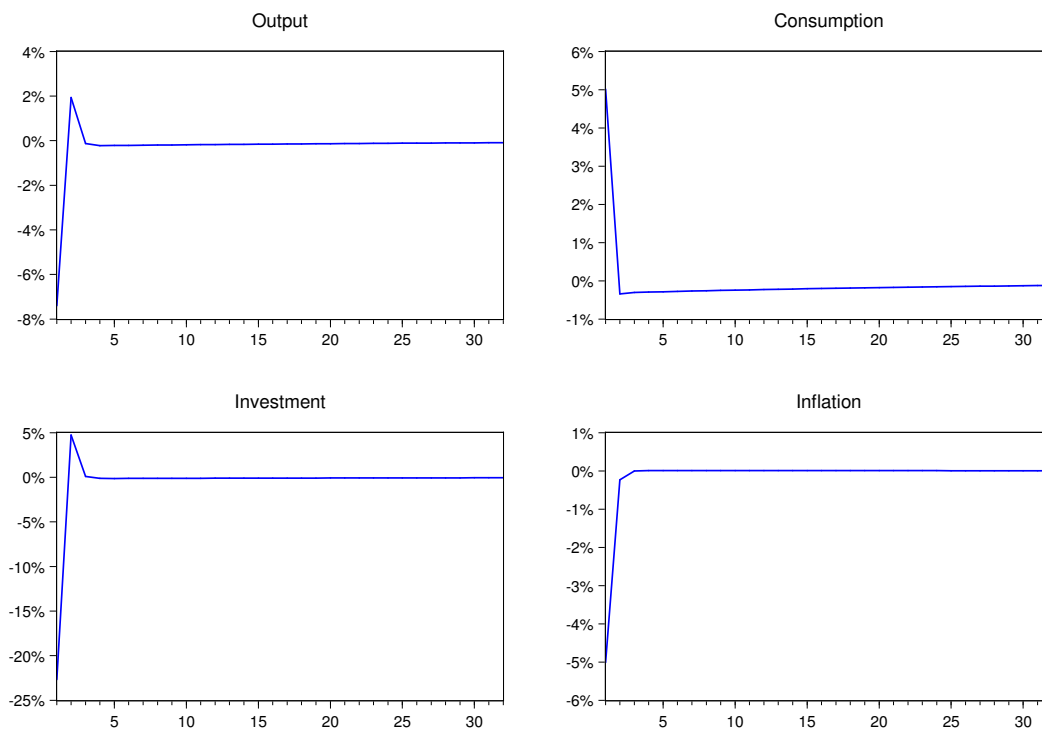
(b) Impulse responses to an interest-rate shock

Figure 4.9: Impulse responses to shocks under interest rate rule
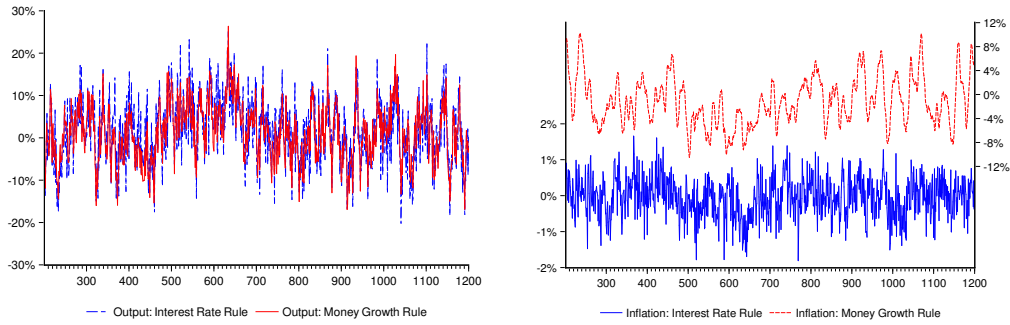
Figure 4.10: Model simulations of output and inflation

run when there is a productivity shock and the economy experiences more volatility. However, increasing R seems indifferent when experiencing an interest-rate shock, as plotted in Figure 4.12, the response of output is less stronger at first, and converges to the steady state a bit more quickly. Investment shows very little difference with different R. Inflation drops less when R is higher, but remains identical afterwards when converging to the steady state. Thus, increasing the steady state levels of R will not alter the effects to the economy from an interest-rate shock, which is different from the result when the money growth rule is in use. It indicates that the transmission mechanism through interest rate is not changed by increasing nominal interest rate in the long run, and the economy remains stable when experiencing an interest-rate shock during financial liberalisation.

4.4 Robustness check

To check the robustness and compare the result with the new Keynesian DSGE model with cash-in-advance in the last section, this section uses a money-in-utility model where the variable referring to real money balances enters the utility function of households. As before, households choose to deposit at financial intermediates and hold money balances to consume and invest during her unlimited lifetime. Firms employ labour and utilise capital to produce intermediate goods whilst retailers buy intermediate goods from firms in a competitive market, and

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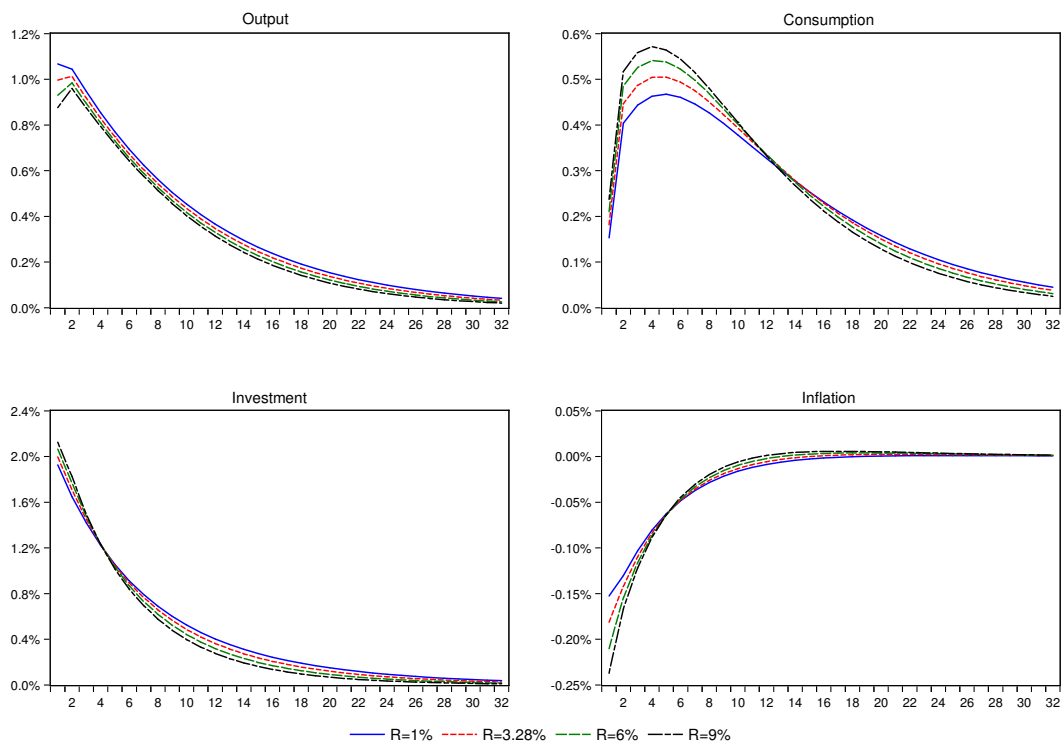
Figure 4.11: Impulse responses to a productivity shock with different R under interest rate rule
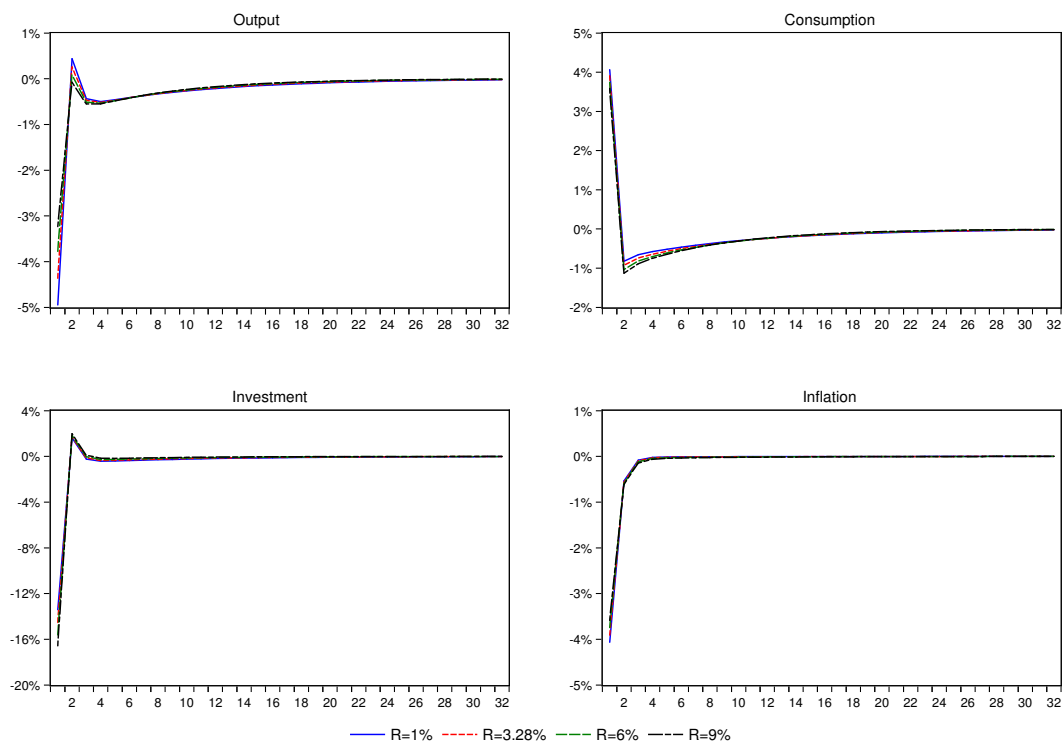
Figure 4.12: Impulse responses to an interest-rate shock with different R under interest rate rule

differentiate them at no costs. Retailers then sell them in a monopolistic competitive market and therefore have some monopoly power and set prices in a Calvo-type manner. The model structure follows Zhang (2009) without taking wage rigidity into consideration. In addition, this section employs Bayesian estimation methods to estimate the parameters of the central bank's monetary policy. Following that, the money growth rule and the interest rate rule are compared.

4.4.1 Model structure

The representative household maximises her lifetime utility which depends on real consumption, C_t, labour supply, N_t, and real money balances, M_t:

$$\max \mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left(\frac{1}{1-\sigma} C_t^{1-\sigma} - \psi^N \frac{1}{1+\phi} N_t^{1+\phi} + \frac{1}{1-\gamma} M_t^{1-\gamma} \right) \right\}$$

subject to

$$C_t + D_t + M_t + I_t = \frac{R_{t-1} D_{t-1}}{\Pi_t} + W_t N_t + \tilde{r}_t^K K_{t-1} + \frac{M_{t-1}}{\Pi_t} + F_t^R$$

where $I_t = K_t - (1-\delta) K_{t-1}$. γ is the inverse of elasticity of real money holdings. All the variables and parameters above remain as same as in the previous section.

Solving the problem above yields the FOCs with respect to consumption and deposits:

$$\frac{1}{R_t} = \beta \mathbb{E}_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{1}{\Pi_{t+1}} \right]$$

The FOC with respect to N_t reads the optimal choice of labour supply:

$$W_t = (C_t)^{\sigma} \psi^N N_t^{\phi}$$

Also, the FOC with respect to capital, K_t, gives:

$$1 = \beta \mathbb{E}_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \left(\tilde{r}_{t+1}^K + 1 - \delta \right) \right]$$

Lastly, the FOC with respect to real money balances, M_t, reads:

$$M_t^{-\gamma} C_t^{\sigma} = \frac{R_t - 1}{R_t}$$

The log-linearised equations of above FOCs are outlined as below, with lowercase letters referring to the percentage deviations from the steady state, and absolute deviations for inflation, interest rate and money growth rate.

$$c_t = \mathbb{E}_t c_{t+1} - \sigma^{-1} \left(r_t - \mathbb{E}_t \pi_{t+1} \right) \tag{4.51}$$

$$w_t = \sigma c_t + \phi n_t \tag{4.52}$$

$$r_{t+1}^K = \frac{\sigma}{1 - \beta (1 - \delta)} \left(c_{t+1} - c_t \right) \tag{4.53}$$

$$m_t = \frac{\sigma}{\gamma} c_t + \frac{\beta}{\gamma (\beta - \Pi)} r_t \tag{4.54}$$

The behaviour of firms is as same as in the last section, which produces intermediate goods following the Cobb-Douglas function in equation (4.37). The real marginal cost and wage level are provided in equations (4.38) and (4.39), respectively. Retailers purchase intermediate goods from firms and differentiate them at no cost. Retailers, as before, set prices in a Calvo-type fashion. The FOC is given in equation (4.44). Real marginal cost in steady state equals to the markup, $\frac{\epsilon}{\epsilon - 1}$. The log-linearised equation yields the Phillips curve. In addition, a cost-push shock, u_t^c, is augmented in the curve.

$$\pi_t = \tau \pi_{t-1} + \beta \left(\mathbb{E}_t \pi_{t+1} - \tau \pi_t \right) + \frac{(1 - \theta)(1 - \theta \beta)}{\theta} mc_t + u_t^c \tag{4.55}$$

This section compares the two monetary policy rules, i.e. the money growth rule

and the interest rate rule, and the monetary policy equations of the central bank are as same as in the last section. Following the GMM estimation results in the last section, the money-growth shock is assumed to follow the $AR(1)$ process whilst the interest-rate shock is a white-noise error.

4.4.2 Model estimation

According to DeJong *et al.* (2000), model structure, model parameterisation and the data together constitute the main potential sources of unknown in the empirical work. Given the model structure, the parameters in conventional approach of estimation are regarded as fixed ones. However, in Bayesian estimation, parameters are treated as random variables so that prior distributions are introduced when estimating the posterior distribution based on the data. To begin with, consider a model with parameter matrix ϑ to be estimated using the sample data $\mathcal{Y}$, then a joint distribution $p(\mathcal{Y}, \vartheta)$ can be factored into a prior distribution of parameter, $p(\vartheta)$, and a distribution of the data given ϑ, i.e. $p(\mathcal{Y} \mid \vartheta)$. The latter, when interpreted as a function of ϑ, is the likelihood function, $L(\vartheta \mid \mathcal{Y})$. According to Bayesian theorem,

$$p(\vartheta \mid \mathcal{Y}) = \frac{L(\vartheta \mid \mathcal{Y}) \, p(\vartheta)}{p(\mathcal{Y})}$$

where $p(\vartheta \mid \mathcal{Y})$ is the posterior distribution of parameters, and $p(\mathcal{Y}) = \int p(\mathcal{Y} \mid \vartheta) \, p(\vartheta) \, d\vartheta$ is the marginal density that is independent of ϑ.

Therefore, the posterior probability is proportional to the product of the likelihood and the prior probability, i.e. $p(\vartheta \mid \mathcal{Y}) \propto L(\vartheta \mid \mathcal{Y}) \, p(\vartheta)$. Following that, the Markov Chain Monte Carlo (MCMC) method can be employed to optimise the posterior with respect to the parameters.

4.4.2.1   Data

To estimate the model, four macroeconomic variables are selected as observables for the period of 1996Q1 to 2015Q4. Table 4.3 describes the construction and source of the data. Data are seasonally adjusted. In addition, as log-linearised model is used in this chapter, all the variables thus represent the percentage deviations (or absolute deviations) from the steady state. Consequently, the original non-stationary output data are detrended using the one-sided Hodrick–Prescott filter ($\lambda = 1600$)[8], whist stationary data are subtracted by their mean, such as inflation, money growth rate and interest rates.

4.4.2.2   Calibrated parameters and priors

Table 4.4 reports the values of calibrated parameters set in this model. All the values were set in the last section. For example, the discount factor $\beta = 0.997$ is set according to the average annual inflation rate and deposit rate, whilst the depreciation ratio of capital is calibrated to be 4%, which is consistent from the annual data. The aggregated provincial-level data in China suggest that the labour income accounts for 47% of total income, meaning $\alpha = 1 - 0.47 = 0.53$. Also, the inverse of Frisch elasticity is set to be 1/3 according to Chen *et al.* (2012).

Other parameters are estimated using the Bayesian estimation technique. The choice of prior distributions in this model follows current literature or is relatively uninformative. For example, Smets & Wouters (2003) and Gerali *et al.* (2010) suggest a Beta distribution for smoothing parameters such as ϕ_r and ϕ_g^g, where the domain is $[0, 1)$. The parameters measuring the responses of policy rate deviations to inflation and output, ϕ_π and ϕ_y, are assumed to have priors of gamma or normal distribution, so are those in the money growth rule. The coefficient of relative risk

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[8]Pfeifer (2014) discussed the advantage of the backward-looking one-sided HP filter against the two-sided one for DSGE estimation. This one-sided HP filter method is proposed and used by Stock & Watson (1999).

Table 4.3: Description of data

Name	Description
Policy interest rate, R_t	7-day Shibor from 2007 to 2015, while Chibor was used between 1996 and 2006. Daily gross rates are taken arithmetic average to construct quarterly data.
	Source: the PBoC website and shibor.org.
Inflation, Π_t	Consumer Price Index (CPI) is used to represent the price level. Inflation is defined as the quarterly difference at the annual rate.
	Source: OECD Main Economic Indicators via Datastream
Output, Y_t	Real quarterly GDP is obtained by deflating nominal GDP by the CPI.
	Source: Oxford economics via Datastream and National Bureau of Statistics of China website.
Money growth, $\tilde{g}_t$	Growth rate of nominal broad money M_2, which is calculated as quarterly difference of M_2 at the annual rate.
	Source: the PBoC website and Oxford economics via Datastream.

Note: Data of inflation, output and money growth are seasonally adjusted. All the interest rates and inflation data are transformed into the quarterly gross rates before entering the model.

Table 4.4: Model calibration

Description	Calibrated value
Annual inflation rate	2.07%
Annual deposit rate	3.28%
Intertemporal discount factor	$\beta = \dfrac{\Pi}{R} = 0.997$
Capital depreciation rate	$\delta = 4\%$
Output elasticity of capital	$\alpha = 0.53$
Inverse of Frisch elasticity	$\phi = 1/3$

aversion of households, σ, is assumed to adhere to a gamma distribution with the mean of 2 and the standard deviation of 0.5. Smets & Wouters (2003) suggest θ and τ to be Beta distributed, therefore this section sets both to have a mean of 0.5 and a standard deviation of 0.1. Autoregressive parameters of exogenous shocks of productivity ratio are assumed to have a strict prior beta distribution with a mean of 0.8 and a standard deviation of 0.1, respectively. The standard deviation of each driving force is equipped with the inverse Gamma distribution with the mean of 0.01 and the standard deviation of 0.05. Table 4.5 summaries the prior distributions with means and standard deviations for all the parameters and the standard deviations of exogenous driving forces.

4.4.2.3 Posterior estimates

The Bayesian rule gives $p\left(\vartheta \mid \mathcal{Y}\right) \propto L\left(\vartheta \mid \mathcal{Y}\right) p\left(\vartheta\right)$ and hence the likelihood calculated using the Kalman filter and the prior density of parameters are together used to obtain the posterior distribution of the estimated parameters. An essential requirement for the estimation is that the number of observed variables must be smaller or equal to that of shocks and measurement errors, otherwise the stochastic singularity arises in the model[9]. In this simple DSGE model, the number of observables is equal to the number of exogenous shocks.

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[9]Smets & Wouters (2007) use as many exogenous shocks as observables, whilst Schmitt-Grohe & Uribe (2012) add measurement errors of observables into estimation, and proposed that this method is a way to avoid stochastic singularity of the model.

Table 4.5: Prior and posterior distribution of parameters and shocks

Parameter	Prior distribution			Posterior distribution		
	Distribution	Mean	Standard deviation	Mean	90% HPD interval	Median
Money growth rule						
σ	Gamma	2.00	0.5	2.385	[1.499,3.264]	2.345
τ	Beta	0.50	0.1	0.351	[0.190,0.511]	0.345
θ	Beta	0.50	0.1	0.406	[0.319,0.494]	0.407
ϕ_g^g	Beta	0.75	0.1	0.198	[0.126,0.267]	0.195
ϕ_g^π	Normal	0.50	0.5	1.004	[0.800,1.207]	1.003
ϕ_g^y	Gamma	1.50	0.5	0.420	[0.284,0.552]	0.410
ρ_a	Beta	0.80	0.1	0.986	[0.976,0.998]	0.988
ρ_c	Beta	0.80	0.1	0.675	[0.591,0.758]	0.678
ρ_g	Beta	0.80	0.1	0.184	[0.113,0.248]	0.180
σ^g	Inv.Gamma	0.01	0.05	0.015	[0.013,0.017]	0.015
σ^a	Inv.Gamma	0.01	0.05	0.004	[0.003,0.005]	0.004
σ^c	Inv.Gamma	0.01	0.05	0.020	[0.011,0.029]	0.019
Interest rate rule						
σ	Gamma	2.00	0.5	2.540	[1.682,3.380]	2.500
τ	Beta	0.50	0.1	0.445	[0.278,0.606]	0.443
θ	Beta	0.50	0.1	0.286	[0.215,0.357]	0.286
ϕ_r	Beta	0.75	0.10	0.617	[0.520,0.717]	0.624
ϕ_π	Gamma	2.00	0.5	1.104	[1.013,1.185]	1.100
ϕ_y	Normal	0.20	0.15	0.024	[-0.004,0.051]	0.024
ρ_a	Beta	0.8	0.1	0.948	[0.905,0.990]	0.955
ρ_c	Beta	0.8	0.1	0.969	[0.944,0.994]	0.972
σ^r	Inv.Gamma	0.01	0.05	0.004	[0.003,0.005]	0.004
σ^a	Inv.Gamma	0.01	0.05	0.007	[0.006,0.009]	0.007
σ^c	Inv.Gamma	0.01	0.05	0.016	[0.006,0.025]	0.015

Note: 1. Results of posterior means are obtained by running 10 chains of Metropolis-Hastings algorithm, each with 100,000 draws, of which the first 20% are dropped; 2. The average acceptance rates for 10 chains are 0.244 and 0.235 for the money growth rule and the interest rate rule, respectively; 3. HPD interval refers to the highest posterior density credible interval, which is the shortest interval among all intervals that are 90% credible.

Table 4.5 reports the results of posterior estimates. The statistics of posterior probability of parameters reported in the table are obtained using the Metropolis-Hastings algorithm to generate 10 chains, each of which contains 100,000 draws. The average acceptance rates for 10 chains are 24.4% for the model with the money growth rule, and 23.5% for that with the interest rate rule, both of which are close to the suggested rate of 23.4% (Roberts *et al.*, 1997). The first 20% of draws were dropped when computing the statistics. Figure 4.13a and 4.13b plot the kernel estimates of prior and posterior marginal densities for parameters and standard deviations of shocks under two different monetary policy rules.

According to Gerali *et al.* (2010), deviations of the mean of posteriors from that of priors indicate that a parameter is identified. The estimation results of the model with the money growth rule indicate that all the parameters are well identified except for σ, according to Figure 4.13a. Productivity and cost-push shocks are persistent whilst the $AR(1)$ parameter of money-growth shock, u_t^g is 0.184 only. The posterior mean of θ, which refers to the probability that firms do not adjust prices, is 0.406 and is lower than the calibrated result in the last section. It suggests that firms adjust prices frequently within a quarter of period. The degree of indexation to previous inflation, τ, is estimated to be 0.351 according to the posterior mean, which is significantly different from 0.5, or 0.75 used in the last section. The indexation with a relatively lower value is consistent with Smets & Wouters (2007) and Gerali *et al.* (2010) for the estimation of the U.S. and the Euro area. The monetary policy functions based on the money growth rule yield very different result from Liu & Zhang (2010), which was used in previous sections. The smoothing parameter of money growth, ϕ_g^g, is 0.198 only, whilst parameters measuring the responses of money growth deviations to inflation and output, ϕ_g^π and ϕ_g^y, are 1.004 and 0.420, respectively. The results suggest that money growth responds more aggressively to inflation, as ϕ_g^π is slightly above 1, and less aggressively to output, confirming that one of the central bank's main objectives is to curb inflation in China.
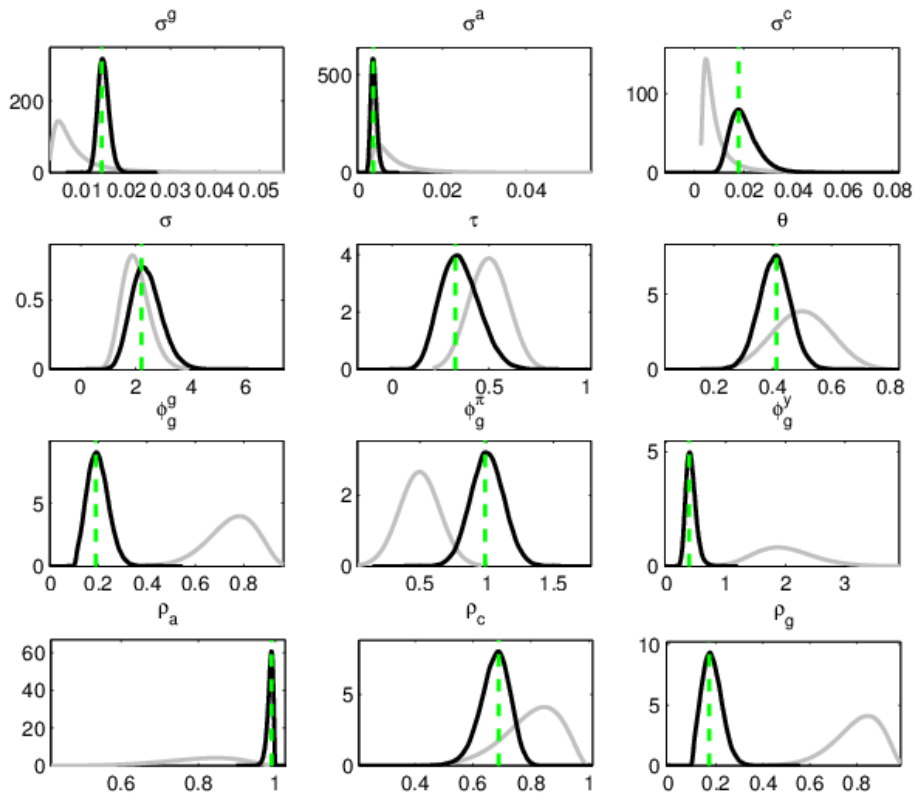
(a) Prior and Posterior marginal distributions: Money growth rule
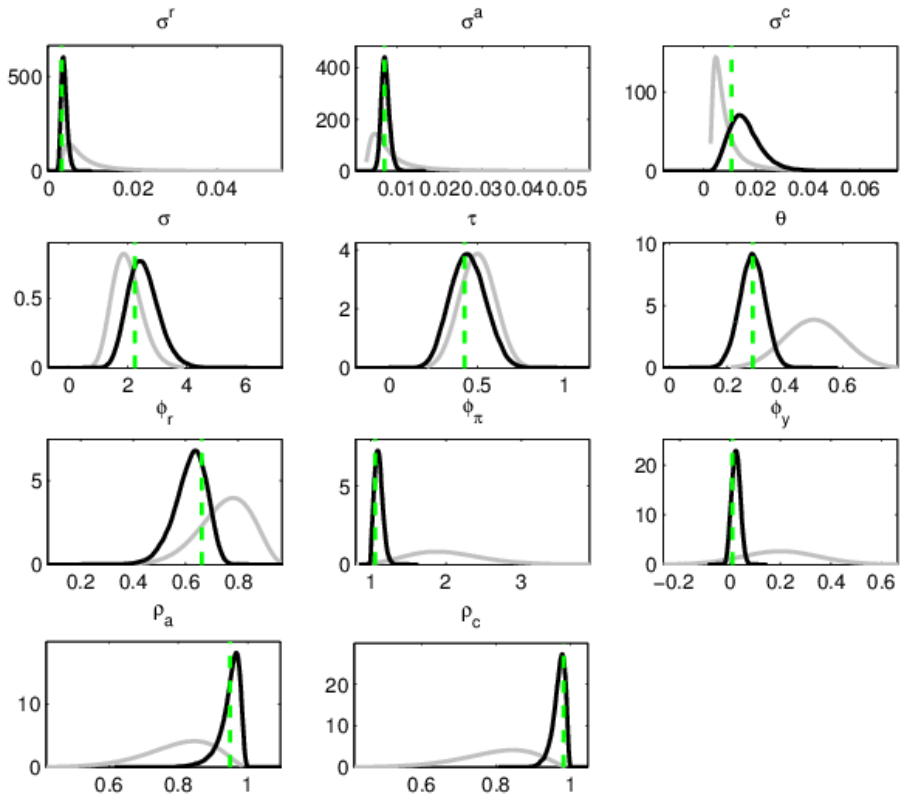
(b) Prior and Posterior marginal distributions: Interest rate rule

Figure 4.13: Prior and Posterior marginal distributions

The results from the model with the interest rate rule, however, show weak iden-tification of τ and σ, and the degree of price stickiness, θ, which is around 0.3 only according to Figure 4.13b. Similarly, productivity and cost-push shocks are both very persistent with the $AR(1)$ parameters greater than 0.9. The interest rate Taylor rule is consistent with previous analysis, with $\phi_\pi > 1$ confirming the aggressive approach to inflation, and a small $\phi_y = 0.024$ indicating the little at-tention to output when the PBoC adjusts policy interest rate. The parameter of last-period interest rate, $\phi_r = 0.617$, showing smaller degree of interest rate smoothing. Comparing the results from the two models indicates that most para-meters are robust, and the results of sensitivity analysis using the built-in global sensitivity analysis toolbox in Dynare based on 20,000 Monte-Carlo samples con-firm that nearly all the parameters give unique saddle-path solution. Besides, the results are examined by means of convergence statistics proposed by Brooks & Gelman (1998), as reported in the appendix. The results confirm convergence and relative stability of the parameter moments.

4.4.3   Impulse response analysis

Given the mean of posteriors as well as values of calibrated parameters above, this model is solved using the methods of undetermined coefficients proposed by Uhlig (1999). Details of this method were discussed in Section 2. Similar to Section 3, a productivity shock and a monetary-policy shock are selected to study the impulse responses of output and inflation to exogenous shocks. The impulse responses to a productivity shock under the money growth rule and the interest rate rule are plotted in Figure 4.14. The left panel reflects the impulse responses under the money growth rule. Output enters the period with a negative value due to high persistence of the productivity shock, and leaps to the peak of 1.5% above the steady state in the following period. Also, this effect lasts longer than 10 years. Inflation, however, initially drops 3% below the steady state level, and recovers
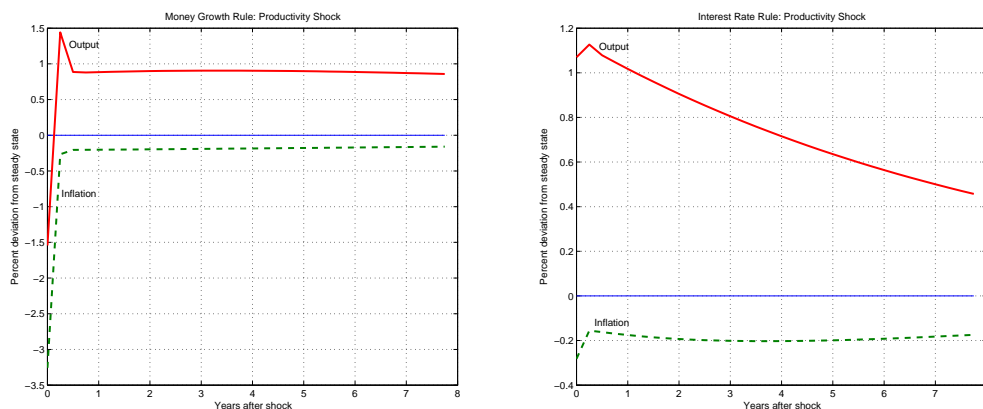
Figure 4.14: Impulse responses to a productivity shock under two rules

soon. To compare with the responses under the interest rate rule in the right panel, far smaller variations of the economy can be observed. Output initially grows to around 1.1% above the steady state, and recovers gradually, faster than that under the money growth rule. Inflation decreases at 0.3% only, and grows to the steady state as quickly as that in the money growth rule. According to Zhang (2009), fluctuations to a productivity shock can be regarded as the loss of the central bank. Therefore, the interest rate rule is more favourable when the central bank aims to reduce the magnitude of volatility of the economy.

Figure 4.15 plots the impulse responses to monetary-policy shocks under two different rules. Both cases see a quick recovery, but the interest-rate shock is more powerful compared to the money-growth shock. As shown in the right panel, a positive shock in interest rate reduces output at 1% at the beginning, and output jumps to 0.2% above the steady state before a decline. However, output in the left panel, when money-growth shock enters, increases to 0.5% only at first, and shrinks to -0.1% before recovering. Similarly, inflation plunges 2.2% in response to an interest-rate shock, whilst it increases by 0.6% only when facing a money-growth shock. Therefore, the results from Bayesian estimation are in favour of Zhang (2009), which suggests that the interest rate rule is more powerful monetary policy response, and helps to stabilise the economy when a productivity shock hits the model.
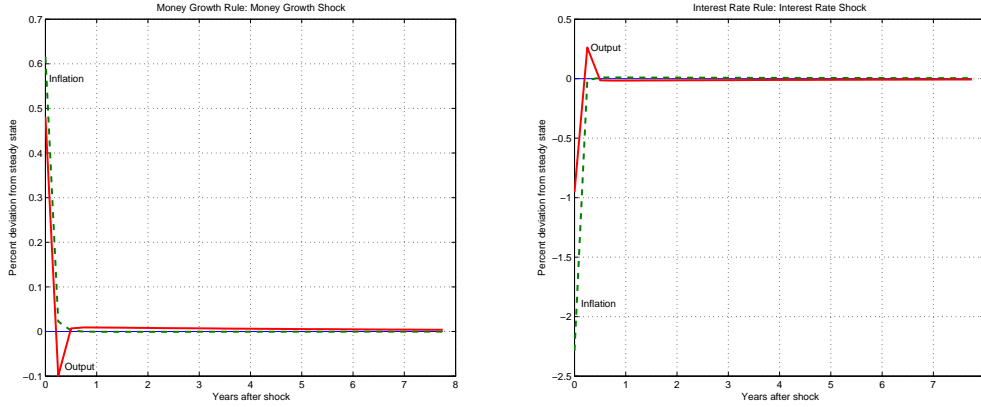
Figure 4.15: Impulse responses to a monetary-policy shock under two rules

4.5 Conclusion

The central bank of China has been using nominal money growth as an important monetary policy tool for decades. The central government and the PBoC set a M2 growth target every year to stabilise the price level and promote the growth of economy. A simple neoclassical RBC model is used in this chapter to capture China's money growth rule. In addition, a cash-in-advance constraint is included so that money is non-neutral in this model. Interest rate liberalisation in this case is known as raising the steady state levels of the nominal deposit rate, as it has long been argued to be artificially low. The main conclusion from this model is that raising deposit rate helps reorganise the economic structure between consumption and investment in China, and improves the efficiency of transmission channel of monetary policy.

In the latest 13th national five-year plan, China will reduce the use of quantity based monetary policy tools like money growth, as it has become more difficult to measure. Instead, price-based policy tools such as the interest rate policy will be used more frequently. Therefore, it is vital to compare both of the monetary policy tools. The results from a new Keynesian DSGE model with a cash-in-advance constraint show that the interest rate rule is more efficient than the money growth rule. To be more specific, inflation lasts shorter period when facing a

productivity shock in terms of the interest rate rule, meaning smaller fluctuations in the economy. Also, the money growth rule is less powerful than the interest rate rule in response of a monetary policy shock. Lastly, a new Keynesian DSGE model with money-in-utility is introduced as well, together with two different monetary policies, so as to check the robustness of the results in the cash-in-advance model. This model follows Zhang (2009) except for describing the retailer's behaviours, and uses a Bayesian estimation approach rather than calibration to estimate some key parameters in the model. The results are in favour of Zhang (2009) and the cash-in-advance model, suggesting the interest rate rule is more powerful and effective, and it is preferable when considering stabilising the economy.

In fact, the method used by Jin *et al.* (2013) to reflect the interest rate liberalisation process is limited to the rough illustration of the economy when experiencing interest rate liberalisation and it is difficult to suggest a proper nominal interest rate. Nevertheless, the result indicates that, given a productivity shock, consumption and investment yield a stronger response when the steady state level of annual interest rate is raised. Besides, as the nominal money growth rule is less efficient and it becomes more difficult to control money supply due to the variability of velocity, the PBoC has actively used required reserve ratio to adjust money supply. The next chapter looks at market-based and nonmarket-based monetary policy tools used simultaneously by the PBoC, together with a more accurate measure of interest rate liberalisation.

4.6 Appendix

4.6.1 Model log-linearisation: cash-in-advance model

In the following log-linearised equations, the lower-case variables except interest rate, inflation and money growth rate, hereafter denote the percentage derivations from the steady states. For interest rate, inflation and money growth, the lower-case letters represent absolute derivations. Assuming the upper-case variables without a time subscript t refer to the levels of steady states, one could log-linearise the model around the steady states.

Firstly, the capital formation of households is log-linearised:

$$k_t = (1 - \delta) k_{t-1} + \delta i_t \tag{4.56}$$

An approximation of the binding cash-in-advance constraint yields:

$$m_{t-1} - \pi_t = c_t \tag{4.57}$$

Then, the FOCs of households are log-linearised as follows:

$$- \sigma c_t = \frac{\beta}{\Pi} \lambda_t + \left(1 - \frac{\beta}{\Pi} \right) \mu_t \tag{4.58}$$

$$\lambda_t = \mathbb{E}_t \lambda_{t+1} - \mathbb{E}_t \pi_{t+1} + r_t \tag{4.59}$$

$$\lambda_t + w_t = \phi n_t \tag{4.60}$$

$$\lambda_t + \sigma \mathbb{E}_t c_{t+1} + \mathbb{E}_t \pi_{t+1} = 0 \tag{4.61}$$

$$\lambda_t = \mathbb{E}_t \lambda_{t+1} + [1 - \beta (1 - \delta)] r_{t+1}^K \tag{4.62}$$

Production function of firms is log-linearised as:

$$y_t = u_t^a + \alpha k_{t-1} + (1 - \alpha) n_t \tag{4.63}$$

Similarly, the FOCs of a representative cost-minimising firm yield the relationship between real cost of labour and capital, as well as the marginal cost:

$$w_t = k_{t-1} - n_t + r_t^K \tag{4.64}$$

$$mc_t = \alpha r_t^K + (1 - \alpha) w_t - u_t^a \tag{4.65}$$

Solving the FOC of retailers yields the Phillips curve

$$\pi_t = \tau \pi_{t-1} + \beta \left(\mathbb{E}_t \pi_{t+1} - \tau \pi_t \right) + \frac{(1 - \theta)(1 - \theta\beta)}{\theta} mc_t \tag{4.66}$$

Next, in terms of the interest rate rule, the log-linearised equation of (4.45) reads:

$$r_t = \phi_r r_{t-1} + (1 - \phi_r)(\phi_\pi \pi_t + \phi_y y_t) + u_t^r \tag{4.67}$$

Alternatively, the log-linearised equations are outlined when the central bank adopts the money growth rule:

$$m_t = m_{t-1} - \pi_t + \frac{g_t}{\Pi} \tag{4.68}$$

$$g_t = \phi_g^g g_{t-1} - \left(1 - \phi_g^g\right)\left(\phi_g^\pi \pi_t + \phi_g^y y_t\right) + u_t^g \tag{4.69}$$

Lastly, the log-linearised market clearing condition is:

$$y_t = \frac{C}{Y} c_t + \frac{I}{Y} i_t \tag{4.70}$$

In addition, the productivity shock, the interest-rate shock and the money-growth shock mentioned above are outlined again as follows:

$$u_t^a = \rho_a u_{t-1}^a + \epsilon_t^a \tag{4.71}$$

$$u_t^r = \rho_r u_{t-1}^r + \epsilon_t^r \tag{4.72}$$

$$u_t^g = \rho_g u_{t-1}^g + \epsilon_t^g \qquad (4.73)$$

When the interest rate rule takes effect, Equations (4.56) to (4.66), together with (4.67), (4.70), (4.71) and (4.72) constitute a system of linear rational expectations differences equations containing 15 endogenous variables, plus 2 exogenous driving forces. Similarly, when using the money growth rule, the system contains 16 endogenous variables and 2 exogenous driving forces, as summarised in equations (4.56) to (4.66), as well as (4.68), (4.69), (4.70), (4.71) and (4.73).

4.6.2   Monte Carlo Markov Chains multivariate diagnostics

The Monte Carlo Markov Chains (MCMC) multivariate diagnostics are plotted in Figure 4.16, generated by Dynare. The red lines represent the specific measures of the parameter vectors within the chains, whilst the blue lines plot the measures between chains. Three measures are used in Dynare, and the first block "interval" in both figures are constructed from an 80% confidence interval of the mean of parameter. "m2" and "m3" in the second and last blocks refer to measures based on variance and third moments. The results reflect an aggregate measure based on the eigenvalues of the variance-covariance matrix of each parameter, and the horizontal axis indicates the number of Metropolis-Hastings iterations. The blue line should be closed to the red line, whilst the red line should be relatively constant, which is the case here, as the red and blue lines are relatively stable after the first 20,000 iterations.
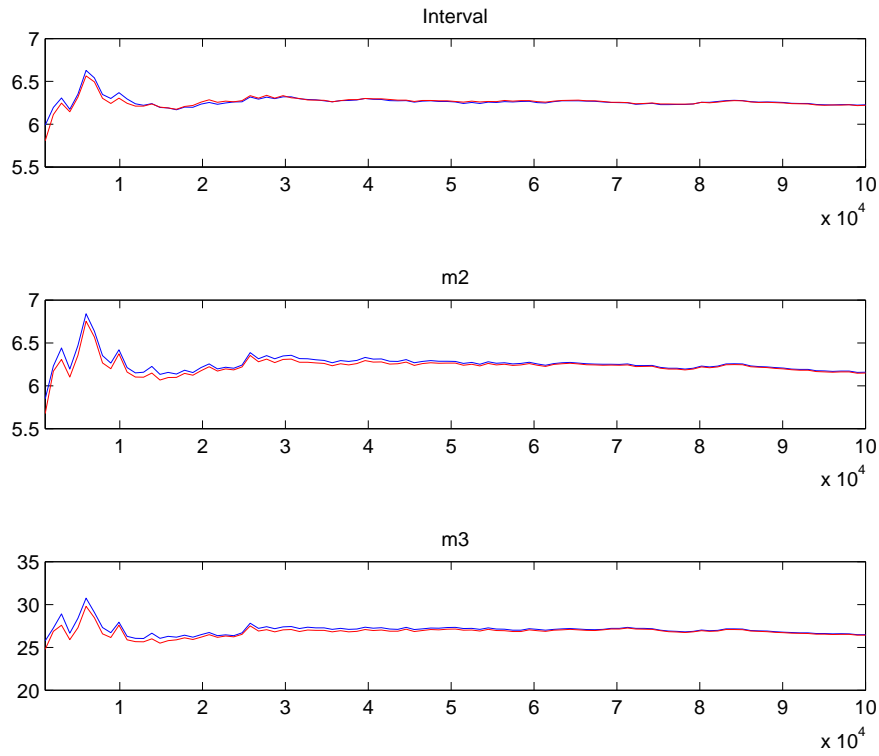
(a) MCMC multivariate convergence diagnostics: Money growth rule
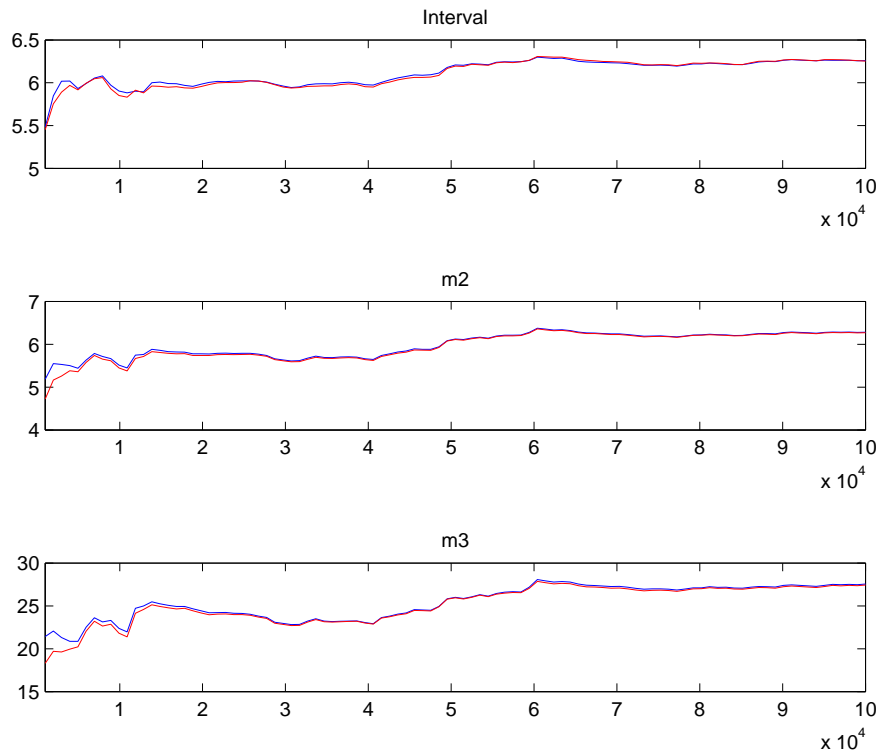
(b) MCMC multivariate convergence diagnostics: Interest rate rule

Figure 4.16: MCMC multivariate convergence diagnostics

Chapter 5

Financial repression in China's monetary policy

5.1 Introduction

Unlike the central banks in developed economies that control benchmark interest rates alone, the PBoC sets both benchmark loan rates and deposit rates. In addition to the interest rate adjustments, the PBoC sets targets of nominal broad money growth and sets high required reserve ratios due to the imperfect monetary policy transmission mechanisms. Moreover, the objective of China's central bank when considering various monetary policy tools appears more complicated than that in developed countries, as it does not only maintain inflation stability, but also helps create job opportunities and maintains the balance of international payments. Interest rate adjustment, together with the adjustment of the required reserve ratio, is often employed to maintain the stability of domestic stock market, so as to maintain social stability and promote economic development.

The PBoC sets benchmark deposit and lending rates that most commercial banks are willing to follow due to the absence of full independence in the financial market.

The adjustments to interest rates on deposits and loans are actively used by the PBoC. To capture these two interest rates in a DSGE model, Chen *et al.* (2012) built a closed economy new Keynesian DSGE model containing patient and impatient households in the spirit of Kiyotaki & Moore (1997), Iacoviello (2005) and Gerali *et al.* (2010). A private banking sector was included in their model and the loan target and the required reserve ratio are also considered when complementing the monetary policy. Moreover, as loan and deposit rates are restricted by the guidance of China's central bank before 2013 and 2015, respectively, Chen *et al.* (2012) proposed an interest rate corridor to capture this restriction. For example, actual loan rates, due to the floor set by the central bank, would be restricted to be equal to policy loan rates provided that market loan rates are lower than policy rates. Similarly, actual deposit rates cannot exceed the ceiling set by the central bank. The method developed by Holden & Paetz (2012) to solve DSGE models with inequality constrains was used to solve the corridors in their model. Following the work of Chen *et al.* (2012), Funke & Paetz (2012) augmented the framework with a domestic bond market, and Funke *et al.* (2015) further included shadow banks in the model. Sinclair & Sun (2015) also suggested that the market interest rates are connected with the policy rates by positive time-varying parameters. In addition, the loan-to-value ratio was included in their model to act as a macroprudential policy instrument, together with the required reserve ratio in China.

In order to capture the repressive financial policies in the DSGE model or on the contrary, the financial liberalisation process, several methods have been implemented in the literature. For example, as mentioned in the last chapter, Jin *et al.* (2013) measured interest rate liberalisation process by increasing its steady state level. In addition, Funke & Paetz (2012) looked into the liberalisation by allowing the PBoC to set benchmark deposit and loan rates to be a weighted average of original policy rates and market rates. The degree of interest rate liberalisation was reflected by changing the weighted parameters in the model. Funke *et al.*

(2015) then considered two scenarios of liberalisation process. The first scenario, named as partial liberalisation, assumes that the central bank stops controlling interest rates but imposes the window guidance on loan quotas remains, whilst the second one looks at a full liberalisation scenario where the window guidance is turned off and so is the interest rate control. Xiao *et al.* (2015) also used the weighted average of policy rates and market rates proposed by Funke & Paetz (2012), and further captured the degree of exchange rate reform by changing the parameter on the exchange rate variable in the Taylor rule. Thus both interest rate and exchange rate liberalisation processes can be monitored in the DSGE model. Other repressive financial policies like high required reserve ratios are also included. In fact, the PBoC actively adjusts this ratio in order to control money growth, as the control on M2 through the money growth rule is challenging and impossible due to the unstable velocity of money. Moreover, Chen *et al.* (2012) proposed that the PBoC imposes the administrative window guidance on bank lending, which is another possible repressive financial policies to be considered in the model.

Although China has witnessed a number of economic and financial reforms since 1978, it is acknowledged that repressive financial policies are still present in China during 1978 until now. It is important to understand the impact of financial repression in China. This chapter therefore has some typical repressive financial policies included in the new Keynesian DSGE model, and investigates the effects on China's economy when removing one or all of these policies to achieve financial liberalisation. To be specific, it builds a new Keynesian closed economy DSGE model following Gerali *et al.* (2010), Chen *et al.* (2012) and Funke & Paetz (2012), with patient and impatient households to capture both deposit and loan rates, and a commercial bank sector is included. Commercial banks are further decomposed by wholesale and retail sectors. Unlike Funke *et al.* (2015) where the wholesale loan and deposit rates in equilibrium are dependent of the parameters in the management cost function, this model introduces a stochastic elasticity of

demand for loans and deposits in the retailing commercial bank section, which is in spirit of Gerali *et al.* (2010). Furthermore, actual deposit and loan rates are represented by a geometric weighted average between market and central bank rates, so that interest rate liberalisation process can be captured by changing the weighted parameters accordingly. Required reserve ratio and the window guidance on bank loans are included in the model. This chapter removes the interest rate corridor, as the model constructed by Chen *et al.* (2012) and Funke & Paetz (2012) was used before the floor of loan rate and the ceiling of deposit rate were removed. The results show that both deposit and lending rates are more sensitive to exogenous shocks after deregulation, and the deregulation process reduces the volatility of inflation. However, the effects of deregulation are significantly affected by the window guidance rule. The interest rate rule adopted by the central bank works to maintain the stability of the economy, and it is more powerful in terms of reducing the volatility of inflation without the window guidance rule. Also, the result provides little evidence of inflation control by introducing a positive shock in the required reserve ratio. Following that, this model further differs from their DSGE models by considering nominal money growth variable in the interest rate Taylor rule. This is important as the PBoC and the central government announce and monitor broad money growth target every year. The modified rule brings about more volatility of inflation, but maintains output at a stable level.

Parameters of DSGE models are determined using numerous different approaches. Pure calibration is used by Kydland & Prescott (1982) and numerous research works due to its strong robustness (see Monacelli, 2005; Zhang, 2009; Chen *et al.*, 2012; Funke & Paetz, 2012; Jin *et al.*, 2013; Funke *et al.*, 2015), but is also criticised for the absence of theory foundation. The Bayesian estimation, however, provides perfect information of observed variables, and therefore has been widely adopted in recent decades (see Smets & Wouters, 2003, 2005; Gerali *et al.*, 2010; Xiao *et al.*, 2015). This chapter, therefore, chooses Bayesian estimation methods to estimate some parameters in the model, with other parameters to be calibrated.

The rest of this chapter is organised as follows. Section 5.2 interprets the structure of the new Keynesian closed economy DSGE model and the log-linearised process, together with the model estimation. The properties of the model in terms of the impulse response analysis are interpreted in Section 5.3. Section 5.4 considers the model with a modified interest rate Taylor rule augmented with nominal money growth. The conclusions are drawn in Section 5.5.

5.2   Model structure

The previous analysis in the last chapter compares the interest rate rule and the money growth rule in a closed economy model, where interest rate liberalisation process is measured by raising the steady state levels of the benchmark interest rates. It shows that the interest rate rule is more effective in terms of transmission mechanisms of monetary policy. Also, the national 13th five-year plan proposes the reform of monetary policy by gradually replacing the quantity-based instruments (i.e. the money growth rule) by the price-based tools (i.e. the interest rate rule).

In this chapter, a two-household closed economy model is developed in the spirits of Iacoviello (2005), Gerali *et al.* (2010) and Chen *et al.* (2012). Households are divided into two groups. i.e. patient households and impatient households. Patient households deposit at commercial banks and provide labour supply during the lifetime, whilst impatient households take loans from banks and hire labours from patient households. Meanwhile, entrepreneurs in the impatient households invest and produce homogeneous intermediate goods. Retailers in the model buy intermediate goods from impatient households in a competitive market, differentiate the goods at no extra costs, and sell them in a monopolistically competitive market. The prices are set by retailers in a Calvo-type staggered manner. Commercial banks consist of two sectors, namely a wholesale sector and a retail sector. The wholesale sector is responsible of managing the bank's assets and distributing

deposits and loans to the retail sector. The retail sector are further formed of a loan branch and a deposit branch. The loan branch offers bank loans to impatient households, whilst the deposit branch raises deposits from patient households. The wholesale sector is assumed to operate in a perfectly competitive market while loan and deposit retail branches are under monopolistic competition and have some market power when determining the market deposit and loan rates. The central bank employs an interest rate (Taylor) rule which closes the model. The central bank also uses a Taylor-type rule to offer the window guidance for bank lending and to set the required reserve ratio. In our model, following Gerali *et al.* (2010), patient households are denoted with the superscript P, whilst impatient households with E. Actual deposit and loan rates are geometric-weighted averages of the benchmark rates and market-determined rates, respectively. Interest rate liberalisation, in this way, can be illustrated by changing the weights of benchmark and market deposit and loan rates.

5.2.1 Patient households

The representative patient household maximises her utility function[1] which depends on real consumption, C_t^P, and real labour supply, N_t:

$$\max \mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \left(\beta^P\right)^t \mathcal{U}_t^h \left(\frac{1}{1-\sigma^P} \left(C_t^P\right)^{1-\sigma^P} - \frac{1}{1+\phi} \left(N_t\right)^{1+\phi} \right) \right\} \qquad (5.1)$$

where $\beta^P \in (0,1)$ is the intertemporal discount factor, σ^P is the coefficient of relative risk aversion of patient households, or the inverse of the elasticity of intertemporal substitution in consumption. ϕ denotes the inverse of wage elasticity of labour supply. $\mathcal{U}_t^h = \exp\left(u_t^h\right)$ captures shifts in the marginal utility of consump-

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[1]Similar to Chapter 4, this chapter uses a separable utility function for patient and impatient households. Recent studies with DSGE models have seen a household utility function that is compatible with a balanced-growth steady state, hence the utility function is non-separable (Smets & Wouters, 2007; Cantore *et al.*, 2015) and the growth of population is considered. Nevertheless, a separable utility function is widely used by, for example, Smets & Wouters (2003), Smets & Wouters (2005) and Gerali *et al.* (2010).

tion and is often referred to as the preference shock of households.

The representative patient household's choice is subject to the following budget constraint (in real terms hereafter):

$$C_t^P + D_t = \frac{R_{t-1}^D D_{t-1}}{\Pi_t} + W_t N_t + F_t^R + F_t^C \tag{5.2}$$

where D_t is the private deposits held in the commercial banks. R_{t-1}^D is the gross interest rate on deposits during $t-1$ and t. $\Pi_t = \dfrac{P_t}{P_{t-1}}$ is the gross inflation where P_t is the price level denoted by the Consumer Price Index. W_t denotes the real wage rate and F_t^R and F_t^C is the lump-sum profits received from retailers and commercial banks.

In equilibrium, the dynamics of consumption, deposits and labour supply are determined by equation (5.2). The first order conditions (FOC) with respect to C_t and D_t yield the Euler equation for patient households:

$$\frac{1}{R_t^D} = \beta^P \mathbb{E}_t \left[\left(\frac{C_{t+1}^P}{C_t^P} \right)^{-\sigma^P} \frac{1}{\Pi_{t+1}} \frac{\mathcal{U}_{t+1}^h}{\mathcal{U}_t^h} \right] \tag{5.3}$$

The FOC with respect to N_t reads the optimal choice of labour supply:

$$W_t = \left(C_t^P \right)^{\sigma^P} N_t^\phi \tag{5.4}$$

5.2.2 Impatient households

The representative impatient household maximises her utility function of current consumption, C_t^E:

$$\max \mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \left(\beta^E \right)^t \mathcal{U}_t^h \left(\frac{1}{1-\sigma^E} \left(C_t^E \right)^{1-\sigma^E} \right) \right\} \tag{5.5}$$

where $\beta^E \in (0,1)$ is the intertemporal discount factor and σ^E denotes the inverse of the intertemporal elasticity of substitution with respect to consumption, C_t^E.

Also, the household's choice is subject to the following budget constraints:

$$C_t^E + W_t N_t + \frac{R_{t-1}^L L_{t-1}}{\Pi_t} + I_t + \mathcal{C}_t^K = \frac{Y_t}{X_t} + L_t \tag{5.6}$$

and

$$K_t = (1 - \delta) K_{t-1} + I_t \tag{5.7}$$

where R_{t-1}^L denotes the gross interest rate on loans during $t - 1$ and t, L_t is the loan taken by impatient households from commercial banks and I_t is investment in current period. K_t is the capital stock and δ is the depreciation rate for capital. The adjustment cost for installing new capital goods is represented by $\mathcal{C}_t^K = \psi^K \left(\frac{I_t \mathcal{U}_t^k}{K_{t-1}} - \delta \right)^2 \frac{K_{t-1}}{2\delta}$, where ψ^K is a parameter of adjustment cost and $\mathcal{U}_t^k = \exp\left(u_t^k\right)$ measures a shock of increasing the adjustment cost. The convex adjustment cost function, according to Chen *et al.* (2012), is vital when sticky prices are considered so as to avoid large shifts of capital stock in response to external shocks. Y_t takes the form of Cobb-Douglas function and denotes the real output for intermediate goods,

$$Y_t = A_t K_{t-1}^\alpha N_t^{1-\alpha} \tag{5.8}$$

where $A_t = \exp\left(u_t^a\right)$ is the total factor productivity with u_t^a representing the productivity shock. X_t represents the mark-up of final over intermediate goods.

The dynamics of C_t^E, L_t, I_t, K_t and N_t are determined in equations (5.6) and (5.7). The FOCs with respect to C_t^E and L_t, similar to patient households, produce the following Euler equation:

$$\frac{1}{R_t^L} = \beta^E \mathbb{E}_t \left[\left(\frac{C_{t+1}^E}{C_t^E} \right)^{-\sigma^E} \frac{1}{\Pi_{t+1}} \frac{\mathcal{U}_{t+1}^h}{\mathcal{U}_t^h} \right] \tag{5.9}$$

Again, the FOC with respect to N_t yields the conventional labour demand curve:

$$W_t = (1 - \alpha) \frac{Y_t}{N_t X_t} \tag{5.10}$$

Lastly, the FOCs with respect to investment and capital read:

$$
\begin{aligned}
\mathcal{U}_t^h \mu_t &= \beta^E \mathbb{E}_t \mathcal{U}_{t+1}^h \left(C_{t+1}^E\right)^{-\sigma^E} \left[\frac{\alpha Y_{t+1}}{K_t X_{t+1}} - \frac{\psi^K}{2\delta} \left(\frac{\mathcal{U}_{t+1}^k I_{t+1}}{K_t} - \delta \right)^2 \right] \\
&\quad + \beta^E \mathbb{E}_t \mathcal{U}_{t+1}^h \left(C_{t+1}^E\right)^{-\sigma^E} \left[\frac{\psi^K}{\delta} \left(\frac{\mathcal{U}_{t+1}^k I_{t+1}}{K_t} - \delta \right) \frac{\mathcal{U}_{t+1}^k I_{t+1}}{K_t} \right] \\
&\quad + (1 - \delta) \beta^E \mathbb{E}_t \mathcal{U}_{t+1}^h \mu_{t+1}
\end{aligned}
\tag{5.11}
$$

where μ_t is the Lagrangian multiplier of equation (5.7), and also denotes the shadow price of capital, $\mu_t = \left(C_t^E\right)^{-\sigma^E} \left(1 + \frac{\psi^K}{\delta} \left(\frac{I_t \mathcal{U}_t^k}{K_{t-1}} - \delta \right) \right) \mathcal{U}_t^k$.

5.2.3 Retailers

In the presence of sticky prices, Bernanke *et al.* (1999) and Iacoviello (2005) assume that retailers have some monopoly power and set the price in a Calvo-type staggered fashion. A continuum of retailers of mass 1, indexed by j, purchase intermediate goods from entrepreneurs in the impatient households and differentiate the goods into $Y_t(j)$ at no cost and sell them at $P_t(j)$. Final goods, Y_t^f is assumed to follow $Y_t^f = \left(\int_0^1 Y_t(j)^{\frac{\epsilon_t - 1}{\epsilon_t}} dj \right)^{\frac{\epsilon_t}{\epsilon_t - 1}}$, where $\epsilon_t > 1$ is the elasticity of substitution between differentiated goods. The price index is defined as $P_t = \left(\int_0^1 P_t(j)^{1 - \epsilon_t} dj \right)^{\frac{1}{1 - \epsilon_t}}$. Therefore, the demand curve of each retailer at time t reads $Y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\epsilon_t} Y_t^f$. Each retailer chooses a sale price $P_t(j)$. In this chapter, following Bäurle & Menz (2008) and Justiniano & Preston (2010), it is assumed that $(1 - \theta)$ of retailers can reset their price optimally in every period, whilst the remaining θ of retailers cannot, but adjust the price according to the

indexation rule in the following manner:

$$P_t(j) = P_{t-1}(j)(\Pi_{t-1})^\tau \tag{5.12}$$

where $\Pi_{t-1} = \dfrac{P_{t-1}}{P_{t-2}}$ is gross inflation of last period, and τ captures the degree of indexation to previous inflation. Although Galí & Gertler (1999) further divided the $(1-\theta)$ of retailers into two subsets containing forward-looking and backward-looking retailers respectively, it showed eventually that compared to forward-looking retailers alone, the result including backward-looking retailers, though statistically significant, is not quantitatively important.

Retailers in this chapter are assumed to behave identically and therefore the index j can be omitted in what follows. Let P_t^n denote the price set by the retailers that are able to reset their price optimally in period t, the aggregate price index can then be defined as:

$$P_t = \left[(1-\theta)(P_t^n)^{1-\epsilon_t} + \theta \left(P_{t-1} \left(\frac{P_{t-1}}{P_{t-2}} \right)^\tau \right)^{1-\epsilon_t} \right]^{\frac{1}{1-\epsilon_t}} \tag{5.13}$$

For the $(1-\theta)$ of retailers who re-optimise their price in period t, the following present discount value of profits is maximised with respect to P_t^n:

$$\max \mathbb{E}_t \sum_{k=0}^{\infty} \theta^k \left\{ \Lambda_{t,t+k} \left(P_t^n \left(\frac{P_{t+k-1}}{P_{t-1}} \right)^\tau - \frac{P_{t+k}}{X_{t+k}} \right) Y_{t+k|t} \right\} \tag{5.14}$$

where $\Lambda_{t,t+k} = \left(\beta^P \right)^k \left(\frac{C_{t+k}^P}{C_t^P} \right)^{-\sigma_p} \frac{P_t}{P_{t+k}}$ is the discount factor retrieved from the patient households, and X_{t+k} is equal to the markup $\dfrac{\epsilon_t}{\epsilon_t - 1}$.

Accordingly, the demand function in period $t+k$ for retailers who reset their price at time t and adjust the price according to the indexation rule henceforth is specified as follows:

$$Y_{t+k|t} = \left(\frac{P_t^n}{P_{t+k}} \left(\frac{P_{t+k-1}}{P_{t-1}} \right)^\tau \right)^{-\epsilon_t} Y_{t+k} \tag{5.15}$$

The first order condition takes the form:

$$0 = \sum_{k=0}^{\infty} \theta^k \mathbb{E}_t \left\{ \Lambda_{t,t+k} Y_{t+k|t} \left(\frac{P_t^n}{P_{t-1}} \left(\frac{P_{t+k-1}}{P_{t-1}} \right)^{\tau} - \frac{\epsilon_t}{\epsilon_t - 1} \frac{1}{X_{t+k}} \left(\frac{P_{t+k}}{P_{t-1}} \right) \right) \right\} \quad (5.16)$$

A cost-push shock, u_t^c is introduced in the Phillips curve by allowing the elasticity of substitution between differentiated goods to be time-varying, i.e. ϵ_t, in the above equation. Lastly, the lump-sum profits, $F_t^R = \left(1 - \frac{1}{X_t} \right) Y_t$, are rebated to patient households.

5.2.4 Commercial banks

The commercial bank sector is based on the partial equilibrium framework of He & Wang (2012). Suppose an economy without financial regulations where banks determine the demand for the amount of deposits and central bank bills, and the supply of bank loans, the deposit and loan rates thus are not regulated and are determined by the market forces. In this model, a continuum of commercial banks of mass 1, indexed by j, consist of two sectors, namely a wholesale sector and a retail sector. The wholesale sector manages bank assets in a perfectly competitive market by generating deposits and offering loans to retail sectors. The retail sector is composed of loan and deposit branches, which offer loans to impatient households and deal with deposits from patient households, respectively.

5.2.4.1 Wholesale sector

A representative wholesale sector in the commercial bank at time t, as in Chen *et al.* (2012), takes the amount of wholesale deposits, D_t^W, at the gross wholesale deposit rate of $R_t^{D,W}$, makes wholesale loans, L_t^W, at the gross interest rate of $R_t^{L,W}$ and borrows from the interbank market. Additionally, some market and non-market based monetary policy instruments are included in the model. For example, the PBoC takes the required reserves from commercial banks according to

the published required reserve ratio, $\tilde{\eta}_t$. Also, the non-market based instrument of administrative window guidance for bank loans imposed by the PBoC and the central government is measured by the quadratic cost[2] $\mathcal{C}_t^W = \frac{\psi^W}{2} \left(\frac{L_t^W}{L_t^{CB}} - 1 \right)^2 L_t^{CB}$, i.e. deviations from the central bank's guided loan amount, L_t^{CB} induce costs, with ψ^W being a cost parameter. Assuming a market of perfect competition one could maximise the representative bank's cash of flows:

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} \left(\beta^B \right)^t \left\{ \begin{array}{l} R_t^{L,W} L_t^W + R_t^B B_t + \tilde{\eta}_t R_t^R D_t^W - R_t^{D,W} D_t^W - R_t^{IB} IB_t - L_{t+1}^W \\ -B_{t+1} + (1 - \tilde{\eta}_{t+1}) D_{t+1}^W + IB_{t+1} - \mathcal{C}_t^W \end{array} \right\} \tag{5.17}$$

subject to the balance sheet of the commercial bank:

$$IB_t + D_t^W = \tilde{\eta}_t D_t^W + L_t^W \tag{5.18}$$

where β^B is the discount factor for the commercial bank, R_t^R denotes the interest rate of required reserves deposited at the central bank, R_t^{IB} is the interbank interest rate, or "Shibor" in China, and IB_t is net borrowing in the non-regulated interbank market such that in equilibrium $IB = 0$. The problem can be solved by maximising a one-period profit that is obtained by substituting equation (5.18) into (5.17):

$$F_t^C \equiv \left(R_t^{L,W} - R_t^{IB} \right) L_t^W - \left(R_t^{D,W} - \tilde{\eta}_t R_t^R - (1 - \tilde{\eta}_t) R_t^{IB} \right) D_t^W - \mathcal{C}_t^W \tag{5.19}$$

which are rebated to patient households in equation (5.2).

The FOCs with respect to L_t and D_t read:

$$R_t^{L,W} = R_t^{IB} + \psi^W \left(\frac{L_t^W}{L_t^{CB}} - 1 \right) \tag{5.20}$$

$$R_t^{D,W} = \tilde{\eta}_t R_t^R + (1 - \tilde{\eta}_t) R_t^{IB} \tag{5.21}$$

Commercial banks are assumed to be able to have unlimited access to the lending

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[2]It is considered that $L = L^{CB}$ in the steady state, so that the cost is zero.

facility operated by the central bank, therefore interbank interest rate, known as Shibor in China, is equal to the benchmark interest rate, $R_t^{IB} = R_t$.

5.2.4.2   Retail sector

Retail sector consists of a representative loan branch and deposit branch. The loan branch receives wholesale loans, L_t^W, at the rate, $R_t^{L,W}$, from the wholesale sector, differentiates them at no costs and makes them to impatient households. Each loan branch, j, has some monopoly power and sets the market aggregated loan rate, $R_t^{L,M}$, by maximising the present discount value of profits:

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_t \left\{ \left(R_t^{L,M}(j) - 1 \right) L_t(j) - \left(R_t^{L,W} - 1 \right) L_t^W(j) \right\}$$

$$\text{s.t. } L_t(j) = \left(\frac{R_t^{L,M}(j) - 1}{R_t^{L,M} - 1} \right)^{-\tilde{\epsilon}_t^L} L_t \tag{5.22}$$

where equation (5.22) is the demand function for bank loans to impatient households, according to Gerali *et al.* (2010). $\tilde{\epsilon}_t^L > 1$ is the stochastic interest elasticity of demand for loans, and determines the interest spreads between market and policy rates. Allowing the elasticity to be a time-varying parameter reflects the degree of bank's independence of central bank's monetary policy. This is consistent with the situation in China where the central bank has removed the control on the retail loan rates. Given $L_t(j) = L_t^W(j)$ and imposing symmetry equilibrium, the FOC yields the following:

$$R_t^{L.M} - 1 = \frac{\tilde{\epsilon}_t^L}{\tilde{\epsilon}_t^L - 1} \left(R_t^{L,W} - 1 \right) \tag{5.23}$$

The deposit branch is similar to the loan branch. A representative deposit branch of a commercial bank, j, collects deposits $D_t(j)$ from patient households and transfers them to the wholesale sector as $D_t^W(j)$ at the aggregate rate, $R_t^{D,W}$. Also, the deposit branch operates at a monopolistically competitive market and

sets the market deposit rates at $R_t^{D,M}$. The present discount value of profits for deposit branch is maximised as below:

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_t \left\{ \left(R_t^{D,W} - 1 \right) D_t^W(j) - \left(R_t^{D,M}(j) - 1 \right) D_t(j) \right\}$$

$$\text{s.t. } D_t(j) = \left(\frac{R_t^{D,M}(j) - 1}{R_t^{D,M} - 1} \right)^{-\tilde{\epsilon}_t^D} D_t \qquad (5.24)$$

where equation (5.24) is the CES-form demand function for deposits, and $\tilde{\epsilon}_t^D < -1$ is the interest elasticity of demand for deposits. Similar to $\tilde{\epsilon}_t^L$, it is assumed to be stochastic to describe China's economy after freeing the control of deposit rates in late 2015. The FOC given $D_t(j) = D_t^W(j)$ and after imposing symmetry reads:

$$R_t^{D,M} - 1 = \frac{\tilde{\epsilon}_t^D}{\tilde{\epsilon}_t^D - 1} \left(R_t^{D,W} - 1 \right) \qquad (5.25)$$

The equations above regarding to commercial banks determine the market interest rates on loans and deposits. Although the PBoC has been freeing the controls on both rates, it still publishes the benchmark deposit and loan rates which banks are all likely to follow. Therefore, there are still some deviations between actual and market-determined deposit and loan rates, which is discussed as below.

5.2.5 Monetary policy

The market and non-market based monetary policies instruments adopted in this model are described and used in Chen *et al.* (2012) and Funke & Paetz (2012). As was pointed out in the national 13-th five-year plan, the central bank and the central government are phasing out the quantity-based monetary policy instruments. Macroeconomic regulations and controls in future tend to rely more on the price-based methods. The PBoC sets the benchmark interest rate based on the interest rate in past period, inflation and output. Suppose that the PBoC sets the

benchmark interest rate following a Taylor-type rule:

$$R_t = R_{t-1}^{\phi_r} \left(R \left(\frac{\Pi_t}{\bar{\bar{\Pi}}} \right)^{\phi_\pi} \left(\frac{Y_t}{Y} \right)^{\phi_y} \right)^{(1-\phi_r)} \exp\left(\epsilon_t^r\right) \tag{5.26}$$

where R_t is the policy interest rate set by the central bank, $\bar{\Pi}$ denotes the inflation target and ϵ_t^r captures the interest-rate shock. The parameters, ϕs, measure the preferences with respect to lagged policy rate, inflation, output gap, respectively.

However, the PBoC does not publish the benchmark interest rate, but the benchmark deposit and loan rates respectively. The benchmark deposit and loan rates are assumed to follow the modified forms of the Taylor rule above:

$$R_t^{D,CB} = \left(R_{t-1}^{D,CB} \right)^{\phi_r^d} \left(R^{D,CB} \frac{R_t}{R} \right)^{\left(1-\phi_r^d\right)} \tag{5.27}$$

$$R_t^{L,CB} = \left(R_{t-1}^{L,CB} \right)^{\phi_r^l} \left(R^{L,CB} \frac{R_t}{R} \right)^{\left(1-\phi_r^l\right)} \tag{5.28}$$

To distinguish between the deposit and loan rates set by the central bank and those by the market forces in the commercial banks sector, a subscript of CB is interpreted as the central-bank rates. $R_t^{D,CB}$ and $R_t^{L,CB}$ therefore, denote and central-bank benchmark deposit and loan rates, respectively.

As stated earlier, although China has removed the control of interest rates on loans and deposits, the PBoC keeps publishing the benchmark deposit and loan rates which banks tend to follow in order to minimise the potential risk. Commercial banks in China, have not set interest rates independently. In line of this, the actual interest rates of deposits and loans faced by patient and impatient households, are defined as a weighted geometric average between the central-bank rates and the market-determined rates:

$$R_t^D = \left(R_t^{D,M} \right)^{\phi^D} \left(R_t^{D,CB} \right)^{1-\phi^D} \tag{5.29}$$

$$R_t^L = \left(R_t^{L,M}\right)^{\phi^L} \left(R_t^{L,CB}\right)^{1-\phi^L} \tag{5.30}$$

where the weight parameters, $0 < \phi^D$, $\phi^L < 1$, measure the degree of interest rate deregulation. For example, $\phi^D = 0$ means a fully controlled deposit rates set by the central bank, whilst actual deposit rates are determined by market forces when $\phi^D = 1$. The floor of loan rates and the ceiling of deposit rates were removed in 2013 and 2015, respectively. Nevertheless, it is unlikely to set ϕ^D and ϕ^L to be equal to 1, as commercial banks still tend to follow current policy rates in order to minimise risks.

In addition, the PBoC imposes the administrative window guidance for bank loans. Credit supply is controlled by setting the target, L_t^{CB}, to guide the amount and direction of bank loans. Assume the credit supply target follows a Taylor-type rule used by Funke & Paetz (2012):

$$L_t^{CB} = \left(L_{t-1}^{CB}\right)^{\phi_l^{cb}} \left(L^{CB} \left(\frac{L_t}{L}\right)^{\phi_l^l} \left[\left(\frac{\Pi_t}{\overline{\overline{\Pi}}}\right)^{\phi_l^\pi} \left(\frac{Y_t}{Y}\right)^{\phi_l^y}\right]^{1-\phi_l^l}\right)^{1-\phi_l^{cb}} \tag{5.31}$$

where ϕs are parameters capturing the preferences of the central bank. Note that ϕ_l^π and ϕ_l^y are negative as inflation and output over the target and potential levels would reduce the growth of credit supply in order to cool down the economy. $\phi_l^{cb} > 0$ smooths the fluctuations of the loan targets. The window guidance is also known as one of macroprudential policy tools to maintain financial stability.

In addition to the regulated deposit and loan rates and the window guidance, the PBoC employs the market-based monetary policy tool, the required reserve ratio for example, to manage the amount of money supply. The required reserve ratio, according to Chen *et al.* (2012) and Gerali *et al.* (2010), is considered to follow the rule:

$$\tilde{\eta}_t = \tilde{\eta}_{t-1}^{\phi_\eta^\eta} \left(\tilde{\eta} \left(\frac{\Pi_t}{\overline{\overline{\Pi}}}\right)^{\phi_\eta^\pi}\right)^{1-\phi_\eta^\eta} \exp\left(u_t^\eta\right) \tag{5.32}$$

where ϕs, as before, denote the parameters reflecting central bank's preferences,

and u_t^η captures the required-reserve-ratio shock. Required reserve ratio, according to the above rule, is set based on inflation and the lagged ratio on its own.

Lastly, the interest rate of required reserves deposited at the central bank, R_t^R, is assumed to passively follow the benchmark rate.

5.2.5.1   Shocks

To close the model, all the shocks except the interest-rate shock are set to follow the $AR(1)$ process, i.e. $u_t^j = \rho_j u_{t-1}^j + \epsilon_j^j$. The interest-rate shock is assumed to be a white-noise process.

5.2.5.2   Log-linearised equations

With goods market clearing condition $Y_t = C_t + I_t$, where $C_t \equiv C_t^P + C_t^E$, general equilibrium dynamics around the steady state levels can be derived from the equations above. Assuming inflation in the steady state equals the inflation target, $\Pi = \bar{\Pi}$, the steady states of the variables can be computed. For example, the steady state from equation (5.3) yields $R^D = \dfrac{\bar{\Pi}}{\beta^P}$. The model is then log-linearised around the steady state, as shown in the Appendix.

5.2.6   Model estimation

Estimating the DSGE models regarding to China can be challenging due to the absence of some key data as well as structural changes. In the previous chapter, calibration method is adopted, which is used by numerous DSGE papers focusing on China. However, the availability of China's quarterly data since 1996 has improved a lot, therefore a Bayesian approach to estimate some parameters of the central bank's policy is possible, and even necessary to yield more reliable results. In this chapter, some well-known parameters are calibrated following the

related model in the literature or according to the steady state equations with the mean of real data, whilst others are estimated using Bayesian methods. As this chapter aims to analyse China's economy in terms of financial repression and liberalisation, the period selected covers 1996Q1 until 2015Q4, when progress of financial liberalisation as well as sustainable economic growth is witnessed.

5.2.6.1 Calibration

Some well-known parameters are calibrated according to the similar model in existing research work, as well as the steady state equations. The calibrated parameters are summarised in Table 5.1. All the variables without a time subscript t refer to the steady state levels. Some parameters have same values as in the last chapter. For example, the parameters measuring the relative risk aversion of patient and impatient households are both equal to 2, i.e. $\sigma^P = \sigma^E = 2$. The inverse of wage elasticity of labour supply, or the inverse of Frisch elasticity is calibrated as $\phi = \dfrac{1}{3}$ as in the previous chapter. Funke & Paetz (2012) suggest the net mark-up of final over intermediate goods to be 10%, indicating that $X = 1.1$, and set the parameter measuring the adjustment cost for installing new capital goods to be 2, i.e. $\psi^K = 2$. The cost parameter measuring the window guidance for loan targets, ψ^W, is set to be 1, according to Funke & Paetz (2012). Similar to previous chapter, the depreciation rate of capital, $\delta = 0.04$, is set following Zhang (2009). Also, summing up the data of individual provinces yields the approximation of national level of GDP, where labour income accounts for 47% of total income, meaning $\alpha = 1 - 0.47 = 0.53$. In addition, the central bank's policy parameters measuring the central bank's window guidance for bank loans are obtained from Funke & Paetz (2012), due to the unavailability of the data for target loans, L_t^{CB}, which suggests that $\phi_l^{cb} = 0.5$, $\phi_l^l = 0.3$, $\phi_l^\pi = -50$ and $\phi_l^y = -5$. The weighted parameters measuring the degree of deposit and loan rates deregulation, ϕ^D and ϕ^L, are initially set to be 0.6.

Table 5.1: Calibrated parameters

Description	Calibrated value
Relative risk aversion of household	$\sigma^P = \sigma^E = 2$
Inverse of Frisch elasticity	$\phi = 1/3$
Mark-up of final over intermediate goods	$X = 1.1$
Adjustment cost parameter for new investment	$\psi^K = 2$
Adjustment cost parameter for window guidance	$\psi^W = 1$
Capital depreciation rate	$\delta = 4\%$
Output elasticity of capital	$\alpha = 0.53$
Weights measuring interest rate liberalisation	$\phi^D = 0.6,\ \phi^L = 0.6$
Window guidance rule	$\phi_l^{cb} = 0.5,\ \phi_l^l = 0.3$
	$\phi_l^\pi = -50,\ \phi_l^y = -5$

The policy interest rate is often referred to as the 7-day interbank offered rate in China. In this model, the 7-day Shanghai Interbank Offered Rate (Shibor) is selected. However, as the Shibor was established in late 2006, the 7-day China Interbank Offered Rate (Chibor) is used for the period from 1996 to 2006. The equilibrium level of net annual policy rate is set according to the mean of the interbank offered rate, which is 3.76%, meaning that $R^{IB} = R = \dfrac{3.76\%}{400\%} + 1 = 1.0094$, which is the aggregate quarterly level. The net annual interest rate on required reserves is lower than the policy rate in China, with the mean of 2.65% during this period. The average quarterly inflation rate is 2.07% at the annual rate, whilst the deposit and lending rates published by the central bank in equilibrium is 3.28% and 6.39%, respectively. Also, the required reserve ratio in equilibrium is 12%, according to the data published by the PBoC.

The steady state equations of (5.20) and (5.21) give the steady state levels of wholesale loan and deposit rates, i.e. $R^{L,W} = R^{IB}$ and $R^{D,W} = \tilde{\eta} R^R + (1 - \tilde{\eta}) R^{IB}$. The interest elasticity of demand for bank loans in equilibrium, $\tilde{\epsilon}^L$, is calibrated to be 2.8, indicating the steady-sate expressions for mark-up over the policy interest rate to be around 1.56. In fact, since the PBoC eventually removed the control on loan rates in July 2013, the Loan Prime Rate (LPR) has started to be published every day where the price quotation group consists of nine main commercial banks in China, and is to some extent considered as the market determined loan rate. The

Table 5.2: Calibrated steady state levels

Description	Calibrated steady state value
Annual inflation rate	2.07%
Annual interbank offered rate (policy rate)	3.76%
Annual interest rate on required reserves	2.65%
Central bank annual lending rate	6.39%
Central bank annual deposit rate	3.28%
Interest elasticity of demand for bank loans	$\tilde{\epsilon}^L = 2.8$
Interest elasticity of demand for bank deposits	$\tilde{\epsilon}^D = -20$
Required reserve ratio	$\tilde{\eta} = 12\%$
Loan to income ratio	$L/Y = 1.08$

mark-up of 1.56 is consistent with the relationship between LPR and the interbank rate during this period. The deposit rate control was removed in late 2015, and no market determined rate is available at present. Nevertheless, it is believed that actual deposit rate will increase in response of the removal of deposit rate ceilings. In spirit of this, $\tilde{\epsilon}^D$ in this chapter is set to be -20, meaning a 0.17% interest rate spread between the wholesale deposit rate and the market retail deposit rate[3]. Thus, the market determined interest rates on loans and deposits in steady state can be computed according to equations (5.23) and (5.25). Furthermore, as actual deposit and loan rates are considered in equations (5.29) and (5.30) as a geometric weighted average between the central bank rate and the market rate, their steady state levels, R^D and R^L, can be obtained accordingly. The weighted parameters, ϕ^D and ϕ^L, are initially set to be 0.6, which yields the intertemporal discount factors of patient and impatient households to be $\beta^P = \dfrac{\Pi}{R^D} = 0.997$ and $\beta^E = \dfrac{\Pi}{R^L} = 0.990$. The loan to income ratio, $\dfrac{L}{Y}$, in equilibrium is 1.08 based on the data of bank loans and GDP. Calibrated steady state levels are provided in Table 5.2 and 5.3.

The steady state equations of the model also give the consumption to income

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[3]Since $R^{D,W} = \tilde{\eta}R^R + (1 - \tilde{\eta}) R^{IB} = 1.009067$ and the markdown $\dfrac{\tilde{\epsilon}^D}{\tilde{\epsilon}^D - 1}$ in the steady state are known, $R^{D,M}$ is therefore equal to $\left(R^{D,W} - 1\right) \dfrac{\tilde{\epsilon}^D}{\tilde{\epsilon}^D - 1} + 1 = 1.008635$ according to equation (5.25), indicating that the interest rate spread between the wholesale deposit rate and the market retail deposit rate is $(1.009067 - 1.008635) \times 400\% = 0.17\%$.

Table 5.3: Selected levels of steady state variables and key parameters

Description	Calibrated value
Mark-up on loan rates	$\dfrac{\tilde{\epsilon}^L}{\tilde{\epsilon}^L - 1} = 1.56$
Mark-down on deposit rates	$\dfrac{\tilde{\epsilon}^D}{\tilde{\epsilon}^D - 1} = 0.95$
Discount factor of patient households	$\beta^P = \dfrac{\Pi}{R^D} = 0.997$
Discount factor of impatient households	$\beta^E = \dfrac{\Pi}{R^L} = 0.990$
Investment to income ratio	$\dfrac{I}{Y} = 0.385$
Consumption of impatient households to income ratio	$\dfrac{C^E}{Y} = 0.086$
Consumption of patient households to income ratio	$\dfrac{C^P}{Y} = 0.529$

ratio as well as the investment to income ratio, as indicated in Table 5.3. For impatient households, the consumption to income ratio in equilibrium is obtained from equations (5.6) and (5.10), which is $\dfrac{C^E}{Y} = \dfrac{\alpha}{X} + \left(1 - \dfrac{1}{\beta^E}\right)\dfrac{L}{Y} - \dfrac{I}{Y}$, where $\dfrac{I}{Y} = \dfrac{\delta K}{Y} = \dfrac{\delta \alpha}{X}\left[\dfrac{1}{\beta^E} - (1 - \delta)\right]^{-1}$ according to equation (5.11). Thus, the consumption to income ratio for patient households in equilibrium is $\dfrac{C^P}{Y} = 1 - \dfrac{C^E}{Y} - \dfrac{I}{Y}$.

5.2.6.2 Bayesian estimation

Data To estimate the remaining parameters in the model, eight macroeconomic variables are selected as observables for the period of 1996Q1 to 2015Q4. Table 5.4 describes the construction and sources of the data used for estimation. Data are seasonally adjusted. In addition, as the log-linearised model is used in this chapter, all the variables thus represent the percentage deviations (or absolute deviations) from the steady state. Consequently, the original non-stationary data are detrended using the one-sided Hodrick-Prescott filter ($\lambda = 1600$)[4] developed by Stock & Watson (1999). Stationary data are subtracted by their mean, such as inflation, money growth rate and interest rates. The data after transformation

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[4]Chapter 4 uses the same method and Pfeifer (2014) discussed the advantage of the backward-looking one-sided HP filter against the two-sided one for DSGE estimation.
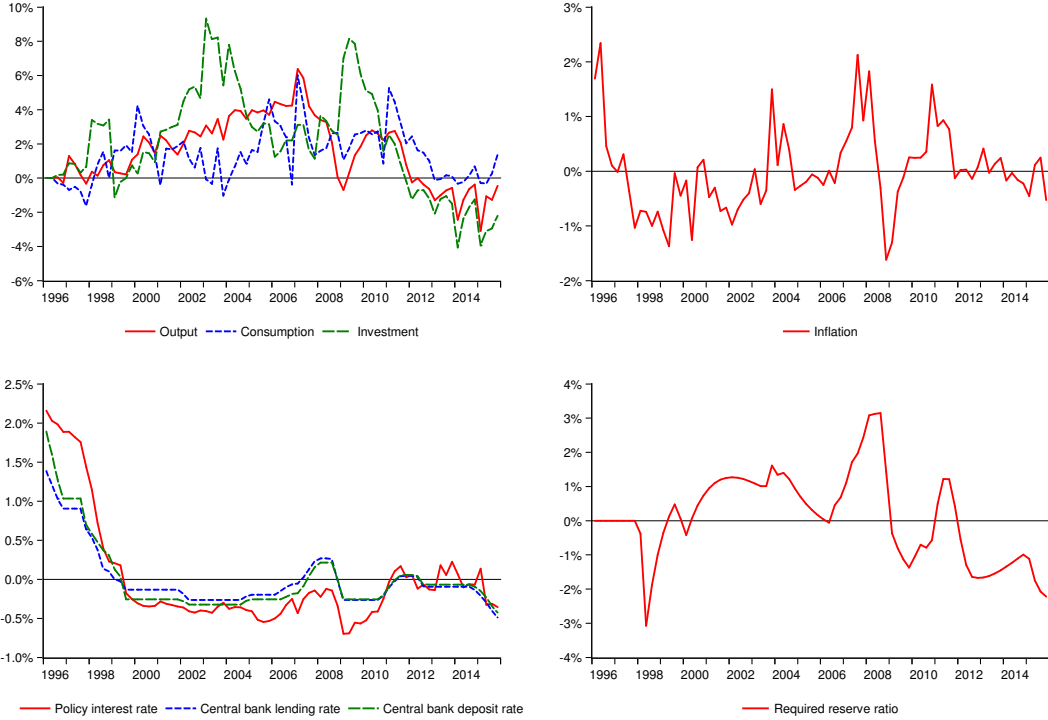
Figure 5.1: Observable variables used in estimation

Note: The names of variables in the legends above indicate the percentage deviations (or absolute deviations) from the HP trend using the one-sided HP filter with $\lambda = 1600$. All the data are demeaned and detrended before entering the estimation process.

are plotted in Figure 5.1.

Prior distributions   In addition to the calibrated parameters, the remaining parameters measuring the central bank's policy decisions and driving the model dynamics are estimated using the Bayesian estimation, where priors play a vital rule. The choice of prior distributions in this model relies on current literature or they are relatively uninformative. For example, Smets & Wouters (2003) and Gerali *et al.* (2010) suggest a Beta distribution for smoothing parameters such as ϕ_r, ϕ_r^d, ϕ_r^l and ϕ_η^η, where the domain is $[0, 1)$. The parameters measuring the response of policy rate deviations to inflation and output, ϕ_π and ϕ_y, are assumed to have priors of gamma distribution. As to the required-reserved-ratio rule in the DSGE model for Bayesian estimating, this model follows the idea of Gerali *et al.* (2010) and sets prior distribution of the parameter, ϕ_η^π, to be Gamma

Table 5.4: Description of data

Name	Description
Output, Y_t	Real quarterly GDP is obtained by deflating nominal GDP by the CPI.
	Source: Oxford economics via Datastream and National Bureau of Statistics of China website.
Consumption, C_t	Real quarterly consumption is obtained by deflating nominal private consumption by the CPI.
	Source: Oxford economics via Datastream and National Bureau of Statistics of China website.
Investment, I_t	Real investment is obtained by deflating gross fixed capital formation by the CPI.
	Source: Oxford economics via Datastream and National Bureau of Statistics of China website.
Inflation, Π_t	Consumer Price Index is used to represent the price level. Inflation is defined as the quarterly difference at the annual rate.
	Source: OECD Main Economic Indicators via Datastream
Policy interest rate, R_t	7-day Shibor from 2007 to 2015, while Chibor was used between 1996 and 2006. Daily gross rates are taken arithmetic average to construct quarterly data.
	Source: the PBoC website and shibor.org.
Central bank deposit rate, $R_t^{D,CB}$	1-year deposit rate published by the PBoC. Daily data are taken arithmetic average to construct quarterly data.
	Source: the PBoC website.
Central bank loan rate, $R_t^{L,CB}$	1-year loan rate published by the PBoC. Daily data are taken arithmetic average to construct quarterly data.
	Source: the PBoC website.
Required reserve ratio, $\tilde{\eta}_t$	Required reserve ratio on large financial institutions, published by the PBoC.
	Source: the PBoC website.

Note: Data of inflation, output and money growth are seasonally adjusted. All the interest rates and inflation data are transformed into the quarterly gross rates.

Table 5.5: Prior and posterior distribution of structural parameters

Parameter	Distribution	Mean	Standard deviation	Mean	90% HPD interval	Median
		Prior distribution		Posterior distribution		
θ	Gamma	0.50	0.10	0.371	[0.283,0.460]	0.373
τ	Gamma	0.50	0.10	0.483	[0.320,0.646]	0.483
ϕ_r	Beta	0.75	0.10	0.915	[0.890,0.941]	0.916
ϕ_π	Gamma	2.00	0.50	2.202	[1.597,2.788]	2.163
ϕ_y	Gamma	0.10	0.02	0.060	[0.040,0.079]	0.059
ϕ_r^d	Beta	0.75	0.10	0.607	[0.474,0.747]	0.607
ϕ_r^l	Beta	0.75	0.10	0.847	[0.780,0.916]	0.850
ϕ_η^η	Beta	0.75	0.10	0.951	[0.929,0.972]	0.951
ϕ_η^π	Gamma	50.00	0.50	49.977	[49.146,50.806]	49.976

Note: 1. Results of posterior means are obtained by running 10 chains of Metropolis-Hastings algorithm, each with 100,000 draws, of which the first 20% are dropped; 2. The average acceptance rate for 10 chains is 23.49%; 3. HPD interval refers to the highest posterior density credible interval, which is the shortest interval among all intervals that are 90% credible.

distribution with a standard deviation of 0.5, so that it is strictly positive. In addition, Smets & Wouters (2003) and Gerali *et al.* (2010) consider the interest-rate shock to be a white noise, whilst all the other shocks follow the $AR(1)$ process and the autoregressive parameters have a strict prior distribution with a mean of 0.8 and a standard deviation of 0.1. The standard deviation of each driving force is equipped with the inverse-Gamma distribution, which is in favour of literature, with the mean of 0.01 and the standard deviation of 0.05. Table 5.5 and 5.6 summarise the prior distributions with means and standard deviations for all the structural and autoregressive parameters and the standard deviations of exogenous driving forces.

Posterior estimates   The Bayesian rule suggests that $p(\vartheta \mid \mathcal{Y}) \propto L(\vartheta \mid \mathcal{Y}) p(\vartheta)$, where the likelihood function $L(*)$ is computed using the Kalman filter. Table 5.5 and 5.6 also report the results of posterior estimates. The statistics of posteriors of the estimated parameters reported in the tables are obtained using the Metropolis-Hastings algorithm to generate 10 chains, each of which contains 100,000 draws. The average acceptance rate for 10 chains is 23.49%, which is closed to the optimal ratio of 23.4% suggested by Roberts *et al.* (1997). The first 20% of draws were

Table 5.6: Prior and posterior distribution of $AR(1)$ parameters and shocks

Parameter	Prior distribution			Posterior distribution		
	Distribution	Mean	Standard deviation	Mean	90% HPD interval	Median
ρ_h	Beta	0.80	0.10	0.833	[0.680,0.975]	0.856
ρ_k	Beta	0.80	0.10	0.911	[0.846,0.974]	0.919
ρ_a	Beta	0.80	0.10	0.839	[0.698,0.982]	0.858
ρ_c	Beta	0.80	0.10	0.805	[0.654,0.959]	0.818
ρ_{ϵ^L}	Beta	0.80	0.10	0.871	[0.808,0.941]	0.875
ρ_{ϵ^D}	Beta	0.80	0.10	0.868	[0.752,0.963]	0.892
ρ_η	Beta	0.80	0.10	0.506	[0.366,0.645]	0.504
Standard deviation of shocks						
σ^h	Inv.Gamma	0.01	0.05	0.010	[0.002,0.020]	0.007
σ^k	Inv.Gamma	0.01	0.05	0.105	[0.089,0.119]	0.104
σ^a	Inv.Gamma	0.01	0.05	0.004	[0.002,0.006]	0.004
σ^c	Inv.Gamma	0.01	0.05	0.006	[0.002,0.009]	0.005
σ^{ϵ^L}	Inv.Gamma	0.01	0.05	0.159	[0.137,0.180]	0.158
σ^{ϵ^D}	Inv.Gamma	0.01	0.05	0.004	[0.003,0.006]	0.004
σ^r	Inv.Gamma	0.01	0.05	0.002	[0.0015,0.0020]	0.002
σ^η	Inv.Gamma	0.01	0.05	0.044	[0.038,0.050]	0.044

Note: 1. Results of posterior means are obtained by running 10 chains of Metropolis-Hastings algorithm, each with 100,000 draws, of which the first 20% are dropped; 2. The average acceptance rate for 10 chains is 23.49%; 3. HPD interval refers to the highest posterior density credible interval, which is the shortest interval among all intervals that are 90% credible.

dropped when computing the statistics. According to the results, the probability of the retailers who do not adjust prices, θ, is 0.371, suggesting that retailers adjust prices frequently. The degree of indexation to previous inflation, τ, is 0.483. The smoothing parameter of the previous interest rate, ϕ_r, is 0.915, whilst $\phi_\pi = 2.202 > 1$ indicates an aggressive approach to inflation, and the PBoC considers little about the output gap when adjusting the interest rate because of a small ϕ_y of 0.06 only. This estimation result of the Taylor rule is consistent with that when using the GMM method. Also, all the shocks are very persistent except for the required-reserve-ratio shock, u_t^η, with the autoregressive parameter being 0.506. Figure 5.2 plots the kernel estimates of prior and posterior marginal densities for the structural parameters[5]. According to Gerali *et al.* (2010), deviations of the mean of posteriors from that of priors indicate that a parameter is identified. All the structural parameters are well defined. The results show weak identification of τ and ϕ_η^π. The results of the required-reserve-ratio rule are in favour of the GMM estimation result, with the smoothing parameter, ϕ_η^η, being quite persistent and $\phi_\eta^\pi = 49.977$, confirming the main objective is to restrict inflation. Finally, the results are relative stable and converged according to the convergence statistics proposed by Brooks & Gelman (1998).

5.3 Impulse response analysis

5.3.1 Window guidance for bank loans

To illustrate the impact of the window guidance rule for bank loans, Figure 5.3 compares the impulse responses to productivity and cost-push shocks[6] in the pres-

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[5]The prior and posterior marginal densities for the autoregressive parameters and the standard deviations of shocks are presented in the Appendix.

[6]Impulse responses analysis hereafter in this chapter, unless otherwise specified, indicates the impulse responses to positive shocks with the size of one standard deviation.
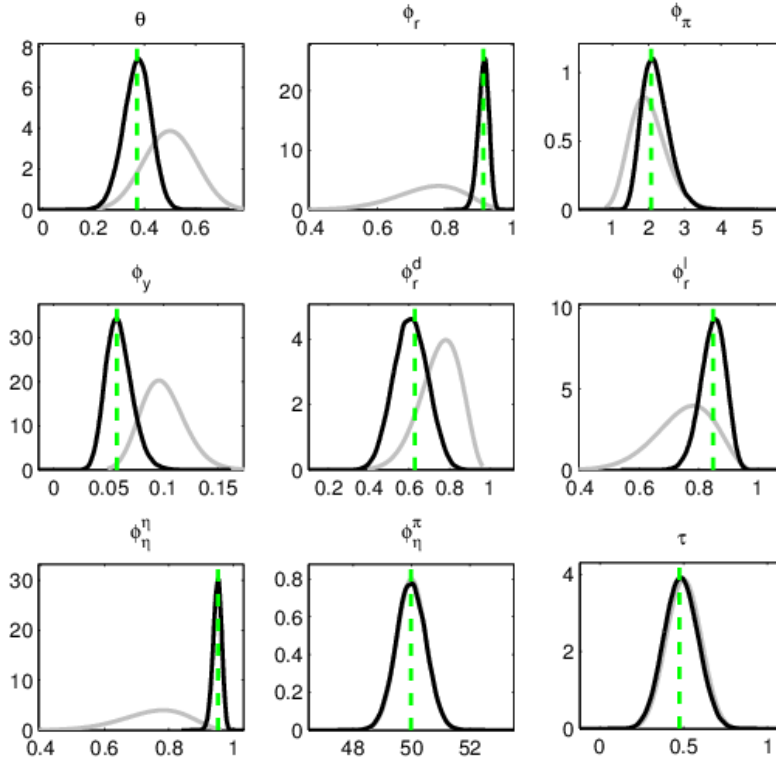
Figure 5.2: Prior and Posterior marginal distributions of structural parameters

ence of the window guidance ($\psi^W = 1$) and when the window guidance rule is removed ($\psi^W = 0$). It shows that overall imposing the window guidance rule reduces the fluctuations of inflation, and imposes a significant control on the growth of bank loans. Also, a positive productivity shock increases the initial response of output when the window guidance takes effect, and the response lasts longer as well. Similar results can be obtained from consumption and investment, whilst interest rate experiences less volatility when considering the window guidance control. In addition, a positive cost-push shock boosts inflation, leading to a sharp rise in interest rate as the central bank tightens the monetary policy. As a result, investment and consumption fall down, and output drops as well. Besides, an upward deposit rate attracts more household savings, thus resulting in an upturn in bank loans as commercial banks convert deposits into loans. However, this increase is offset by introducing the control of credit quotas, i.e. the window guidance, as commercial banks have to follow the loan targets set by the central bank. The window guidance rule also helps reduce the volatility of inflation and

lowers the increase of interest rate, but brings more volatility in consumption and investment, as well as output. Consequently, the window guidance rule controls the loan growth of commercial banks, helps reduce inflation, but gives rise to the volatility of the economy.

5.3.2   Deposit and loan rates liberalisation

The interest rate liberalisation progress of deposit and loan rates can be reflected by changing the weighted parameters, ϕ^D and ϕ^L, in equations (5.29) and (5.30). In the following analysis, three scenarios are considered, namely strict and mild controls as well as the full liberalised case. For simplicity, ϕ^D and ϕ^L are set to be equal. The results show that the effects of deregulation is affected by the window guidance rule.

Scenario 1   Strict control of deposit and loan rates : $\phi^D = \phi^L = 0.1$.

Scenario 2   Mild control of deposit and loan rates: $\phi^D = \phi^L = 0.6$.

Scenario 3   Full liberalisation of deposit and loan rates: $\phi^D = \phi^L = 1$.

The impulse responses to productivity and cost-push shocks are presented in Figure 5.4, in which the central bank does not use the window guidance for bank loans. When deposit and loan rates are both fully liberalised, output increases higher in response to a productivity shock, together with an upturn of investment, as shown in Figure 5.4a. Freeing the controls of deposit and lending rates makes both rates more sensitive to shocks. Lowering deposit rates reduces the household savings, thus bank loans increases less after considering the fall of loan rates. Inflation experiences smaller fluctuations given a productivity shock with market-determined interest rates, and this is also confirmed from a cost-push shock in Figure 5.4b. However, a cost-push shock leads to a significantly higher volatility of output and investment when deposit and loan rates are fully determined by markets. Bank loans climb gradually as investment recovers. Besides, increasing inflation calls for a higher policy rates due to a more aggressive monetary policy, and results in
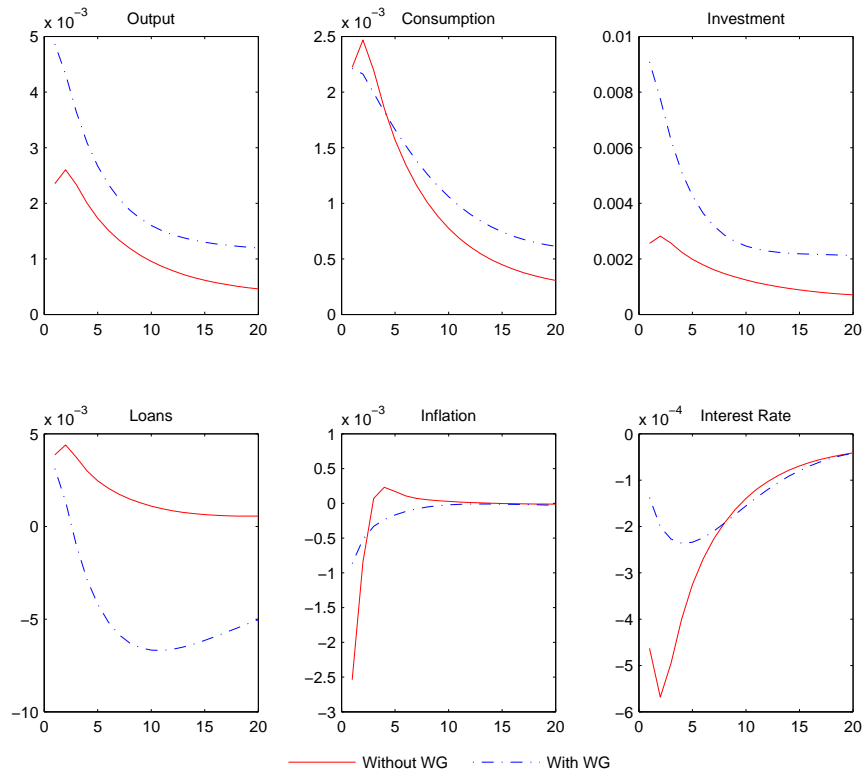
(a) Impulse responses to a productivity shock
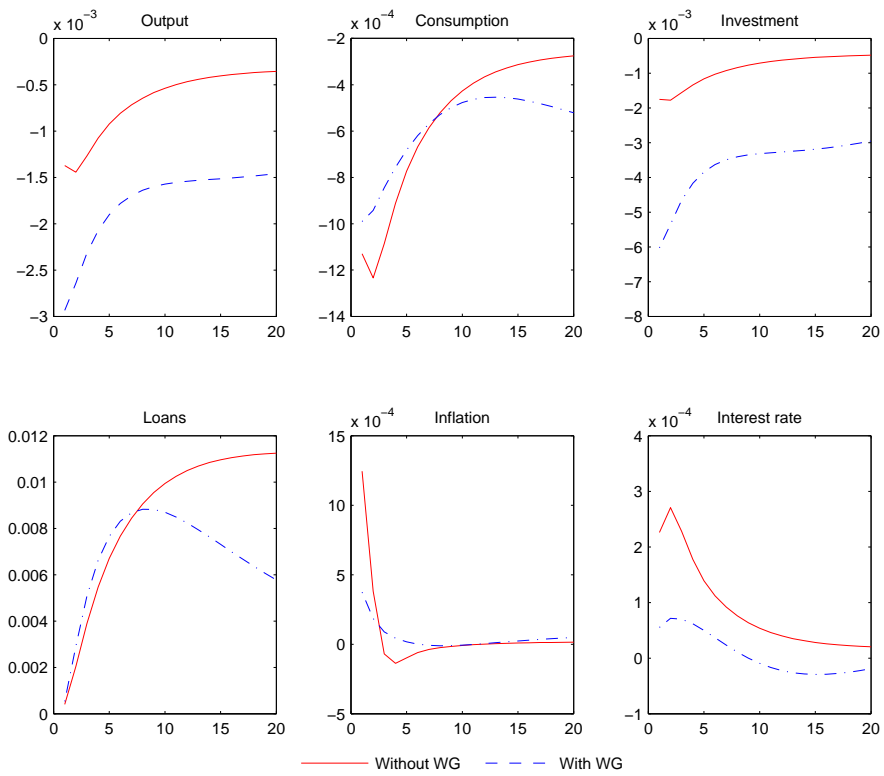
(b) Impulse responses to a cost-push shock
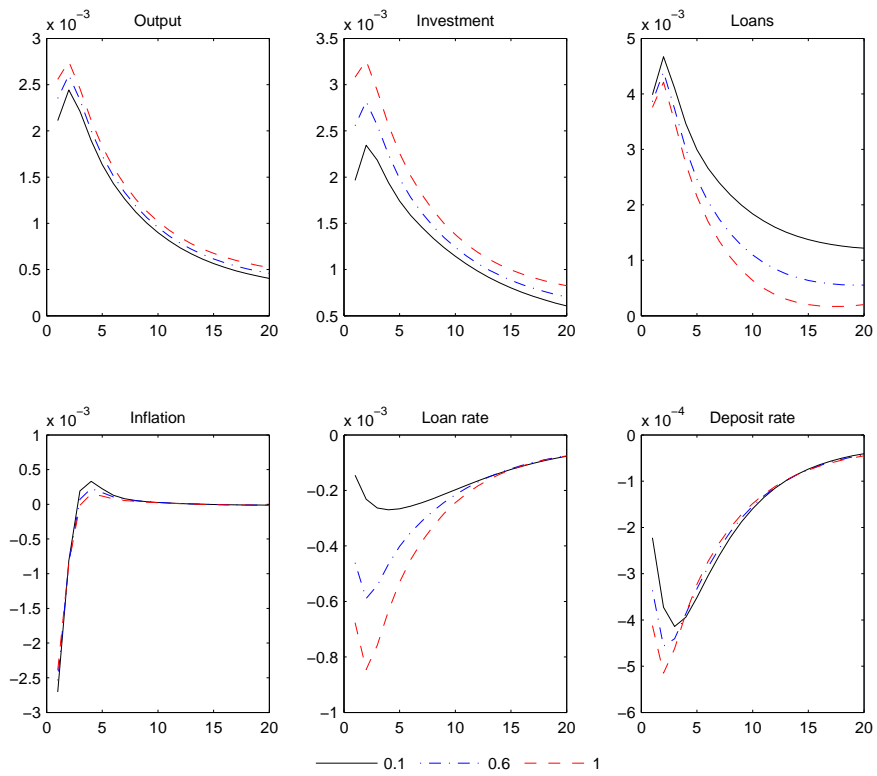
Figure 5.3: Impulse responses to productivity and cost-push shocks

an uplift in deposit and loan rates. The deregulation of deposit and loan rates makes both more volatile. Therefore, the policy rate adjusted by the central bank more actively affects the market-determined deposit and loan rates, making the transmission channels more effective and powerful.

Figure 5.5 plots the impulse responses to the two shocks under the window guidance. The same effects of deposit and loan rates liberalisation can be detected, but with small differences. Output and investment response more strongly due to the liberalisation and inflation decreases less but recovers to the steady state slightly more slowly. In fact, the window guidance boosts the impact of a productivity shock in Figure 5.5a, with the initial response of output lifted by nearly 2% compared to Figure 5.4a. Also, investment has a stronger initial response as well, whilst inflation is less volatile. Similarly, the impacts of a cost-push shock on output and investment are strengthened considerably by introducing the window guidance, as shown in Figure 5.5b. Also, there is little difference between scenarios 2 and 3 when the windows guidance is introduced. Inflation fluctuates smaller in the presence of the window guidance, and deregulations of loan and deposit rates yield fewer changes except for loan rates in response to a productivity shock, where the effectiveness of the monetary policy is improved under the window guidance rule by amplifying the effect of loan rates. The result suggests that the window guidance helps, to some degree, stabilise loan and deposit rates and reduce the volatility of inflation after deregulation.

5.3.3 Monetary policy

This model includes a Taylor-type interest rate rule and the impulse responses to an interest-rate shock are plotted in Figure 5.6. The interest rate rule plays a role that is similar to last chapter when the window guidance is turned off. Output initially reduces in response to an interest-rate shock, and recovers to the steady state afterwards, according to the solid (red) line in Figure 5.6. Consumption and

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(a) Impulse responses to a productivity shock
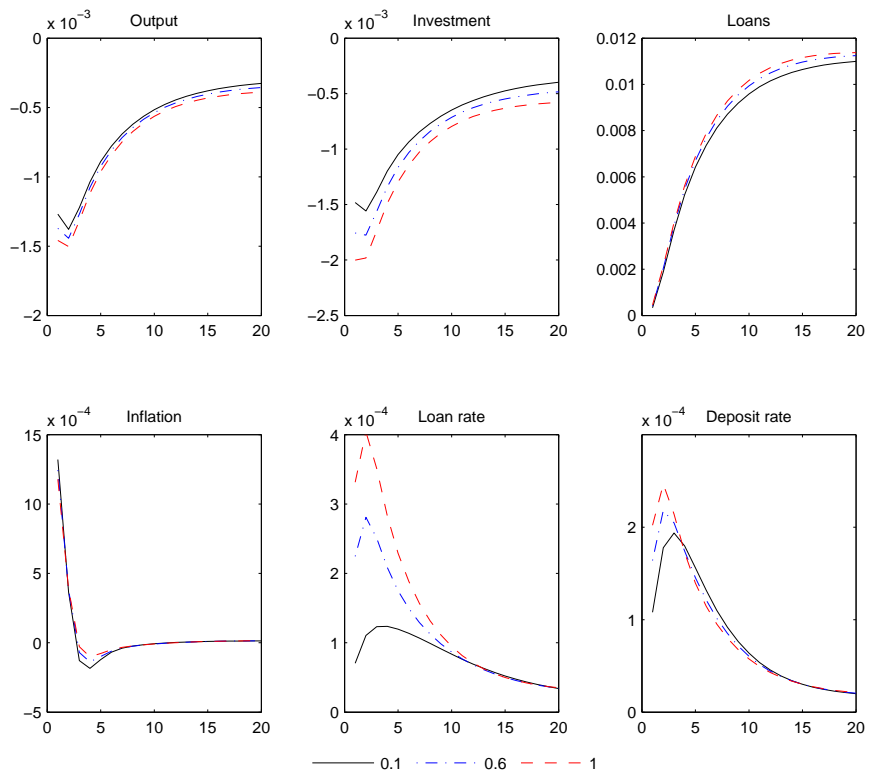
(b) Impulse responses to a cost-push shock

Figure 5.4: Impulse responses to shocks in the absence of window guidance
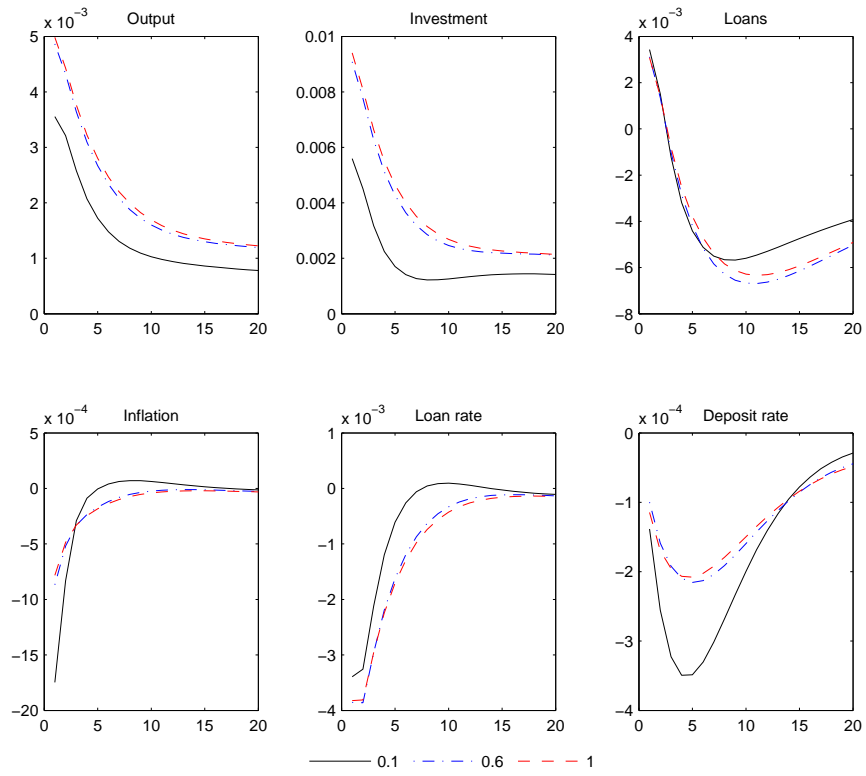
(a) Impulse responses to a productivity shock
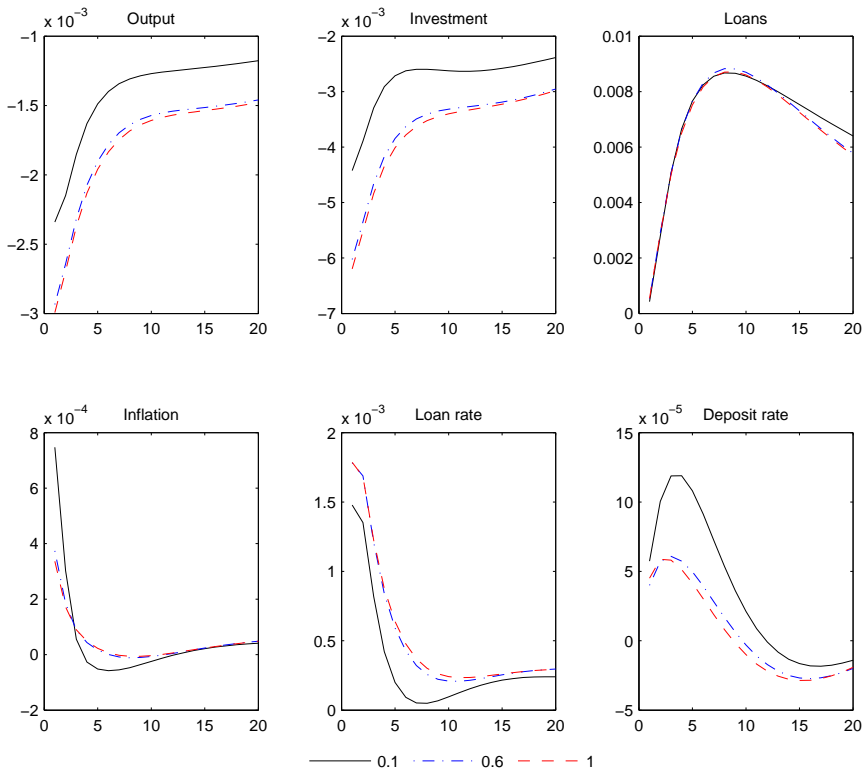
(b) Impulse responses to a cost-push shock

Figure 5.5: Impulse responses to shocks in the presence of window guidance
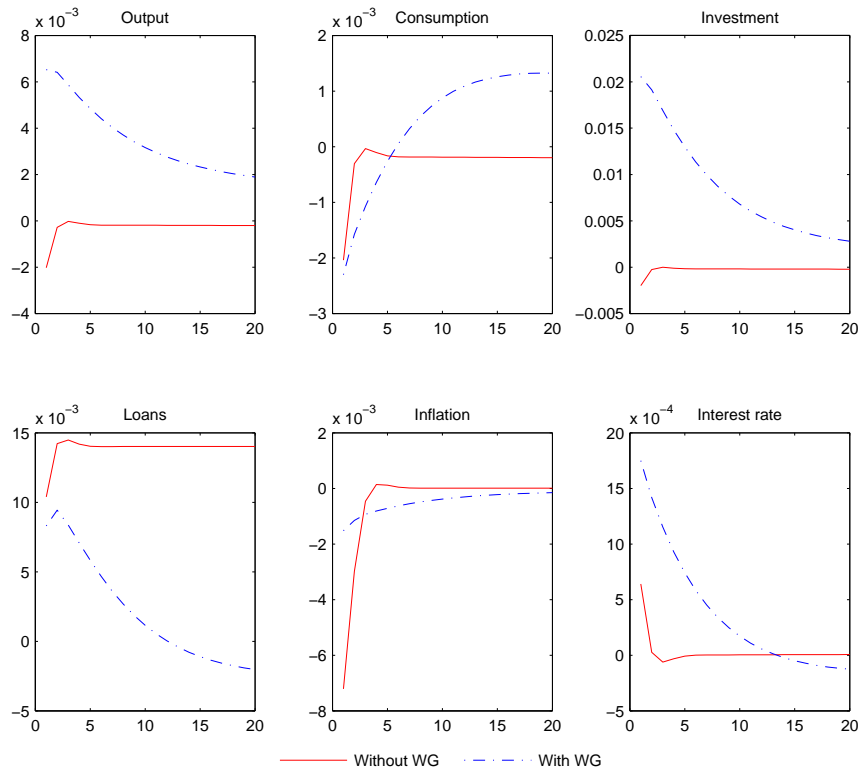
Figure 5.6: Impulse responses to an interest-rate shock

investment perform similarly to output, with a decrease at first. Inflation falls as well, so as to meet the objective of cooling the economy implemented by the central bank. Commercial banks have more deposits due to an increase in the deposit rate, as well as a fall in consumption, and bank loans converted from the deposits shoot up. However, the interest rate rule yields unusual results when the window guidance is included, as shown in the dashed (blue) lines. Investment goes up in response to an increase in the policy rate, resulting an upward shift in output. One possible reason is that a positive policy-rate shock increases the deposit rate and therefore attracts more deposits to be converted into bank loans. As a consequence, loan rates at the wholesale level drop in order to meet the loan target, and actual loan rate falls given that it is mainly determined by the market ($\phi^L = 0.6$ in this case). In addition, the interest rate rule still works to contain inflation as well when the window guidance rule is adopted.

It is acknowledged that the PBoC actively uses the required reserve ratio as an-
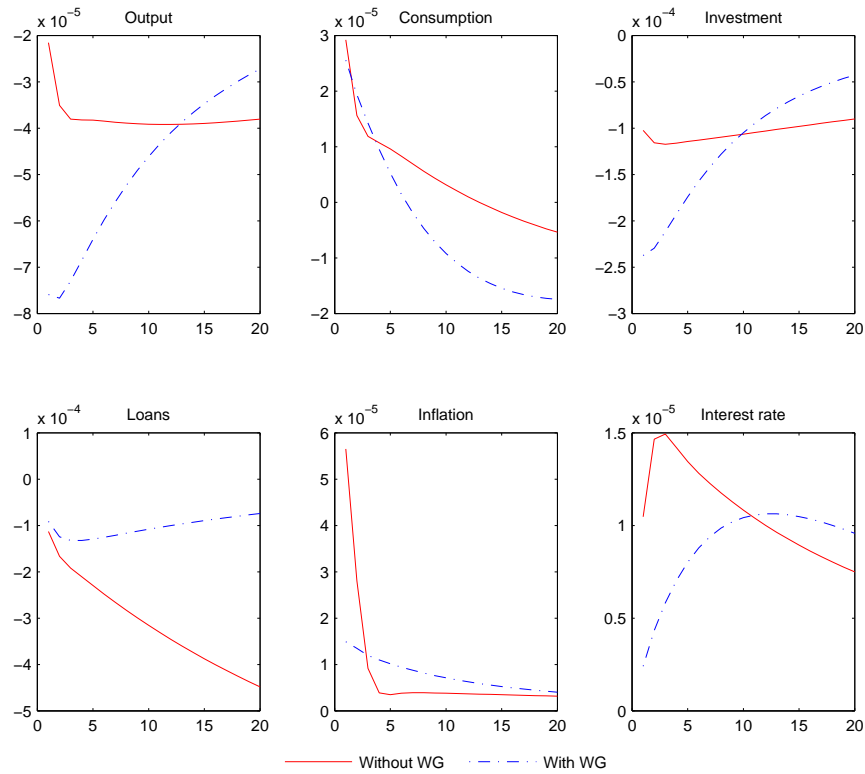
Figure 5.7: Impulse responses to a required-reserve-ratio shock

other monetary policy rule. The impulse responses to a positive shock of required reserve ratio is plotted in Figure 5.7. A positive shock of required reserve ratio reduces bank loans and investment, and interest rate goes up as well. However, the required reserve ratio is not very helpful to stabilise output when the window guidance is away, due to a surge in consumption, and makes little contribution to reducing inflation in both cases. Thus the required reserve ratio is a poor instrument to control inflation and output, but is useful to maintain bank loan levels. Sinclair & Sun (2015) reached a similar conclusion.

5.4 Modified Taylor rule

Now consider that the PBoC sets benchmark interest rate based on the policy rate in the last period, inflation and output, as well as the nominal money growth. The nominal money growth rate, $\tilde{g}_t$, is defined as $\mathcal{M}_t = (1 + \tilde{g}_t)\,\mathcal{M}_{t-1}$, where

$\mathcal{M}_t = P_t M_t$ is the nominal money supply. Therefore,

$$M_t = (1 + \tilde{g}_t) \frac{M_{t-1}}{\Pi_t} \tag{5.33}$$

Suppose that the PBoC sets the benchmark interest rate following a modified Taylor-type rule:

$$R_t = R_{t-1}^{\phi_r} \left(R \left(\frac{\Pi_t}{\bar{\Pi}} \right)^{\phi_\pi} \left(\frac{Y_t}{Y} \right)^{\phi_y} \left(\frac{1 + \tilde{g}_{t-1}}{1 + \tilde{g}} \right)^{\phi_g} \right)^{(1-\phi_r)} \exp\left(\epsilon_t^r\right) \tag{5.34}$$

where R_t is the policy interest rate set by the central bank, $\bar{\Pi}$ denotes the inflation target and ϵ_t^r captures the interest-rate shock. The parameters, ϕs, measure the preferences with respect to lagged policy rate, inflation, output gap and last-period nominal money growth, respectively. Nominal money growth enters the Taylor rule due to the annual M2 growth target set by the PBoC and the central government. Also, in case of an increase in the money demand, the central bank usually adopts an accommodative monetary policy to boost the economy. The monetary policy equation thus takes it into consideration. $\phi_g > 0$ measures the magnetites of money growth control by the PBoC. The GMM estimation suggests that $\phi_g = 0.31$, suggesting a 31-base-point increase in policy rate in response to a 1% increase in last-period nominal money growth.

In addition, money variable is introduced into the utility function of patient households and equation (5.1) now reads:

$$\max \mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \left(\beta^P\right)^t \left(\frac{1}{1 - \sigma^P} \left(C_t^P\right)^{1-\sigma^P} - \frac{1}{1 + \phi} \left(N_t\right)^{1+\phi} + \frac{1}{1 - \gamma} \left(M_t\right)^{1-\gamma} \right) \right\} \tag{5.35}$$

where M_t is the real money balances, and γ measures the inverse of elasticity of real money holdings, which is calibrated to be 3 in the following analysis.

The budget constraint in equation (5.2) is now:

$$C_t^P + D_t + M_t = \frac{R_{t-1}^D D_{t-1}}{\Pi_t} + W_t N_t + \frac{M_{t-1}}{\Pi_t} + F_t^R + F_t^C \qquad (5.36)$$

The FOC with respect to M_t gives:

$$M_t^{-\gamma} \left(C_t^P\right)^{\sigma^P} = \frac{R_t^D - 1}{R_t^D} \qquad (5.37)$$

The impulse responses of productivity and cost-push shocks are plotted in Figure 5.8, by assuming the window guidance is away in the economy. It indicates that a modified Taylor rule with last-period money growth produces smaller fluctuations in output, with a faster speed to recover to the steady state. However, using the modified Taylor rule brings about more volatility of inflation, and the fluctuations last longer as well in both cases.

5.5 Conclusion

It is acknowledged that the PBoC imposes a so-called window guidance rule to control bank loans. The result shows that the window guidance significantly controls the commercial bank loans, helps reduce inflation in response of supply shocks, but brings about more volatility of the economy. Besides, although both loan and deposit rates were announced to be freely determined by the market, the PBoC has not announced further steps about interest rate reforms and continues publishing the benchmark loan and deposit rates, which most commercial banks are willing to follow. By changing the weighted parameters to reflect different degrees of deregulation, this analysis shows that both deposit and lending rates are more sensitive to exogenous shocks, and work to reduce the volatility of inflation. However, the effects of deregulation are significantly affected by the window guidance rule. It makes little difference to the liberalisation process when both deposit
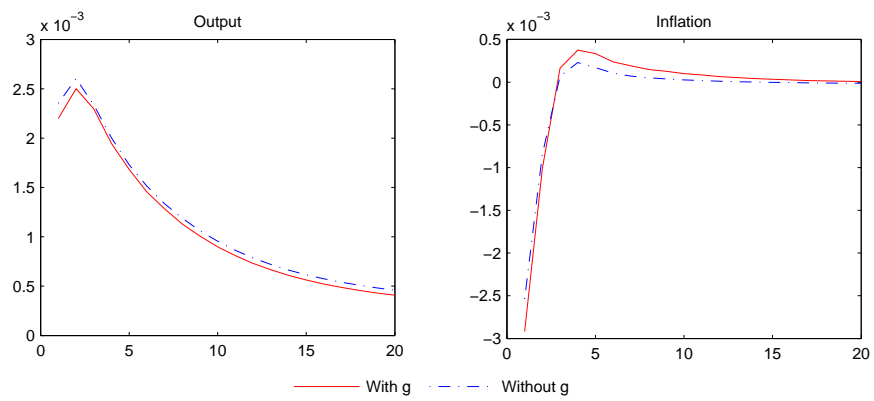
(a) Impulse responses to a productivity shock
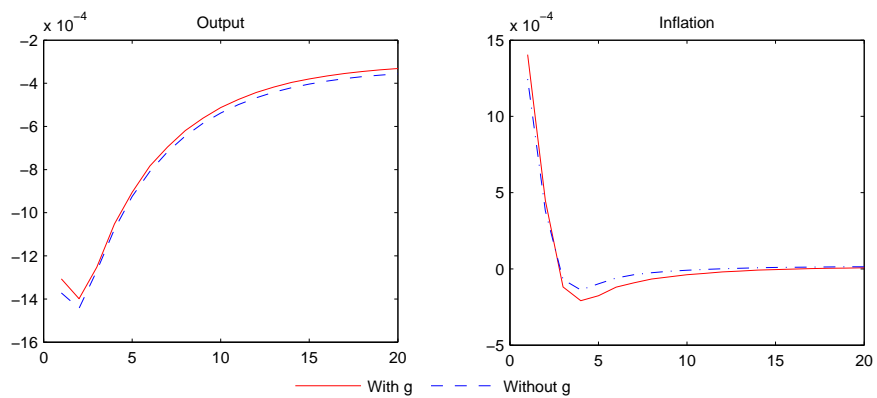
(b) Impulse responses to a cost-push shock

Figure 5.8: Impulse responses to productivity and cost-push shocks

and loan rates are largely freely determined by the market. Therefore, the PBoC should gradually relax the control of bank loans and deregulate the deposit and lending rates, so as to stabilise the economy when facing exogenous shocks.

A Taylor-type interest rate rule is assumed to be used by the PBoC when adjusting the policy rate, and deposit and lending rates are associated with this rule as well. Estimation from the data shows an aggressive Taylor rule is adopted by the PBoC, where the main objective is to contain inflation. Overall the interest rate rule works to maintain the stability of the economy, and it is more powerful in terms of reducing the volatility of inflation without the window guidance rule. In addition, a modified interest rate rule is used in this model to consider the nominal money growth when the PBoC adjusts the interest rate. In fact, in the latest 13th national five-year plan, China will reduce the use of quantity based monetary policy tools like money growth. The modified Taylor rule, though keeps output at a relatively stable level, brings about more volatility of inflation.

Lastly, unlike many advanced economies where the central bank rarely adjusts the required reserve ratio, the PBoC actively uses it in order to control the liquidity. Bank loans are significantly reduced by raising the required reserve ratio. However, the results based on this model show little evidence to control inflation by introducing a positive shock in the required reserve ratio. Moreover, it helps little to stabilise the economy regardless of the use of the window guidance rule. The reason why the PBoC actively adjusts the required reserve ratio is to prevent the money supply and bank credit from expanding excessively, as suggested by McKinnon & Schnabl (2014). The effectiveness and necessity of the required reserve ratio as a macroprudential policy should be examined in an open economy model in future research work.

5.6 Appendix

5.6.1 Model log-linearisation

The lower-case variables except interest rates, inflation, required reserve ratio and nominal money growth rate, hereafter denote the percentage derivations from the steady states. For interest rates, inflation, required reserve ratio and money growth rate, the lower-case letters represent absolute derivations.[7] Assuming the upper-case variables without a time subscript t refer to the levels of steady states, one could log-linearise the model around the steady states.

Firstly, the FOCs of patient households in equations (5.3) and (5.4) can be log-linearised as follows:

$$c_t^P = \mathbb{E}_t c_{t+1}^P - \sigma_P^{-1} \left(r_t^D - \mathbb{E}_t \pi_{t+1} + u_{t+1}^h - u_t^h \right) \tag{5.38}$$

$$w_t = \sigma^p c_t^P + \phi n_t \tag{5.39}$$

The budget constraints of impatient households in equations (5.6) and (5.7) and the Cobb-Douglas function in equation (5.8), after log-linearisation, read:

$$\frac{C^E}{Y} c_t^E = \frac{1}{X} \left(y_t - x_t \right) + \frac{L}{Y} l_t - \frac{1-\alpha}{X} \left(w_t + n_t \right) - \frac{L}{Y} \frac{1}{\beta^E} \left(r_{t-1}^L + l_{t-1} - \pi_t \right) - \frac{I}{Y} i_t \tag{5.40}$$

$$k_t = (1-\delta) k_{t-1} + \delta i_t \tag{5.41}$$

$$y_t = u_t^a + \alpha k_{t-1} + (1-\alpha) n_t \tag{5.42}$$

Similarly, a log-linear approximation of the representative impatient household's FOCs in equations (5.9) (5.10) and (5.11) gives:

$$c_t^E = \mathbb{E}_t c_{t+1}^E - \sigma_E^{-1} \left(r_t^L - \mathbb{E}_t \pi_{t+1} + u_{t+1}^h - u_t^h \right) \tag{5.43}$$

---

[7]For the required reserve ratio, $\tilde{\eta}_t$, absolute deviations from the steady state are represented by $\eta_t = \tilde{\eta}_t - \tilde{\eta}$, where $\tilde{\eta}$ is the steady state level.

$$i_t = k_{t-1} - u_t^k + \frac{1}{\psi^K} \left(\mathbb{E}_t \pi_{t+1} - r_t^L \right) + \beta^E \left(\mathbb{E}_t u_{t+1}^k + \mathbb{E}_t i_{t+1} - k_t \right) \quad (5.44)$$
$$+ \frac{1 - \beta^E + \beta^E \delta}{\psi^K} \left(\mathbb{E}_t y_{t+1} - k_t - \mathbb{E}_t x_{t+1} \right)$$

$$w_t = y_t - n_t - x_t \quad (5.45)$$

Then, a log-linear approximation of the FOC of domestic goods retailers in equation (5.16) yields the Phillips curve. In addition, it allows the elasticity in the demand function $Y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\epsilon_t} Y_t^f$ to be a time-varying parameter, ϵ_t, that fluctuates around the steady state, which introduces a cost-push shock, as described in Khan (2005). For simplify and following Chen *et al.* (2012), a cost-push shock u_t^c is augmented in the Phillips curve to follow the $AR(1)$ process:

$$\pi_t = \tau \pi_{t-1} + \beta_P \left(\mathbb{E}_t \pi_{t+1} - \tau \pi_t \right) - \frac{(1-\theta)(1-\theta\beta^P)}{\theta} x_t + u_t^c \quad (5.46)$$

The budget constraint faced by commercial banks is given by equation (5.18), with the net position in the interbank market in equilibrium is zero. The constraint is therefore,

$$\eta_t = (1 - \tilde{\eta}) d_t - (1 - \tilde{\eta}) l_t \quad (5.47)$$

where the subscript W in deposits and loans are removed since it assumes that the loans and deposits in the wholesale sector are equal to those in the retail sector.

In addition, the FOCs of the wholesale sector in equations (5.20) and (5.21) are log-linearised as:[8]

$$r_t^{L,W} = r_t^{IB} + \frac{\psi^W}{R^{IB}} \left(l_t - l_t^{CB} \right) \quad (5.48)$$

$$\left((1-\tilde{\eta}) R^{IB} + \tilde{\eta} R^R \right) r_t^{D,W} = \left(R^R - R^{IB} \right) \eta_t + \tilde{\eta} R^R r_t^R + (1-\tilde{\eta}) R^{IB} r_t^{IB} \quad (5.49)$$

Since banks have unlimited access to the lending facility, the following equation is

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[8]In equation (5.49), a standard Taylor expansion for $\tilde{\eta}_t$ is used to calculate the absolute deviation η_t: $\frac{1+\tilde{\eta}_t}{1+\tilde{\eta}} = 1 + \left(\frac{1}{1+\tilde{\eta}} \right) (\tilde{\eta}_t - \tilde{\eta}) = 1 + \frac{\eta_t}{1+\tilde{\eta}}$.

included:

$$r_t^{IB} = r_t \tag{5.50}$$

The market-determined interest rates on loans and deposits are reflected by the first order conditions in equations (5.23) and (5.25), with the log-linearised equations as below:

$$r_t^{L,M} = \frac{\epsilon^L}{\epsilon^L - 1} r_t^{L,W} + u_t^{\epsilon^L} \tag{5.51}$$

$$r_t^{D,M} = \frac{\epsilon^D}{\epsilon^D - 1} r_t^{D,W} + u_t^{\epsilon^D} \tag{5.52}$$

where $\dfrac{\epsilon^L}{\epsilon^L - 1}$ is the markup on loan rates, and $\dfrac{\epsilon^D}{\epsilon^D - 1}$ is the markdown on deposit rates. $u_t^{\epsilon^L}$ and $u_t^{\epsilon^D}$, assumed to be exogenous innovations to interest rate spreads, denote the shocks of the markup on loan rates and the markdown on deposit rates, respectively.

Central banks sets the benchmark deposit and loan rates, the window guidance for credit target, as well as the required reserve ratio. Also, actual deposit and loan rates are reflected by taking a weighted average of the market-determined rates and the central bank benchmark rates. The rules are summarised from equation (5.26) to equation (5.32). The log-linearised equations are:

$$r_t = \phi_r r_{t-1} + (1 - \phi_r)(\phi_\pi \pi_t + \phi_y y_t) + \epsilon_t^r \tag{5.53}$$

$$r_t^{D,CB} = \phi_r^d r_{t-1}^{D,CB} + (1 - \phi_r^d) r_t \tag{5.54}$$

$$r_t^{L,CB} = \phi_r^l r_{t-1}^{L,CB} + (1 - \phi_r^l) r_t \tag{5.55}$$

$$r_t^D = (1 - \phi^D) r_t^{D,CB} + \phi^D r_t^{D,M} \tag{5.56}$$

$$r_t^L = (1 - \phi^L) r_t^{L,CB} + \phi^L r_t^{L,M} \tag{5.57}$$

$$l_t^{CB} = \phi_l^{cb} l_{t-1}^{CB} + (1 - \phi_l^{cb}) [\phi_l^l l_t + (1 - \phi_l^l)(\phi_l^\pi \pi_t + \phi_l^y y_t)] \tag{5.58}$$

$$\eta_t / \tilde{\eta} = (\phi_\eta^\eta / \tilde{\eta}) \eta_{t-1} + (1 - \phi_\eta^\eta) \phi_\eta^\pi \pi_t + u_t^\eta \tag{5.59}$$

Next, the interest rate of required reserves deposited at the central bank, R_t^R, is assumed to passively follow the benchmark rate:

$$r_t^R = r_t \tag{5.60}$$

Lastly, the market clearing condition after log-linearisation is:

$$y_t = \frac{C^P}{Y} c_t^P + \frac{C^E}{Y} c_t^E + \frac{I}{Y} i_t \tag{5.61}$$

and the aggregate consumption is outlined as:

$$c_t = \frac{\frac{C^P}{Y}}{1 - \frac{I}{Y}} c_t^P + \left(1 - \frac{\frac{C^P}{Y}}{1 - \frac{I}{Y}}\right) c_t^E \tag{5.62}$$

All the shocks, except the white-noise interest-rate shock, are assumed to follow the $AR(1)$ process:

$$u_t^h = \rho_h u_{t-1}^h + \epsilon_t^h \tag{5.63}$$

$$u_t^k = \rho_k u_{t-1}^k + \epsilon_t^k \tag{5.64}$$

$$u_t^a = \rho_a u_{t-1}^a + \epsilon_t^a \tag{5.65}$$

$$u_t^c = \rho_c u_{t-1}^c + \epsilon_t^c \tag{5.66}$$

$$u_t^{\epsilon^L} = \rho_{\epsilon^L} u_{t-1}^{\epsilon^L} + \epsilon_t^{\epsilon^L} \tag{5.67}$$

$$u_t^{\epsilon^D} = \rho_{\epsilon^D} u_{t-1}^{\epsilon^D} + \epsilon_t^{\epsilon^D} \tag{5.68}$$

$$u_t^\eta = \rho_\eta u_{t-1}^\eta + \epsilon_t^\eta \tag{5.69}$$

Equations (5.38) to (5.69) constitute a system of linear rational expectations differences equations containing 32 endogenous variables, plus 8 exogenous driving forces.

5.6.2 Prior and posterior marginal densities

Figure 5.9 plots the kernel estimates of prior and posterior marginal densities for the autoregressive parameters and the standard deviations of shocks.
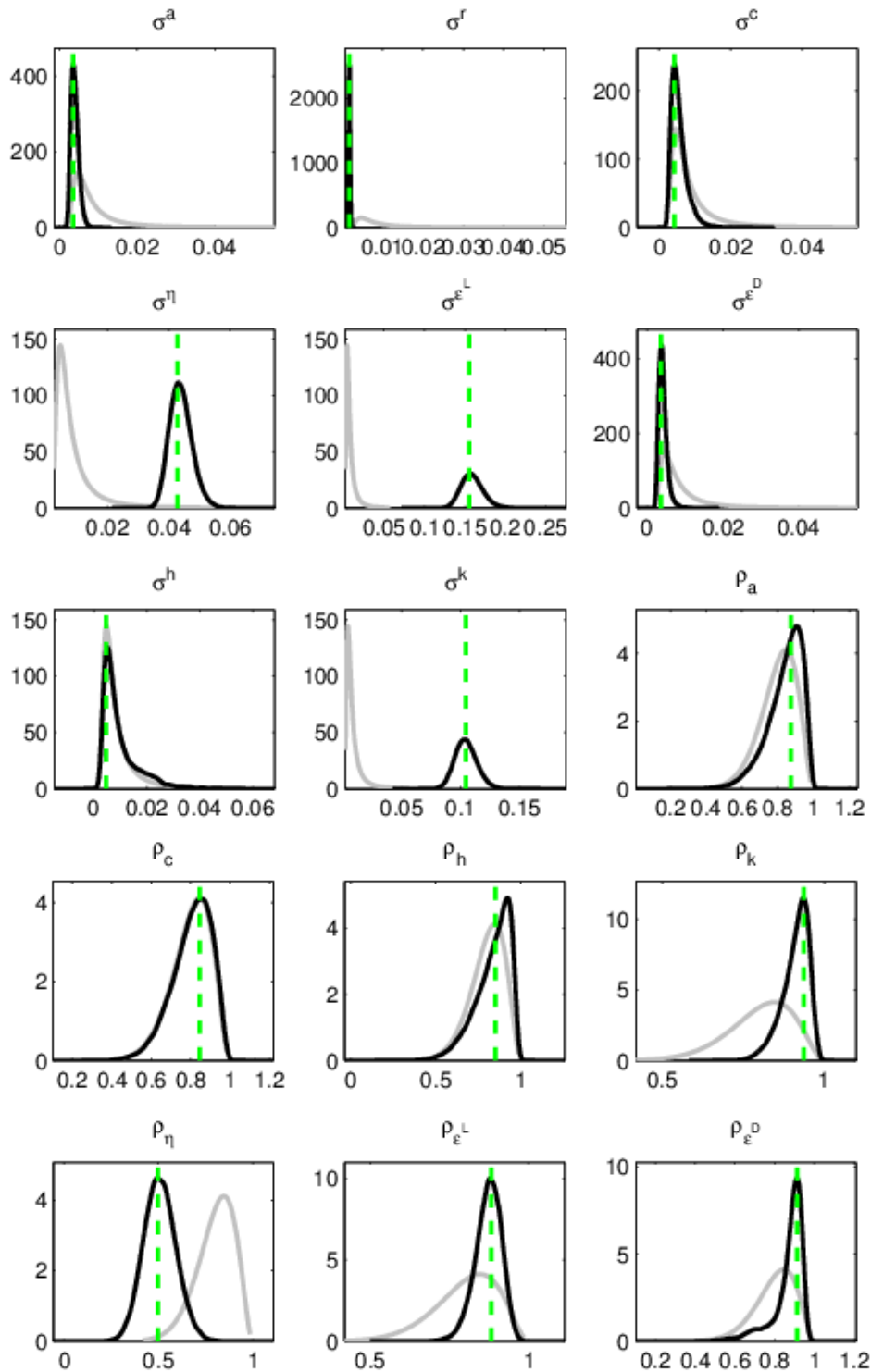
Figure 5.9: Prior and Posterior marginal distributions

Chapter 6

Investigating sources of real exchange rate fluctuations

6.1 Introduction

One of the main concepts of financial liberalisation is exchange rate reform in addition to interest rate liberalisation. The exchange rate system in China has experienced several changes since 1978, each with distinct features. In fact, it is very difficult to identify the exchange rate regime before 1994. A dual exchange rate system was adopted between 1979 and 1993. The official exchange rate was used for nontradable transactions whilst the international settlement rate was applied to authorised merchandise trade between 1979 and 1984. After that, the official exchange rate and the international settlement rate determined in swap centres coexisted until 1994 (Wang, 2005). On 1 January 1994, China officially announced the decision to implement a managed floating exchange rate system with reference to the U.S. dollar. However, the exchange rate of RMB to U.S. dollars was de facto fixed at 8.277 from 1998, as shown in Figure 6.1. On 21 July 2005, China embarked on a managed floating exchange rate system where the RMB exchange rate is adjustable by referring to a basket of currencies, rather than
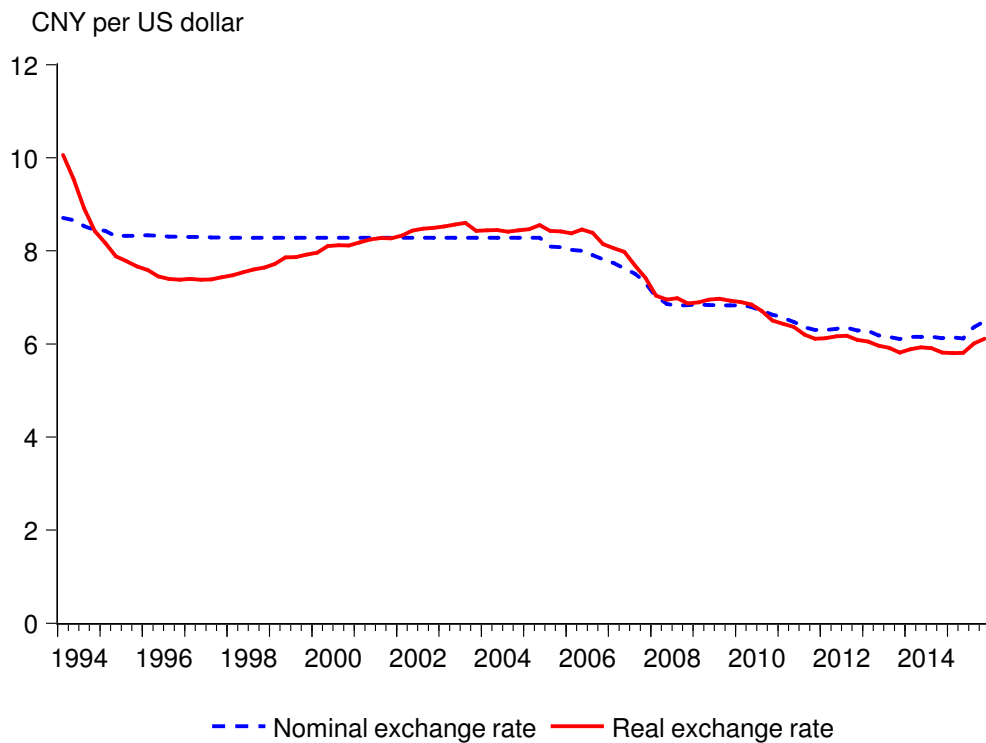
Figure 6.1: Nominal and real exchange rates against U.S. dollars

pegged to U.S. dollars only (Cheng, 2013). The nominal exchange rate against the dollar appreciated immediately by 2.1% on that day. Meanwhile, the daily range of fluctuations was allowed to be ±0.3%, and later ±0.5% in May 2007. Although the details of the basket of currencies remain unknown to the public, a continuous appreciation of the exchange rate against U.S. dollars to 6.83 has been witnessed since 2005 up to July 2008. During the global financial crisis in 2008 and 2009, the RMB was pegged to the dollar at 6.83 and started to appreciate gradually from September 2009. The upward crawling peg against the U.S. dollar persisted up to 6.12 in July 2015, and a minor depreciation was captured again after that. Prasad *et al.* (2005) suggest that a more flexible exchange rate arrangement is in China's own interest in that China has been more exposed to various types of macroeconomic shocks, and the flexibility helps to better adjust to such shocks and facilitates a more independent monetary policy.

According to Huang & Guo (2007), the Chinese RMB has long been regulated dur-

ing these years, so that identifying a path of exchange rate is challenging and even impossible based on historical evidences. Moreover, real exchange rate is usually related to the export price competitiveness. Therefore, it is vital to examine the sources of real exchange rate movements and it has important implications for the PBoC to make decisions about the future exchange rate reform.

The sources of real exchange rate variations have long been debated. Using a disequilibrium approach, Dornbusch (1976) explains that the interaction of nominal monetary shocks with sticky prices contributes to variations, whilst Stockman (1987) argued that the fluctuations arise due to output market disequilibrium led by real variables like productivity, labour supply and government expenditure. In addition to the development of exchange rate regime, China has witnessed continuous and rapid development during this period, with expected structural changes. Therefore, supply shocks, i.e. a sudden shift in the supply curve, are expected to be responsible for real exchange rate fluctuations during this period. Also, nominal shocks, or monetary shocks equivalently, play a role in terms of high inflation. China has undergone several periods of high inflation since the mid-1990s, with an average annual inflation of above 10%. In addition, inflation rate surged again during the subprime crisis in 2007-2008, and remained at 2-3% in recent years. Lastly, real exchange rate is widely acknowledged to be driven by demand shocks shifting the demand curve, as demand shocks eventually affect the prices of goods and services.

In terms of a managed floating exchange rate regime that is currently adopted in China, what are the main sources of real exchange rate movements and how important each type of structural shocks is responsible for the fluctuations in China? This chapter seeks to answer this question by estimating a structural VAR model. In the spirit of Blanchard & Quah (1989) where real exchange rate movements are broken down and led by structural shocks in the economy, it follows Clarida & Gali (1994) by considering three kinds of structural shocks including real relative supply and demand shocks and nominal monetary shocks, and employs a trivari-

ate structural VAR model to look into movements of real exchange rate, as well as relative output and price levels. The model proposed by Clarida & Gali (1994) in this chapter is modified by replacing the perfect capital mobility assumption, with a more appropriate assumption that the mobility is not perfect. Technically, this modification replaces the uncovered interest rate parity (UIP) condition with a balance of payments equation and introducing a parameter, κ, which denotes the degree of capital mobility. Although it modifies the expected magnitudes of the effects of the shocks on the underlying variables, it does not as it turns out, affect any of the reduced form expected signs. Following that, The long-run restrictions are imposed following Clarida & Gali (1994) in order to estimate the model using quarterly data covering 1995 until 2015. The results from impulse responses analysis and variance decomposition suggest that real relative demand shocks are the principal sources of real exchange rate fluctuations both temporarily and permanently, whilst relative supply and nominal shocks contribute to variations of real exchange rate at a considerable level. In order to check the robustness of the result, this chapter also looks at a sub-sample period between 2005Q3 until 2015Q2, during which the exchange rate system is managed floating with reference of a group of different currencies. The results are overall consistent with the findings from the model with a full sample size. Moreover, as model with quarterly data is subject to insufficient observations, this chapter then uses monthly data to estimate the model with long-run restrictions for the period between July 2005 and June 2015. According to the result, relative demand shocks are the principal sources driving real exchange rate fluctuations, which is in favour of previous results. However, nominal monetary shocks are less important in driving variations of real exchange rate than relative supply shocks, which is a different result from previous findings using quarterly data. Following that, sign restrictions are imposed to identify supply and nominal shocks to compare the previous results and the model with monthly data yields consistent result as that based on quarterly data with long-run restrictions.

This chapter is organised as follows. Following the introduction in this section, Section 6.2 outlines and interprets the modified Clarida & Gali (1994) theoretical framework, to allow for imperfect capital mobility, and Section 6.3 explains the methodologies of estimating a structural VAR model. Data selection and some preliminary analyses are presented in Section 6.4. Following that, Section 6.5 gives the main empirical results based on quarterly data, together with a sub-sample analysis. Monthly data are collected and used to compute the empirical results with the application of both long-run and sign restrictions, as presented in Section 6.6. Section 6.7 concludes.

6.2   Theoretical framework

The model used in this study is a stochastic rational expectations open-economy Mundell-Fleming-Dornbusch model developed by Clarida & Gali (1994) following the work of Obstfeld *et al.* (1985). In this chapter the model is modified to allow for the fact that China's capital market are not fully integrated with the world capital markets and therefore capital mobility is expected to be imperfect. Price rigidity is assumed to be present in the short run, whilst money neutrality is posited in the long run. All the variables except interest rates are in natural logarithms, defined in terms of home country variable relative to foreign country equivalent. For example, $y_t \equiv y_t^h - y_t^f$. The open-economy IS equation is then defined as:

$$y_t^d = \eta q_t - \sigma \left(i_t - E_t \left[p_{t+1} - p_t \right] \right) + d_t \tag{6.1}$$

where y_t^d is the relative aggregate demand for output, q_t is the real exchange rate, i_t is the interest rate difference between home and foreign countries, p_t is the relative price of output, and d_t denotes all the exogenous changes in the IS curve such as fiscal shocks. The relative expected rate of inflation at time t, $E_t \left[p_{t+1} - p_t \right]$ is to keep up at time $t + 1$. η, $\sigma > 0$ are parameters. The standard LM equation in the

money market is given by:

$$m_t - p_t = y_t - \lambda i_t \tag{6.2}$$

where m_t is the relative demand for money, $\lambda > 0$ is a parameter of i.

In addition, the interest rate differential, i_t, in Clarida & Gali (1994) is determined by the UIP condition, $i_t = E_t[e_{t+1} - e_t]$, where the nominal interest rate differential of home and foreign country levels is equal to the expected changes in the relative nominal exchange rate. In contrast, this chapter assumes China's capital market is less fully integrated with global markets. Thus the UIP relationship is replaced by an equation of balance of payments. The nominal exchange rate moves to bring about *ex ante* balance of payments equilibrium, which is given by:

$$\tau q_t + \kappa (i_t - E_t[e_{t+1} - e_t]) = 0 \tag{6.3}$$

where $\tau > 0$ is a parameter and the other parameter, κ, denotes the degree of capital mobility, which is assumed to be strictly greater than zero. When $\kappa \to \infty$ there is perfect capital mobility and the UIP condition holds.

Lastly, the relative price level in period t is described in the price-setting equation:

$$p_t = (1 - \theta) E_{t-1} p_t^* + \theta p_t^* \tag{6.4}$$

According to the price-setting equation (6.4), prices are perfectly flexible when $\theta = 1$ and thus output is purely determined by the supply curve. If $\theta = 0$, however, prices are inflexible and predestined in the last period. In order to solve the model, Clarida & Gali (1994) specified three stochastic processes driving the relative output supply, y_t^s, the exogenous changes in the IS curve, d_t, and the relative money, m_t, in the following equations:

$$y_t^s = y_{t-1}^s + u_t^s \tag{6.5}$$

$$m_t = m_{t-1} + u_t^n \tag{6.6}$$

$$d_t = d_{t-1} + u_t^d - \gamma u_{t-1}^d \tag{6.7}$$

where u_t^s, u_t^n and u_t^d are relative supply shocks, nominal shocks (or monetary shocks equivalently) and relative non-monetary demand shocks, respectively. Supply and nominal shocks are permanent due to the random walk settings in equation (6.5) and equation (6.6). Demand shocks, however, consist of permanent and transitory elements, and the transitory component is corrected in the next period, as shown in equation (6.7).

The model can then be solved in a flexible-price equilibrium with rational expectations where $\theta = 1$. The long-run solutions are summarised in equations (6.8), (6.9) and (6.10)[1]:

$$y_t^* = y_t^s \tag{6.8}$$

$$q_t^* = (\eta + \sigma\tau/\kappa)^{-1} (y_t^s - d_t) + (\eta + \sigma\tau/\kappa)^{-1} (\eta + \sigma + \sigma\tau/\kappa)^{-1} \sigma\gamma u_t^d \tag{6.9}$$

$$p_t^* = m_t - y_t^s - \beta (y_t^s - d_t) + \alpha\gamma u_t^d \tag{6.10}$$

where $\alpha = \lambda (\eta - (\lambda\tau/\kappa) (\eta + \sigma + \sigma\tau/\kappa)) (1 + \lambda)^{-1} (\eta + \sigma\tau/\kappa)^{-1} (\eta + \sigma + \sigma\tau/\kappa)^{-1}$ and $\beta = (\lambda\tau/\kappa) (\eta + \sigma\tau/\kappa)^{-1}$.

According to the long-run solutions above and noting that the variables with a superscript * indicate the long-run equilibrium levels, relative output responds only to supply shocks, whilst demand shocks affect the level of the real exchange rate and the relative price level. All the three variables in the long run are driven by supply shocks, whilst nominal shocks are responsible for the variables in the relative price level only. Clarida & Gali (1994) then considered the short-run equilibrium when $\theta < 1$, indicating the sluggish price adjustment. The price-setting equation thus becomes:

$$p_t = p_t^* - (1 - \theta) \left(u_t^n - (1 + \beta) u_t^s + (\alpha\gamma + \beta) u_t^d \right) \tag{6.11}$$

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[1]See Appendix 6.8.1 for the details of both long-run and short-run solutions

According to equation (6.11), the price level decreases in reaction to positive supply shocks, but less than p_t^*. Similarly, it increases but less than p_t^* in response to positive nominal and demand shocks. The real exchange rate under sluggish price adjustment in the short period is described as:

$$q_t = q_t^* + \nu \left(1 - \theta\right) \left(u_t^n - \left(1 + \beta\right) u_t^s + \left(\alpha\gamma + \beta\right) u_t^d\right) \tag{6.12}$$

where $\nu = \left(1 + \lambda\right) \left(\left(\lambda + \sigma\right) \left(1 + \tau/\kappa\right) + \eta\right)^{-1}$. The real exchange rate under sticky prices is driven by all the three structural shocks in the short run, with nominal shocks suggest a positive temporary impact. Lastly, the IS equation in the short run reads:

$$y_t = y_t^* + \left(\eta + \sigma + \sigma\tau/\kappa\right) \nu \left(1 - \theta\right) \left(u_t^n - \left(1 + \beta\right) u_t^s + \left(\alpha\gamma + \beta\right) u_t^d\right) \tag{6.13}$$

where short-run relative output is affected by nominal and demand shocks, in addition to supply shocks, which is different from the long run.

Equations (6.11), (6.12) and (6.13) summarise the stochastic open macro equilibrium where all the three structural shocks influence y_t, q_t and p_t contemporaneously. However, as all the three variables are expected to converge to equilibrium levels with flexible prices in the long run, Clarida & Gali (1994) then imposed three restrictions on the equilibrium in the long run. To be specific, nominal shocks and demand shocks have no permanent impacts on the relative output. Besides, nominal shocks have no persistent effects on the real exchange rate, either. All the short-run dynamics, however, are set to be freely determined.

6.3 Econometric methodologies

6.3.1 The structural vector autoregression model

This chapter employs the structural vector autoregression (VAR) model that is widely used to study the sources of real exchange rate fluctuations. Lastrapes (1992) built a bivariate structural VAR model to study the sources of real exchange rate movements in terms of real and nominal shocks, whilst Clarida & Gali (1994) constructed a trivariate structural VAR model to incorporate real demand and supply shocks, as well as nominal monetary shocks in the analysis. As was initially proposed by Sims (1980), VAR model serves as an alternative to the conventional large-scale dynamic simultaneous models. Kilian (2011) discussed numerous structural VAR models as well as alternative ways for identification of shocks. To begin with, consider a K-dimensional time series x_t, $t = 1, 2, ...T$, and x_t can be approximated in a VAR model with finite order p, which reads:

$$B_0 x_t = B_1 x_{t-1} + B_2 x_{t-2} + ... + B_p x_{t-p} + u_t \qquad (6.14)$$

where $B's$ are parameter matrices and u_t is a vector of structural shocks, with zero mean and uncorrelated with each other. Equivalently, the model can be written as:

$$B(L) x_t = u_t$$

where $B(L) \equiv B_0 - B_1 L - B_2 L^2 - ... - B_p L^p$ is the autoregressive lag order polynomial. The variance-covariance matrix of u_t is usually normalised such that:

$$E\left(u_t u_t^T\right) = \Sigma_u = I_k$$

Therefore, the number of endogenous variables is equal to the number of structural shocks. To estimate the model, the reduced-form should be derived by expressing x_t as a function of its own lags. To do this, multiply by B_0^{-1} on both sides of

equation (6.14) to get:

$$B_0^{-1} B_0 x_t = B_0^{-1} B_1 x_{t-1} + B_0^{-1} B_2 x_{t-2} + ... + B_0^{-1} B_p x_{t-p} + B_0^{-1} u_t$$

Define $A_i = B_0^{-1} B_i$ and $\varepsilon_t = B_0^{-1} u_t$, the equation above reads:

$$x_t = A_1 x_{t-1} + A_2 x_{t-2} + ... + A_p x_{t-p} + \varepsilon_t \tag{6.15}$$

Or equivalently,

$$A(L) x_t = \varepsilon_t$$

where $A(L) = I - A_1 L - A_2 L^2 - ... - A_p L^p$ is the lag order polynomial. Therefore, the parameters, A_i, and the disturbance term, ε_t, as well as the variance-covariance matrix of the disturbance term, $\Sigma_\varepsilon = E\left(\varepsilon_t \varepsilon_t^T\right)$ can be estimated via standard estimation methods. However, what is concerned here is the responses of x_t to structural shocks, u_t, other than to disturbances, ε_t. To obtain u_t, B_0^{-1} should be estimated, as $\varepsilon_t = B_0^{-1} u_t$. To solve B_0^{-1}, consider the variance-covariance matrix of the disturbance term, Σ_ε:

$$\Sigma_\varepsilon = E\left(\varepsilon_t \varepsilon_t^T\right) = B_0^{-1} E\left(u_t u_t^T\right) \left(B_0^{-1}\right)^T = B_0^{-1} \left(B_0^{-1}\right)^T \tag{6.16}$$

Since Σ_ε can be estimated, this system of nonlinear equations can be solved for the unknown parameters in B_0^{-1} using numerical estimation methods, provided that the number of unknown parameters in B_0^{-1} is less than or equal to the number of equations in VAR. One common way to meet this condition is to impose zero restrictions on the selected elements of B_0^{-1}.

6.3.2 Long-run restrictions

Alternatively, long-run restrictions can be imposed in the VAR, which is more feasible in terms of economic theory. To do this, recall $B(L) x_t = u_t$ and the

corresponding structural vector moving average (VMA) representation reads

$$x_t = B(L)^{-1} u_t = C(L) u_t \tag{6.17}$$

where $C(L) = B(L)^{-1}$. Also, the reduced form of VAR model above, $A(L) x_t = \varepsilon_t$, gives the corresponding VMA representation:

$$x_t = A(L)^{-1} \varepsilon_t = D(L) \varepsilon_t$$

where $D(L) = A(L)^{-1}$. Additionally, it is known that $A(L) = B_0^{-1} B(L)$, hence $B_0^{-1} = A(L) B(L)^{-1}$. The long-run relationships can be reflected by setting $L = 1$, meaning $B_0^{-1} = A(1) B(1)^{-1}$. Therefore the variance-covariance matrix of the disturbances can be interpreted as

$$\Sigma_\varepsilon = B_0^{-1} \left(B_0^{-1}\right)^T = \left[A(1) B(1)^{-1}\right] \left[A(1) B(1)^{-1}\right]^T$$

Pre-multiply by $A(1)^{-1}$ and post-multiply by $\left[A(1)^{-1}\right]^T$ on both sides yield:

$$
\begin{aligned}
A(1)^{-1} \Sigma_\varepsilon \left[A(1)^{-1}\right]^T &= A(1)^{-1} A(1) B(1)^{-1} \left[B(1)^{-1}\right]^T [A(1)]^T \left[A(1)^{-1}\right]^T \\
&= B(1)^{-1} \left[B(1)^{-1}\right]^T
\end{aligned}
$$

Replacing $A(1)^{-1}$ and $B(1)^{-1}$ by $D(1)$ and $C(1)$, respectively, one can obtain the following relationship:

$$D(1) \Sigma_\varepsilon D(1)^T = C(1) C(1)^T \tag{6.18}$$

It is known that the LHS of the equation above can be estimated from the data in terms of long-run relationships. Selected elements in $C(1)$ can be estimated by imposing $\dfrac{K(K-1)}{2}$ restrictions on it, where K is the number of endogenous variables, or equivalently the number of equations in VAR. Once $C(1)$ is able to be estimated after imposing restrictions, $B_0^{-1} = A(1) C(1)$ is obtained in order to

get the estimate of u_t through $\varepsilon_t = B_0^{-1} u_t$.

To further study the fluctuations of real exchange rate, this chapter then refers to the model of Clarida & Gali (1994) by adding three endogenous variables in the structural VAR model, i.e. $K = 3$. The three variables, namely the relative output y_t, the relative price level p_t and the real exchange rate q_t are non-stationary in levels but stationary after taking first-order difference. Therefore, the variables enter the structural VAR model as $x_t = [\Delta y_t, \Delta q_t, \Delta p_t]^T$, and the long-run representation of equation (6.17), according to Ahmad & Pentecost (2009), is written as follows:

$$
\begin{bmatrix} \Delta y_t \\ \Delta q_t \\ \Delta p_t \end{bmatrix} = \begin{bmatrix} C_{11}(1) & C_{12}(1) & C_{13}(1) \\ C_{21}(1) & C_{22}(1) & C_{23}(1) \\ C_{31}(1) & C_{32}(1) & C_{33}(1) \end{bmatrix} \begin{bmatrix} u_t^s \\ u_t^d \\ u_t^n \end{bmatrix}
\tag{6.19}
$$

where $u_t = \left[u_t^s, u_t^d, u_t^n \right]^T$ captures three kinds of structural shocks, i.e. real relative supply shocks, u_t^s, real relative demand shocks, u_t^d and nominal monetary policy shocks, u_t^n.

According to the analysis above, in this case, $\dfrac{K(K-1)}{2} = 3$ long-run restrictions on $C(1)$ are necessary so as to identify the structural shocks. The long-run restrictions following the idea of Blanchard & Quah (1989) suggest that monetary policy shocks are neutral in the long run, thus having no persistent effects on the output level and the level of real exchange rate, i.e. $C_{13}(1) = C_{23}(1) = 0$. Besides, real relative demand shocks have no continuous effects on output in the long run, indicating $C_{12}(1) = 0$. In other words, the cumulative impacts of these shocks are zero in the long run.

6.3.3 Sign restrictions

In addition to the long-run restrictions imposed in the structural VAR, Uhlig (2005), Peersman (2005) and Fry & Pagan (2007) imposed sign restrictions on

the matrix, B_0^{-1}, where each type of identified structural shocks is associated with a unique sign pattern. To describe the idea of sign restrictions, recall that initially one could impose short-run restrictions on the matrix, B_0^{-1}, in order to estimate equation (6.16). One popular way of disentangling the structural shocks from the reduced-form disturbances is to 'orthogonalise' the reduced-form errors, according to Kilian (2011), which makes the shocks uncorrelated. Consequently, B_0^{-1} becomes a lower triangular matrix after imposing $\dfrac{K(K-1)}{2}$ restrictions. Mathematically, one can obtain lower triangular Cholesky decomposition, P, that satisfies $\Sigma_\varepsilon = PP^T$, but it is appropriate only if the recursive structure embodied in P is consistent with the economic theory. Now consider $B_0^{-1} = PQ$ where Q is an orthogonal $K \times K$ matrix, so that the relationship in equation (6.16) is still satisfied. The set of admissible models can then be constructed by repeatedly drawing at random from the set $\mathbf{Q}$ of orthogonal matrices Q, and discarding the cases where the solutions for B_0^{-1} do not satisfy the prior sign restrictions imposed on B_0^{-1} (Kilian, 2011; Rubio-Ramírez *et al.*, 2010).

6.4 Data selection

6.4.1 The data

Given the availability of the data, the period involved in this study covers 1995Q1 until 2015Q2, during which China has been officially using a managed floating exchange rate system with reference to a combination of different currencies. The relative output level, the real exchange rate and the relative price level are considered in the trivariate structural VAR model, all of which are computed as the log difference of the home level from China's trading partners equivalent. The relative output level, y_t, is measured by the natural log difference between real GDP in China and foreign country, and the log of real exchange rate, q_t, is constructed from the log of nominal exchange rate, e_t, interpreted as the domestic price of

foreign currency. Therefore, the log of real exchange rate can be calculated as $q_t = e_t + p_t^f - p_t^h$, where p_t^h and p_t^f are the logs of home and foreign CPI, respectively. The relative price level, p_t, is defined as the log difference between home and foreign price level, $p_t = p_t^h - p_t^f$. In this study, the foreign country is considered to be a time-varying traded-weighted average of China's major trading partners. Specifically, this chapter chooses the U.S., Euro Area, Japan, South of Korea, the U.K., Malaysia, Singapore and Thailand as China's important trading partners and the trade-weights are obtained from the Bank for International Settlements, which is summarised in the Appendix 6.8.2. The quarterly real GDP data, the end-period nominal exchange rates and the CPI data in all countries are collected from the IMF International Financial Statistics (IFS) database. For China, as the GDP and the CPI data in some years are unavailable in the IFS, the data are collected from the Oxford Economics database via Datastream.

6.4.2 Unit root test and cointegration test

Before estimating VAR models, it is necessary to verify the level of integration of the variables. This chapter adopts various methods of unit root tests including the widely used augmented Dickey-Fuller (ADF) test, the Phillips-Perron (PP) test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. In addition, another test proposed by Perron (1989) and developed by Perron (1997) is considered as well, of which the null hypothesis is that there is a unit root with a structural break in the series. This test was also used in Chapter 3. Table 6.1 summarises the unit root test results from various test methods. The results, overall, indicate that all the variables are $I(1)$, and the first differences of all the variables are stationary.

Although no economic reason suggests that there is a cointegration relationship, a cointegration test is conducted so as to make sure the VAR model is appropriately specified. Since all the variables are $I(1)$, Johansen's maximum likelihood based reduced rank regression test for cointegration, proposed by Johansen & Juselius

Table 6.1: Unit root tests: quarterly sample

Variable	ADF			PP		
	Level	1st Diff	Result	Level	1st Diff	Result
y	0.239	-6.874*	I(1)	0.229	-7.012*	I(1)
q	-0.307	-7.392*	I(1)	-0.268	-7.405*	I(1)
p	-1.216	-3.548*	I(1)	-1.471	-4.989*	I(1)

Variable	KPSS			Perron		
	Level	1st Diff	Result	Level	1st Diff	Result
y	1.129*	0.238	I(1)	-3.394	-8.383*	I(1)
q	0.613*	0.292	I(1)	-2.222	-8.569*	I(1)
p	0.691*	0.108	I(1)	-3.638	-5.884*	I(1)

Note: 1. t-statistics are reported in the table. 2. A superscript * hereafter in this chapter indicates statistically significant at the 5% level. 3. The null hypothesis of KPSS test is that data is stationary, whilst the null hypothesis of all the other tests indicates a unit root. 4. The 5% critical values for the ADF and PP tests with a constant is -2.898, 0.463 for the KPSS test, and -5.23 for the Perron test.

Table 6.2: Johansen's maximum likelihood cointegration test: quarterly sample

Null hypothesis	Trace test	5% Critical value	Maximal eigenvalue test	5% Critical value
$h = 0$	21.541	29.797	11.105	21.132
$h \leq 1$	10.436	15.495	9.557	14.265
$h \leq 2$	0.879	3.841	0.879	3.841

Note: The results from lag length section criteria suggest the lag order is 1 for the VAR model with levels of each variable and h denotes the number of cointegrating relations under different hypothesis.

(1990), Johansen (1991) and Johansen (1995), is therefore employed in this section. The results are outlined in Table 6.2. Both trace statistic test and maximal eigenvalue tests suggest no cointegration in the model with levels of each variable. It is then appropriate to proceed to the VAR model estimation where variables are in first differences.

Lastly, the lag order of the structural VAR is chosen to be 2, according to the information criteria and the serial correlation and heteroscedasticity tests. Moreover, to capture the implicit exogenous shifts and potential structural changes, a dummy variable is introduced in the VAR to measure the potential regimes change ($d = 1$ for periods 1998Q1 to 2005Q2, and 0 otherwise), when the nominal RMB exchange rate was pegged to the U.S. dollar at 8.277 during 1998Q1 and 2005Q2. The like-

lihood ratio test for the significance of the dummy variable suggests a likelihood ratio of 12.883, which is significant compared to the null with 7.815 for the 5% critical value.

6.5   Empirical results

6.5.1   Impulse response analysis

The dynamic effects of structural breaks can be analysed by the impulse response functions in assessing the directions and magnitude of responses of variables. Figure 6.2 depicts the impulse responses of the three underlying variables to the structural shocks with the size of one standard deviation[2]. The figures represent the accumulative responses as the variables enter the structural VAR as first differences. According to the first row of Figure 6.2, positive real relative supply shocks exert a strong positive effect on relative output, with an immediate growth of 0.7%, and it takes more than 8 quarters to achieve the new equilibrium level, which is consistent with the theoretical priors. Relative demand shocks and nominal shocks contribute to a small short-run increase in relative output, and it dies out at the 20-quarter horizon due to the long-run restrictions imposed.

Results from the response of real exchange rate to relative supply shocks report some counter-intuitive results, as plotted in the second row. Real relative supply shocks trigger a 0.8% real exchange rate appreciation immediately, but result in a permanent depreciation in the long run. The early-period appreciation is also captured by Clarida & Gali (1994), Astley & Garratt (2000) and Ahmad & Pentecost (2009) for some industrial and developing countries. Relative demand shocks are expected to contribute to an appreciation of real exchange rate, which is not what

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[2]In addition to EViews, Structural VAR source code written by Anders Warne is used in Matlab to help estimate the model. The source code is available at http://www.texlips.net/svar/source.html.

the figure indicates. Astley & Garratt (2000) explained this by pointing out a limitation of the structural VAR model. To be specific, the structural VAR model fails to restrict the sign of each shock in the structural impulse responses matrices, as the method involves solving a quadratic equation. In this case, if $C(1)$ solved in equation (6.18) is accepted, then $C(1)Z$ should be accepted as well provided that the elements on the principal diagonal of the diagonal matrix Z are either -1 or 1. Therefore, the sign of the elements for each column in B_0^{-1} is underdetermined. In this case, relative demand shocks are actually identified as negative shocks in the figure.[3] Therefore, a permanent exchange rate appreciation is observed in response of positive relative demand shocks, and the level of appreciation is 2.5% in the long run, with smooth adjustment from the short-run dynamics. Nominal shocks contribute to a 0.5% real exchange rate depreciation at a significant level during the first 10 quarters, and the effect dies out in terms of the long-run restrictions imposed in the model.

The relative price level initially falls slightly by 0.1% in response of relative supply shocks, and recovers at the 20-quarter horizon. Positive real relative demand shocks, interpreted as the inverse of the figure, result in a small rise in the relative price level, which is theory-consistent. Also, nominal shocks contribute to a perpetual rise in the relative price level in the long run, and it takes about 16 quarters for the relative price level to adjust to the new equilibrium level.

6.5.2 Forecast error variance decompositions

In order to determine the importance of each type of structural shocks in reaction to a given change of a variable, forecast error variance decompositions are usually calculated, as shown in Table 6.3. The numbers in the table represent the percentage of forecast error variance attributable to three types of structural shocks

[3]In this case, the response of the relative output to positive demand shocks in the first row in Figure 6.2 is negative, which is not as expected. Nonetheless, the overall effect is small and not statistically significant.
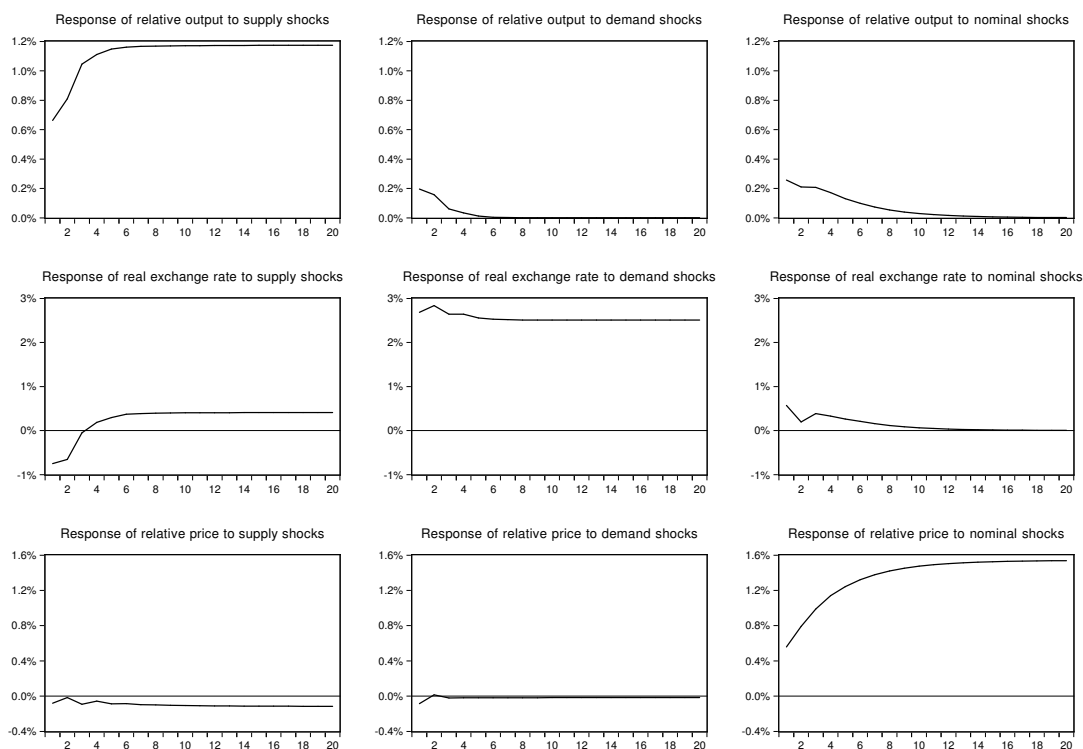
Figure 6.2: Accumulated impulse responses to one standard deviation structural shocks: full quarterly sample

at different forecast horizons. According to the results, China's relative output fluctuations are primarily attributable to real relative supply shocks by explaining 83.34% of the variance of relative output at the 20th quarter, which is in line with the result from the impulse response analysis above. In fact, the long-run restrictions underlie this argument in the long run. However, the dominance of relative supply shocks is also observed at shorter horizons during which no restrictions are imposed. For example, relative supply shocks account for 83.46% of relative output movements at the first quarter. Nominal shocks are considered as the second largest contributor in the decomposition of relative output variance, according for 10.03% at the 20-quarter period. Relative demand shocks have the smallest effect on the variance decomposition of relative output, with the number of 6.63% at the 20th quarter.

Relative demand shocks account for about 58.79% of real exchange rate variations at the period for 20 quarters, which is therefore the main sources of movements

of the RMB real exchange rate against a weighted average of eight trading partners. This is consistent with most of literature for both developed and developing countries (see Astley & Garratt, 2000; Detken *et al.*, 2002; Wang, 2005; Huang & Guo, 2007 and Ahmad & Pentecost, 2009). Besides, nominal shocks contribute to 29.28% of the variations at the 1-quarter horizon, and continuously play an important role in driving movements of real exchange rate in the long run, accounting for 29.74% at the 20-quarter horizon. Ahmad & Pentecost (2009) also found that nominal shocks acted as an important role in South Africa, explaining 28% of movements of real exchange rate at the 20-quarter horizon. Besides, Dibooglu & Kutan (2001) discovered similar importance of nominal shocks in Poland with a period of high inflation. Clarida & Gali (1994) found that nominal shocks accounted for 28% and 15% of real exchange rate variations in Germany and Japan, respectively, at the 12-quarter horizon. The importance of nominal shocks against supply shocks was also found in An & Kim (2010) for Japan and Mumtaz & Sunder-Plassmann (2013) for the U.K. and the Euro zone. The reason, according to Ahmad & Pentecost (2009), is because those countries, like South Africa, Germany and Japan, are in fact financially developed economies. However, evidence from other financially developed industrial countries in Astley & Garratt (2000) and Clarida & Gali (1994) for example, fails to support the importance of nominal shocks in driving real exchange rate movements by concluding a very low degree of nominal shocks in driving the real exchange rate movements. The role of nominal shocks needs further investigations. Wang (2005) and Huang & Guo (2007) found little importance of nominal shocks in determining real exchange rate fluctuations in China, which is in contrast to our result, and they proposed that the little importance of nominal shocks were due to the actual fixed exchange rate regimes and the strict control of capital accounts in China. In addition, Astley & Garratt (2000) suggested the cross-checks of the robustness of the results by looking at some bilateral exchange rates. Consequently, this section further selects the GBP/CNY (RMB real exchange rate against British pounds) and the JPY/CNY

(RMB real exchange rate against Japanese Yen) exchange rates, and the results[4] suggest that relative demand shocks dominate real exchange rate fluctuations at all horizons, and nominal shocks come as the second largest sources, accounting for 18.43% and 14.36% for variations of real exchange rate against GBP and JPY, respectively, at the 20-quarter horizon. Relative supply shocks, nonetheless, account for around 10% for real exchange rate variations in both cases. In this section, relative supply shocks account for 11.28% at the first quarter, and increase slightly to 11.47% at the 20-quarter horizon in the long run. Clarida & Gali (1994) suggested that less than 5% of real exchange rate variations were originated from supply shocks among Germany, Japan, Britain, and Canada with flexible exchange rate regime, but Huang & Guo (2007) also found a ratio of over 20% were attributable to relative supply shocks during the period before 2005. In China, according to Huang & Guo, the importance of relative supply shocks in driving real exchange rate movements was reflected by the supply-side reforms such as the restructuring of state-owned enterprises and technology innovations. The overall results confirm that relative demand shocks are the main sources of fluctuations in real exchange rate, but relative supply and nominal shocks play some roles as well.

Lastly, many of fluctuations of long-run relative price levels are attributable to nominal shocks, with a ratio of 72.14% at the 20-quarter horizon. Relative demand shocks come as the second, accounting for 24.34% at the 20-quarter horizon, and relative supply shocks only account for 3.52%. This result is in contrast of Wang (2005), where supply shocks are the main sources of fluctuations of relative price levels.

6.5.3 Sub-sample analysis

Instead of introducing a dummy variable to capture potential regime changes in the model above, this section investigates the period during which China has been

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[4]See Appendix 6.8.3 for the table results.

Table 6.3: Variance decomposition of forecast errors: full quarterly sample

Horizon	Fraction of relative output variance due to			Fraction of real exchange rate variance due to			Fraction of relative price variance due to		
	Supply	Demand	Nominal	Supply	Demand	Nominal	Supply	Demand	Nominal
1	83.46%	6.47%	10.07%	11.28%	59.44%	29.28%	0.28%	28.63%	71.09%
2	83.26%	6.17%	10.57%	11.06%	60.27%	28.67%	2.99%	23.57%	73.44%
3	83.71%	6.41%	9.88%	11.52%	59.83%	28.65%	2.63%	25.16%	72.21%
4	83.53%	6.50%	9.97%	11.53%	59.46%	29.01%	3.56%	24.41%	72.03%
8	83.34%	6.63%	10.03%	11.48%	58.85%	29.67%	3.53%	24.36%	72.11%
12	83.34%	6.63%	10.03%	11.47%	58.80%	29.73%	3.53%	24.34%	72.14%
16	83.34%	6.63%	10.03%	11.47%	58.79%	29.74%	3.52%	24.34%	72.14%
20	83.34%	6.63%	10.03%	11.47%	58.79%	29.74%	3.52%	24.34%	72.14%

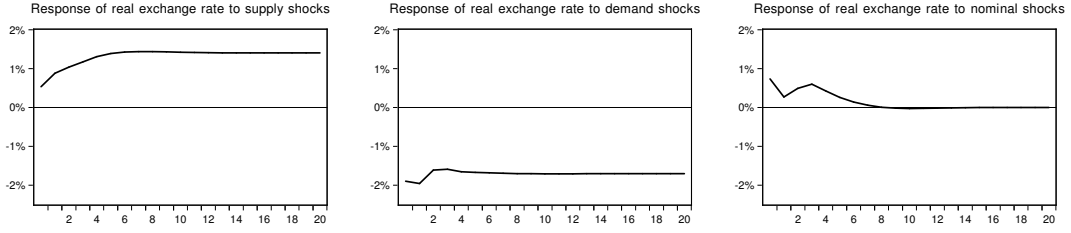| Response of real exchange rate to supply shocks | Response of real exchange rate to demand shocks | Response of real exchange rate to nominal shocks |

Figure 6.3: Accumulated impulse responses of the real exchange rate: sub quarterly sample

using a managed floating exchange rate regime where exchange rate is adjustable with reference to a group of currencies since July 2005. In particular, the sub-sample covers the period of 2005Q3 until 2015Q2. Furthermore, to capture the potential effect of financial crisis during 2007 to 2008, a dummy variable is added into the structural VAR(2) model with $d = 1$ for 2007Q4 to 2009Q1, and $d = 0$ for other periods. Impulse responses of real exchange rate to structural shocks of one standard deviation are shown in Figure 6.3. The results are theoretical-consistent, with a real depreciation of above 1% due to positive supply shocks, and a real appreciation of 2% in response of positive demand shocks. Besides, nominal shocks contribute to a small rise during the first 8 quarters, but the effect dies out in the long run due to the restriction imposed in the model. The variance decompositions of real exchange rate are presented in Table 6.4, and the results confirm that relative demand shocks are the main sources of real exchange rate fluctuations in the long run, by accounting for 73.18% of fluctuations of real exchange rate for the period of 20 quarters. Nominal shocks are the next principal sources of real exchange rate variations, which is consistent with the previous finding. In fact, nominal shocks account for 12.08% at the 1-quarter horizon, and 17.5% at the 20-quarter horizon. Lastly, supply shocks account for 9.32% of the fluctuations. Overall, the results from the sub-sample analysis are consistent with the main results for the whole sample period.

Table 6.4: Variance decompositions of real exchange rate: sub quarterly sample

Horizon	Supply	Demand	Nominal
1	6.46%	81.46%	12.08%
2	8.53%	75.74%	15.74%
3	8.69%	75.19%	16.12%
4	8.98%	74.76%	16.26%
8	9.32%	73.23%	17.45%
12	9.32%	73.18%	17.50%
16	9.32%	73.18%	17.50%
20	9.32%	73.18%	17.50%

6.6 Further evidence from monthly data

In the previous section, a sub-sample analysis is conducted to investigate the period when the RMB exchange rate has been managed floating with reference to a basket of currencies. However, Juvenal (2011) questioned the precision of impulse responses due to finite observations, and meanwhile it is challenging to detect the shocks. To provide further evidence of sources of the real exchange rate fluctuations during this period, this section uses monthly data to improve the quality of impulse responses analysis.

6.6.1 The monthly data

The monthly data covers the period between July 2005 and June 2015. The three variables in the structural VAR are constructed as before, referring to relative levels to a traded-weighted average of major trading partners of China. However, as monthly GDP data is not available for most countries, monthly industrial production index is chosen to be a proxy of nominal output. Accordingly, the price level is represented by the producer price index (PPI), and the real exchange rate is thus calculated by the PPI and the end-period monthly nominal exchange rate. Deflating the industrial production by the PPI gives real output. All the data for China's eight trading partners and the nominal exchange rates are collected

from the IMF International Financial Statistics (IFS) database. The industrial production index and the PPI for China are retrieved from the National Bureau of Statistics database of China.

Before proceeding to the estimation of the structural VAR, unit root tests and cointegration tests are conducted, with the same methods used in Section 6.5. According to Table 6.5, results from the ADF test, the PP test, the KPSS test and the Perron test suggest that all the variables are stationary at first differences, i.e. $I(1)$. Johansen's maximum likelihood trace and maximal eigenvalue tests suggest no cointegration relationships among the variables, as reported in Table 6.6. Therefore, it is appropriate to consider estimating a structural VAR model in which Δy_t, Δq_t and Δp_t are endogenous variables. The lag order of the structural VAR is chosen to be 3, according to the result based on the information criteria. Also, to capture the potential effects of financial crisis during 2007 to 2008, a dummy variable is introduced into the model with $d = 1$ for the periods between September 2007 and March 2009, and $d = 0$ otherwise. The likelihood ratio test for the significance of the dummy variable gives a ratio of 17.876, which is significant compared to the 5% critical value of 7.815.

6.6.2 Empirical results: monthly data

To study the direction and magnitude of responses of the variables, Figure 6.4 depicts the accumulated impulse responses to the structural shocks. The responses of the relative output are shown in the first row. Positive supply shocks increase the relative output level to 1.5% in the long run, whilst demand and nominal shocks have no long-lasting effects, due to the prior restrictions imposed when solving the model. However, both shocks trigger a slight increase at the 1 to 2-month horizon. The second row suggests the responses of the real exchange rate to each structural shock. Consistent with what the theoretical model suggests, positive supply shocks bring about an immediate 1% real exchange rate depreciation, and the effects last

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Table 6.5: Unit root tests: monthly sample

Variable	ADF			PP		
	Level	1st Diff	Result	Level	1st Diff	Result
y	-2.269	-9.761*	I(1)	-2.699	-9.711*	I(1)
q	-0.530	-10.772*	I(1)	-0.497	-10.773*	I(1)
p	-1.014	-8.820*	I(1)	-0.876	-8.633*	I(1)

Variable	KPSS			Perron		
	Level	1st Diff	Result	Level	1st Diff	Result
y	1.273*	0.457	I(1)	-2.674	-9.693*	I(1)
q	1.244*	0.052	I(1)	-4.593	-11.550*	I(1)
p	0.678*	0.136	I(1)	-3.509	-7.173*	I(1)

Note: 1. t-statistics are reported in the table. 2. A superscript * hereafter indicates statistically significant at the 5% level. 3. The null hypothesis of KPSS test is that data is stationary, whilst the null hypothesis of all the other tests indicates a unit root. 4. The 5% critical values for the ADF and PP tests with a constant is -2.886, 0.463 for the KPSS test, and -5.23 for the Perron test.

Table 6.6: Johansen's maximum likelihood cointegration test: monthly sample

Null hypothesis	Trace test	5% Critical value	Maximal eigenvalue test	5% Critical value
$h = 0$	22.560	24.276	15.584	17.797
$h \leq 1$	6.976	12.321	6.942	11.225
$h \leq 2$	0.034	4.130	0.034	4.130

Note: The results from lag length section criteria suggest the lag order is 6 for the VAR model with levels of the underlying variables and h denotes the number of cointegrating relations under different hypothesis.
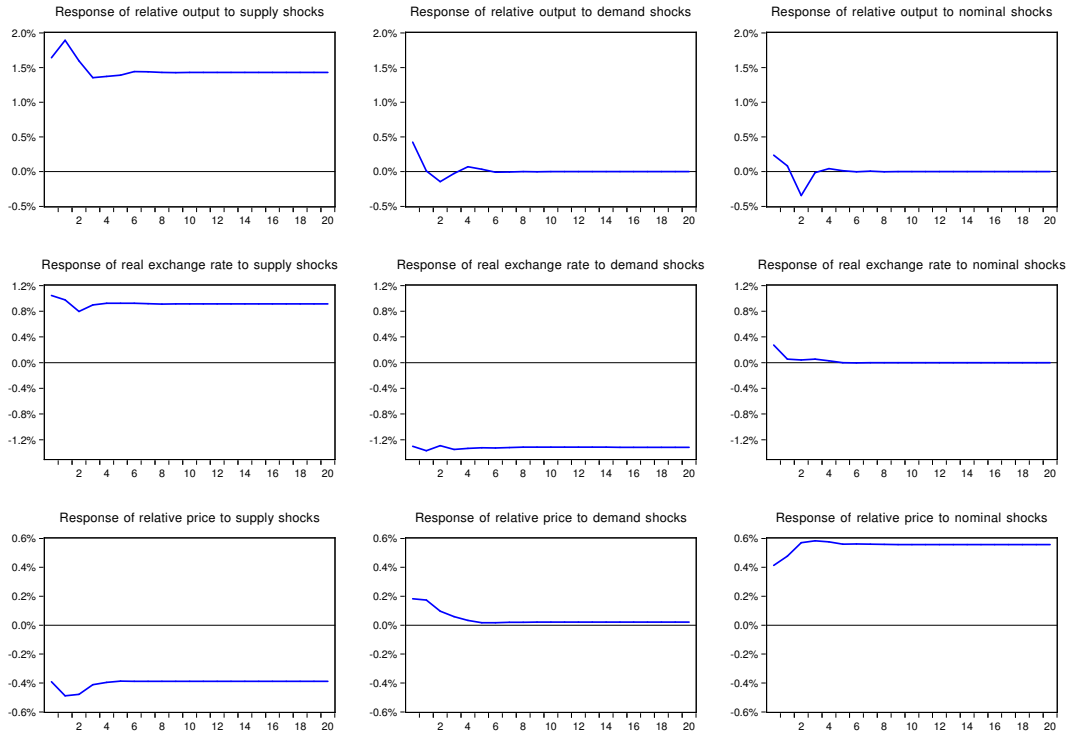
Figure 6.4: Accumulated impulse responses to one standard deviation structural shocks: monthly sample

in the long run. Also, positive demand shocks contribute to more than 1.2% real appreciation at the 20-month horizon, whilst nominal shocks contribute to a temporary depreciation in the first 6 months, and the impact dies out afterwards. Lastly, the relative price level reduces permanently by 0.4% in response of positive supply shocks, and positive demand shocks lead to a short-run increase of the relative price level by 0.2% at the 1-month horizon. Besides, nominal shocks raise the new equilibrium relative price level by 0.5% above in the long run. Overall, the results are consistent with the findings when using quarterly data for a full sample period.

Table 6.7 outlines the results of variance decompositions of real exchange rate. Given a variation in real exchange rate, relative demand shocks are considered to be responsible for 74.76% of the fluctuations at the 1-month horizon, and then 72.17% of the variations at the 24-month horizon, which act as the principal sources of real exchange rate fluctuations in all periods. This finding is consistent with

Table 6.7: Variance decompositions of real exchange rate: monthly sample

Horizon	Supply	Demand	Nominal
1	21.22%	74.76%	4.02%
2	21.53%	73.22%	5.25%
3	22.62%	72.21%	5.17%
6	22.54%	72.18%	5.28%
9	22.53%	72.17%	5.30%
12	22.53%	72.17%	5.30%
18	22.53%	72.17%	5.30%
24	22.53%	72.17%	5.30%

the results from quarterly data. However, supply shocks act as the next important role in explaining real exchange rate movements, rather than nominal shocks when using quarterly data. Specifically, relative supply shocks contribute to 21.22% of movements of the real exchange rate for the first month, and slightly increase to 22.53% after 24 months. Nominal shocks account for 5.3% of real exchange rate fluctuations at the 24-month horizon. The results are consistent with Huang & Guo (2007), which found that over 20% of real exchange rate fluctuations came from relative supply shocks. Nevertheless, relative demand shocks remain as the main sources of the real exchange rate variations in both short and long periods.

6.6.3 Sign-restrictions analysis: monthly data

As the credibility of imposing long-run restrictions in finite samples is questioned by Faust & Leeper (1997), this section imposes sign restrictions to compare the result with that of the long-run restrictions. To verify the importance of supply and nominal shocks in explaining real exchange rate variations, sign restrictions are imposed to identify these two types of shocks, as described in Table 6.8, whilst demand shocks are left freely determined for simplicity. Following the spirit of the theoretical model, the relative output does not decline for the first half year in response of positive supply shocks, while the relative price level does not increase for half a year. In addition, real exchange rate does not appreciate in response

Table 6.8: Sign restrictions: monthly sample

| Variable	Relative supply shocks	Nominal shocks
Δy_t	1-6 months, +	1-6 months, +
Δq_t	1-3 months, +	1-3 months, +
Δp_t	1-6 months, -	1-6 months, +

Note: + indicates an increase whilst - represents a fall.

to positive supply shocks for the first quarter. Besides, nominal shocks boost the relative output and price level for the first 6 months. Also, real exchange rate does not appreciate for 3 months due to nominal shocks.

To solve the model and construct the impulse responses, a Monte Carlo experiment is conducted by repeatedly drawing at random from the set $\mathbf{Q}$ of orthogonal matrices Q, and recording the solutions for B_0^{-1} that match the prior signs. The procedure is repeated until 1000 satisfactory draws are recorded[5]. Figure 6.5 depicts the impulses responses to supply and nominal structural shocks with the size of one standard deviation. The solid line represents impulse median responses and the two dashed lines refer to the confidence intervals. The results reflect the sign restrictions imposed and are consistent with the theoretical framework. Positive supply shocks bring about 1% increase in the relative output level, and reduce the relative price level by less than 0.6%. In addition, the real exchange rate depreciates in response to positive supply shocks. The magnitudes are not much different from those under long-run restrictions in Figure 6.4. However, nominal shocks lead to a permanent increase in the relative output and price level, and the real exchange rate depreciates by 0.7% in the long run.

In the absence of identification of demand shocks, Table 6.9 provides the variance decompositions of real exchange rate, and nominal shocks are responsible for 41.16% of real exchange rate variations for the first month, but the number declines to 21.59% at the 48-month horizon. Supply shocks enter by contributing to 27.25% of real exchange rate movements, and 7.99% at the 48-month horizon.

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[5]The Matlab toolbox used to solve the model with sign restrictions are provided by Ambrogio Cesa-Bianchi, available at https://sites.google.com/site/ambropo/MatlabCodes.
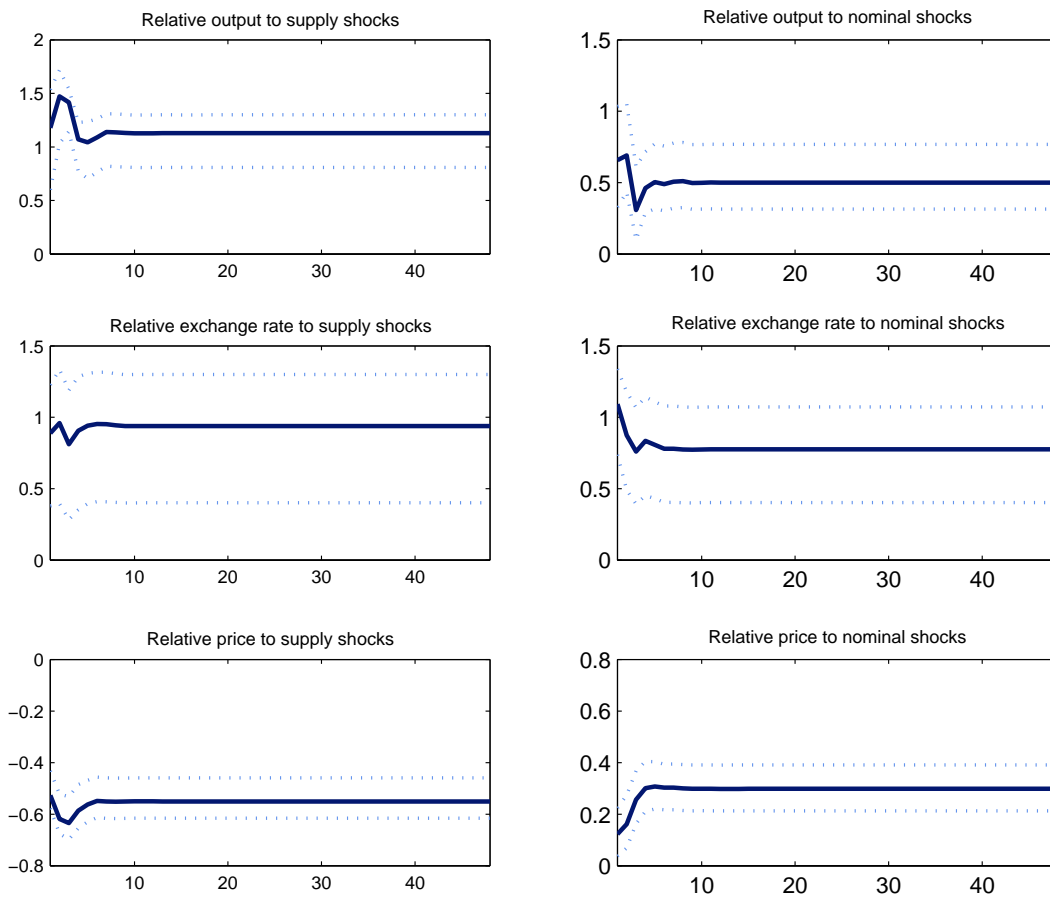
Note: The confidence intervals correspond to the impulse responses excluding the first and last 15% of those in the whole set where the responses are stored in an ascending order.

Figure 6.5: Accumulated impulse responses to one standard deviation structural shocks: monthly sample with sign restrictions

Table 6.9: Variance decompositions of real exchange rate: monthly sample with sign restrictions

Horizon	Supply	Nominal	Horizon	Supply	Nominal
1	27.25%	41.16%	18	10.57%	24.39%
2	21.39%	37.85%	24	9.62%	23.43%
3	20.87%	35.61%	30	9.00%	22.97%
6	16.92%	31.22%	36	8.49%	22.45%
9	14.11%	27.85%	42	8.23%	22.02%
12	12.36%	26.18%	48	7.99%	21.59%

This result is consistent with that from quarterly data, but is not in favour of the findings using monthly data with long-run restrictions. Nevertheless, it shows that demand shocks dominate in real exchange rate variations, but the importance of nominal and supply shocks could not be discarded.

6.7 Conclusion

China's financial liberalisation has contributed to rapid economic growth and considerable structural changes, and further directions of exchange rate reform are highlighted in recent years. To investigate the sources of real exchange rate fluctuations, this chapter employs a trivariate structural VAR model to find out to what extent real exchange rate fluctuations are attributable to the fundamental macroeconomic shocks. Meanwhile, the changes in the relative output and price levels are also examined in the model. To estimate the structural VAR model, this chapter imposes long-run restrictions proposed by Clarida & Gali (1994), and also sign restrictions used by Uhlig (2005), Peersman (2005) and Fry & Pagan (2007). Firstly, a full sample period covering 1995Q1 to 2015Q2 is investigated, with long-run restrictions to solve the structural VAR model. Following that, this chapter looks at a sub-sample period covering 2005Q3 to 2015Q2, when the RMB exchange rate is under managed floating system. Different frequencies of data are also considered in this chapter. It uses monthly data between July 2005 and June 2015 to estimate the model under the long-run restrictions, and then compares the

supply and nominal shocks using the methods of imposing sign restrictions. Most results from the impulse response analysis are theoretical-consistent, as relative demand shocks bring about a long-run real appreciation, a rise in the relative output and a decline in the relative price level. Nominal shocks increases the price level in the long run, whilst relative supply shocks contribute to a decline in the relative price level, a real depreciation and a significant permanent increase in the relative output level.

The results from variance decompositions suggest that real relative demand shocks are the principal sources of real exchange rate fluctuations in all cases during the period of financial liberalisation, which is in favour of numerous literature regarding to economies with managed floating exchange rate system. Relative supply shocks are found to be important as well in driving real exchange rate movements, as the supply-side structural reform in China has been successful in recent decades. Moreover, the results based on monthly data under the long-run restrictions indicate a more important role of supply shocks, whilst results from quarterly data under the long-run restrictions, as well as monthly data using the sign restrictions, suggest that supply shocks are less important than nominal shocks. For example, nominal shocks also account for 10% to 30% of real exchange rate movements in the model with quarterly data, indicating a certain degree of financial liberalisation in the country. The role of nominal shocks is limited due to the officially closed capital account and the de facto U.S. dollar-pegged exchange rate regime currently in China. Nonetheless, both supply and nominal shocks play a considerable role in explaining real exchange rate fluctuations. In addition, the result from the model with quarterly data confirms that real supply shocks are the main sources of relative output movements, and the relative price level is mainly driven by nominal and demand shocks.

6.8 Appendix

6.8.1 Solving the theoretical model

6.8.1.1 Long-run solutions: $\theta = 1$

In the long run, equation (6.4) reads $p_t = p_t^*$ and output is supply-determined, i.e. $y_t^* = y_t^s$, which is equation (6.8). To solve the long-run equilibrium level of the real exchange rate, q_t^*, assume q_t^* takes the following form under rational expectations:

$$q_t^* = h_1 y_{t-1}^s + h_2 d_{t-1} + h_3 u_t^s + h_4 u_t^d + h_5 u_{t-1}^d \tag{6.20}$$

Taking expectations of above equation at t yields:

$$E_t q_{t+1}^* = h_1 y_t^s + h_2 d_t + h_5 u_t^d \tag{6.21}$$

Substituting equation (6.3)(6.7)(6.8) and (6.21) into (6.1) and considering $y_t^d = y_t^s$ in equilibrium, one can obtain the following relationship:

$$q_t^* = \frac{1 + \sigma h_1}{\eta + \sigma + \sigma\tau/\kappa}\left(y_{t-1}^s + u_t^s\right) + \frac{\sigma h_2 - 1}{\eta + \sigma + \sigma\tau/\kappa}\left(d_{t-1} + u_t^d - \gamma u_{t-1}^d\right) + \frac{\sigma h_5}{\eta + \sigma + \sigma\tau/\kappa}u_t^d \tag{6.22}$$

Comparing equation (6.22) with (6.20) solves the parameters, hs, i.e. $h_1 = 1/\left(\eta + \sigma\tau/\kappa\right)$, $h_2 = -h_1$ and $h_5 = -\gamma h_2$. Therefore, the long-run equilibrium level of the real exchange rate, q_t^*, is solved as indicated by equation (6.9):

$$q_t^* = \left(\eta + \sigma\tau/\kappa\right)^{-1}\left(y_t^s - d_t\right) + \left(\eta + \sigma\tau/\kappa\right)^{-1}\left(\eta + \sigma + \sigma\tau/\kappa\right)^{-1}\sigma\gamma u_t^d$$

Similarly, to solve the long-run price level, p_t^*, assume the "trial solution" is of the form:

$$p_t^* = g_1 y_{t-1}^s + g_2 m_{t-1} + g_3 d_{t-1} + g_4 u_t^s + g_5 u_t^n + g_6 u_t^d + g_7 u_{t-1}^d \tag{6.23}$$

Taking expectations at t gives:

$$E_t p^*_{t+1} = g_1 y^s_t + g_2 m_t + g_3 d_t \tag{6.24}$$

Recall and rearrange equation (6.2) and (6.3):

$$(1 + \lambda) p^*_t = m_t - y^s_t + \lambda \left(E_t q^*_{t+1} - (1 + \tau/\kappa) q^*_t \right) + \lambda E_t p^*_{t+1} \tag{6.25}$$

Substituting equation (6.21) and (6.24) into (6.25) and solving for p^*_t gives:

$$
\begin{aligned}
p^*_t &= \frac{1 + \lambda g_2}{1 + \lambda} (m_{t-1} + u^n_t) + \frac{\lambda g_1 - 1 - \dfrac{\lambda \tau/\kappa}{\eta + \sigma \tau/\kappa}}{1 + \lambda} (y^s_{t-1} + u^s_t) \\
&\quad + \frac{\lambda g_3 + \dfrac{\lambda \tau/\kappa}{\eta + \sigma \tau/\kappa}}{1 + \lambda} \left(d_{t-1} + u^d_t - \gamma u^d_{t-1} \right) \\
&\quad + \frac{\lambda g_7 + \dfrac{\lambda \eta \gamma}{(\eta + \sigma \tau/\kappa)(\eta + \sigma + \sigma \tau/\kappa)}}{1 + \lambda} u^d_t
\end{aligned}
\tag{6.26}
$$

Comparing equation (6.26) with (6.23) solves the parameters, gs. Therefore the long-run price level can be solved as equation (6.10) indicates:

$$p^*_t = m_t - y^s_t - \beta (y^s_t - d_t) + \alpha \gamma u^d_t$$

where $\alpha = \lambda \left(\eta - (\lambda \tau/\kappa)(\eta + \sigma + \sigma \tau/\kappa) \right) (1 + \lambda)^{-1} (\eta + \sigma \tau/\kappa)^{-1} (\eta + \sigma + \sigma \tau/\kappa)^{-1}$ and $\beta = (\lambda \tau/\kappa)(\eta + \sigma \tau/\kappa)^{-1}$.

6.8.1.2 Short-run solutions: $\theta < 1$

In the short run, $\theta < 1$ indicates sluggish price adjustment. To solve the price level, p_t, recall equation (6.4) and taking expectations through it at time $t - 1$ gives:

$$E_{t-1} p_t = (1 - \theta) E_{t-1} p^*_t + \theta E_{t-1} p^*_t = E_{t-1} p^*_t \tag{6.27}$$

Substituting equation (6.4) into (6.27) under rational expectations gives:

$$E_{t-1}p_t^* = m_{t-1} - (1+\beta)\,y_{t-1}^s + \beta\left(d_t - u_t^d\right) \tag{6.28}$$

Substituting equation (6.28) back into the price setting equation (6.4) solves the short-run price level, which is outlined in equation (6.11):

$$p_t = p_t^* - (1-\theta)\left(u_t^n - (1+\beta)\,u_t^s + (\alpha\gamma + \beta)\,u_t^d\right)$$

Next, to solve q_t, substitute equation (6.1) into (6.2) and rearrange the equation, one can obtain the following relationship:

$$\eta q_t = m_t - d_t + (\sigma + \lambda)\left(E_t q_{t+1} - (1+\tau/\kappa)\,q_t\right) + \lambda E_t p_{t+1} - (1+\lambda)\,p_t \tag{6.29}$$

where $E_t p_{t+1} = m_t - (1+\beta)\,y_t^s + \beta\left(d_t - \gamma u_t^d\right)$ is calculated by taking expectations through equation (6.4).

Assume that the solution of q_t is of the form:

$$q_t = w_1 y_{t-1}^s + w_2 d_{t-1} + w_3 u_t^s + w_4 u_t^d + w_5 u_{t-1}^d + w_6 u_t^n \tag{6.30}$$

Taking expectations at time t gives:

$$E_t q_{t+1} = w_1 y_t^s + w_2 d_t + w_5 u_t^d \tag{6.31}$$

Substituting equation (6.31) into (6.29) and solving for q_t, and comparing the equation with equation (6.30) yields the solution for the short-run real exchange rate, which is outlined in equation (6.12):

$$q_t = q_t^* + \nu(1-\theta)\left(u_t^n - (1+\beta)\,u_t^s + (\alpha\gamma + \beta)\,u_t^d\right)$$

where $\nu = (1+\lambda)\left((\lambda + \sigma)(1+\tau/\kappa) + \eta\right)^{-1}$. The real exchange rate under slug-

gish price adjustment is driven by all the three structural shocks in the short run.

Finally, the relative output in the short run can be solved by rearranging equation (6.1):

$$y_t = (\eta + \sigma + \sigma\tau/\kappa)\, q_t - \sigma E_t q^*_{t+1} + d_t \tag{6.32}$$

Substituting equation (6.12) and (6.21) into (6.32) reads the solution for the short-run IS curve, which is equation (6.13):

$$y_t = y^*_t + (\eta + \sigma + \sigma\tau/\kappa)\, \nu\, (1 - \theta) \left(u^n_t - (1 + \beta)\, u^s_t + (\alpha\gamma + \beta)\, u^d_t \right)$$

6.8.2 Trade weights used to construct relative variables in structural VAR

Table 6.10 presents the trade weights of China's major trading partners, i.e. the Euro Area, the U.S., Japan, South of Korea, the U.K., Malaysia, Singapore and Thailand, which are used to construct the relative output and price level, as well as the real exchange rate. The time-varying trade weights are compiled by the Bank for International Settlements, and account for approximately 70% of China's exports and imports. The trade weights are normalised when constructing the relative variables. For example, in 1995, the normalised trade weight of the Euro Area in China with all the eight trading partners is 17.706%/76.669%=0.231.

6.8.3 Forecast error variance decomposition of bilateral exchange rates

Results from variance decomposition of the real exchange rate against GBP and JPY are reported in Table 6.11. Before construing the structural VAR models, all the underlying variables are tested for unit roots and the results suggest that all

Table 6.10: Trade weights of China's major trading partners

	1995	1996-1998	1999-2001	2002-2004	2005-2007	2008-2010	2011-2015
Euro Area	17.706%	17.183%	16.637%	17.946%	18.555%	19.555%	18.674%
U.S.	20.412%	22.811%	24.154%	22.044%	21.078%	18.982%	17.760%
Japan	25.886%	22.975%	21.474%	19.601%	16.254%	15.416%	14.126%
Korea	6.227%	7.177%	6.975%	7.847%	8.305%	8.148%	8.465%
U.K.	2.234%	2.573%	3.301%	3.147%	3.141%	2.915%	2.910%
Malaysia	0.979%	1.101%	1.358%	1.844%	1.938%	1.964%	2.154%
Singapore	2.299%	2.818%	2.485%	2.596%	2.930%	2.610%	2.744%
Thailand	0.926%	1.240%	1.386%	1.541%	1.758%	1.965%	2.147%
Total	76.669%	77.878%	77.771%	76.565%	73.957%	71.555%	68.980%

Note: Data reported in this table are calculated based on the original data from the Bank for International Settlements.

the variables are $I(1)$. Johansen maximum likelihood cointegration test indicates no cointegration in the VAR models, and the lag order selected via information criteria suggests VAR(2) for the GBP/CNY model and VAR(1) for the JPY/CNY model, respectively.

Table 6.11: Variance decomposition of bilateral real exchange rates: full quarterly sample

Horizon	GBP/CNY			JPY/CNY		
	Supply	Demand	Nominal	Supply	Demand	Nominal
1	0.74%	83.10%	16.16%	10.85%	76.72%	12.43%
2	5.56%	78.82%	15.61%	10.72%	75.87%	13.41%
3	7.06%	74.84%	18.09%	10.66%	75.42%	13.92%
4	8.00%	73.75%	18.25%	10.64%	75.20%	14.16%
8	8.26%	73.36%	18.38%	10.62%	75.02%	14.35%
12	8.26%	73.30%	18.42%	10.62%	75.01%	14.36%
16	8.26%	73.30%	18.43%	10.62%	75.01%	14.36%
20	8.26%	73.29%	18.43%	10.62%	75.01%	14.36%

Chapter 7

Conclusions and future research

Financial repression has long been an attractive research area since 1973 when both McKinnon and Shaw introduced it in their respective research work. The literature in this field have grown rapidly during the past decades owing to more frequent financial crises in the world and accelerated financial liberalisation in less developed countries. Price distortion, which is one of the most typical characteristics in terms of financial repression, has been considered to exist extensively in developing countries such as deposit and loan rates control, high required reserve ratios, managed exchange rate regime and strict capital controls. China, like other developing countries, has adopted repressive financial policies and started the financial liberalisation process only in 1978. Interest rate liberalisation in China, the main content of financial liberalisation, is considered to start in 1996 when the Chibor was established and freely determined by the market. Both the floor of loan rates and the ceiling of deposit rates have been removed recently, and it is believed that China has achieved a certain degree of financial liberalisation, but the liberalisation process is still under way and it calls for more up-to-date empirical research work regarding to China's financial liberalisation. Therefore, this thesis has examined China's financial repression in several typical areas and provides a comprehensive empirical investigation on the effects of financial repression and

liberalisation. It suggests that China has achieved a certain degree of financial liberalisation, but should be very prudent when liberalising interest rates, floating exchange rates and even freeing capital controls in order to stabilise the economy both internally and externally, and maintain economic growth at the same time. The conclusions are drawn in each area accordingly.

The first empirical study in this thesis in Chapter 3 which focused on the examination of the credibility of McKinnon's complementarity hypothesis, where money and physical capital are complements rather than substitutes, and investment is positively associated with real deposit rates. The empirical results show some weak evidence to support the hypothesis. Money demand is significantly positively linked to the investment to income ratio, whilst the long-run relationship between fixed capital formation and real deposit rates is positive, but not significant. However, this positive relationship becomes significant when the investment equation is augmented with some additional variables in addition to real deposit rates, which is in favour of McKinnon's complementarity hypothesis. Following that, the domestic savings to income ratio enters the models to replace the investment variable, as suggested by Fry (1978). The results are in contradiction with McKinnon's complementarity hypothesis. The absence of strong evidence to support the complementarity hypothesis in China in the long run may be due to the certain degree of financial liberalisation China has reached, as Fry (1978) argued that the hypothesis was only valid when a country is yet to start financial liberalisation.

McKinnon (1973) and Shaw (1973) have argued that interest rates in developing countries under financial repression like China are below the market equilibrium levels and investment is subject to the shortage of savings, and China has undertaken several steps to liberalise the interest rates on bank loans and deposits. To understand the impacts of interest rate liberalisation, Chapters 4 and 5 constructed DSGE models to investigate interest rate liberalisation in two different ways. In Chapter 4, interest rate liberalisation is reflected by raising its equilib-

rium levels as suggested by Jin *et al.* (2013), and the result suggests that interest rate liberalisation helps reduce the volatility of output by adjusting the structure of China's economy between consumption and investment. Also, it helps improve the efficiency of transmission channel of monetary policy. In addition, China's interest rate liberalisation is subject to other repressive financial policies such as the high required reserve ratio and the window guidance on bank loans. Chapter 5 considers these repressive monetary policies and the liberalisation process of loan and deposit rates are reflected by increasing the weights in market-determined loan and deposit rates relative to policy rates set by the PBoC. It shows that both loan and deposit rates are more sensitive to exogenous shocks and work to reduce the volatility of inflation. However, the effects of deregulation are significantly affected by the PBoC's administrative window guidance on bank loans. In fact, it makes little difference to the liberalisation process when there is a certain degree of freedom. In other words, the window guidance helps stabilise loan and deposit rates to some extent even after deregulation. Therefore, the PBoC should gradually reduce the use of the window guidance rule during the deregulation of loan and deposit rates in order to reduce the volatility of the economy.

China's monetary policy is believed to vary with the process of financial liberalisation. The nominal money growth target has been the official monetary policy indicator since 1994, and it has long been criticised to be too difficult to control as the velocity of money is far from stable in China, as well as in many other countries. Chapter 4 thus evaluates the money growth rule and the interest rate rule in DSGE models. The results from both sets of DSGE models suggest that the interest rate rule is more efficient than the money growth rule, which is consistent with Zhang (2009). Inflation lasts for a shorter period in response to a productivity shock when the interest rate rule takes effect. Also, the interest rate rule is more powerful in response to a monetary-policy shock. Chapter 5 also considers an aggressive interest rate rule, together with the effects of the PBoC's window guidance on bank loans. It concludes that the interest rate rule is more powerful

in terms of reducing the volatility of inflation when the PBoC's window guidance is away. Moreover, Chapter 5 considers a modified interest rate rule which is augmented with nominal money growth variable when the PBoC adjusts the interest rate. The modified interest rate rule brings about more volatility of inflation. In the recent 13th national five-year plan, China has designed to use price-based monetary policy tools more frequently than quantity-based tools such as nominal money growth, which is consistent with the results obtained in this thesis. In addition, unlike many advanced economies where the central banks rarely adjust the required reserve ratio, the PBoC actively uses it in order to control the liquidity. The result suggests that the required-reserve-ratio rule contributes little to controlling inflation and stabilising the economy, though it helps reduce bank loans. However, the effectiveness of the required reserve ratio in terms of maintaining financial stability as a macroprudential policy needs to be investigated in an open economy model, as the PBoC has to actively adjust it due to China's increasing official foreign reserves and domestic money supply under an actual fixed exchange rate regime.

Finally, China's financial liberalisation calls for further reform of the exchange rate regime, as China has been more exposed to various types of macroeconomic shocks during financial liberalisation. In Chapter 6, the sources of real exchange rate fluctuations are investigated during the period of financial reform and the results, based on structural VAR models, suggest that real relative demand shocks are the main sources of real exchange rate movements both at short and long horizons. The dominance of demand shocks in determining real exchange rate fluctuations is confirmed regardless of the long-run restrictions and the sign restrictions imposed when estimating the model. The result suggests that a more flexible exchange rate system should be helpful to offset possible risks and indetermination caused by real demand shocks. However, floating the exchange rate is not a viable policy option at present for China, because its immature creditor status and undeveloped capital markets such a policy may only stimulate hot money flows

and precipitate a currency crisis. Besides, the impulse response analysis suggests the theoretical-consistent results, as relative demand shocks contribute to a long-run real appreciation, a rise in relative output and a descent in the relative price level. Additionally, relative supply shocks exert considerable influence as well in driving real exchange rate fluctuations, as China has witnessed many supply-side structural reforms in recent decades.

One proposal for future research work following current progress in this thesis should look at an open economy DSGE model in Chapter 5 so as to have an exchange rate variable and some foreign shocks included in the analysis. Also, some advanced techniques about imposing sign restrictions on the structural VAR model should be employed in Chapter 6 to identify more possible structural shocks that may affect real exchange rate fluctuations. In addition, future research work may consider the regional effects of financial liberalisation in China, as it is acknowledged that East China is more developed than Middle and West China. The effects of financial liberalisation on China's bank industry are also worth studying and what commercial banks will do in response of future reform of interest rates is another direction to study further, because since removing the ceilings of deposit rates in late 2015 the PBoC has not announced further steps regarding the interest rate reform. Lastly, as liberalising the capital market in China is often considered as the last step to achieve full financial liberalisation, it is important to look into possible risks and benefits when removing capital controls in the future.

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