Money, fiscal policy and the business cycle: How well does the IS-LM model fit post-reform Chinese data?*

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Abstract

Using quarterly data for the period 1980-2009, this study examines the effects of aggregate demand and supply shocks on aggregate fluctuations in China. It further decomposes demand shocks into money supply, money demand and fiscal shocks as in the IS-LM model by applying both long- and short-run restrictions in the context of a structural VAR proposed by Galí (1992). The results show that the estimated impulse responses, in terms of the supply and the three demand shocks, match well with the predictions of the theory. However, as the forecast error variance decompositions show, supply shocks are the main source of fluctuations accounting for about 89% of output variations in the short-run. Given the nature of the Chinese economy, this may indicate that there are still institutional obstacles due to incomplete economic reform which prevents market mechanisms from working fully. Despite the overall dominance of supply shocks, the historical decomposition of the five cycles in output during 1983-2009 detects important roles played by various demand shocks in some sub-periods. The above results are robust to alternative choices of data for money and interest rate.

JEL classification: C32; E12; E32; E4; E5

Keywords: Structural VAR, IS-LM identification, business cycle, reform and transition

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1 Introduction

Since 1978, economic reform in China has brought about massive changes in both it's economic structure and in the way it conducts economic policy. During this period, the Chinese economy has not only experienced rapid economic growth but also significant aggregate fluctuations. In an attempt to understand the latter, following Galí (1992), this paper estimates and identifies a structural vector autoregressive (SVAR) model and examines whether the predictions of the SVAR cohere with a simple theoretical framework broadly based on the IS-LM framework which underpins modern New Keynesian models.

Developing theories for research on business cycle fluctuations has been of crucial importance and highly debated in macroeconomics. Notably, regardless of the differences across theories, there have been two broad consensuses reached by researchers. The IS-LM model popularized in the 1970s as the compromise between Classical economics, Monetary economics and the Keynesian economics and more recently the New-Neoclassical-Synthesis model as a hybrid of the New Keynesian and New Neoclassical economics. Both consensuses share the same spirit that they represent synthesis type of models which are particularly useful for addressing aggregate economic issues. In this sense, the NNCS has been considered by many researchers (see e.g., Galí (2000)) as a modern counterpart of the IS-LM model.

Synthesis type models have important potential use for understanding and modeling economic fluctuations in transition economies. Economic fluctuations in transition economies are considered to be related with both economic reforms and economic policies[1]. On the one hand, economic reforms induce changes in factors that effect productivity and efficiency through changing institutions and economic structure. This results in a macroeconomy that relies more on market mechanisms. Thus, the factors related to reforms are important sources of fluctuations which can broadly be considered as supply side shocks to the economy. On the other hand, transition economies also incur a strong desire for economic policies due to the imperfect working of the market mechanism. These macroeconomic policies represent demand shocks to the economy which also have effects on economic

[1]See for example, Fischer and Sahay (2000) and Dibooglu and Kutan (2001) for their explanations that both economic reforms and stabilization policies are responsible for fluctuations in transition economies. In the case of China, researchers such as Naughton (1995) and Imai (1996) attribute fluctuations during the early stage of reform to some old traditions from the central-planned era such as the government's commitment to high state investment. Some other authors, see e.g., Yu (1997) and Fung *et al.* (2000) emphasize the role of credit channel and monetary policy on macroeconomic instability. The line of research such as Yusuf (1994), Oppers (1997), Qian and Roland (1998), Brandt and Zhu (2000) and Feltensteina and Iwata (2005) provide explanations of cycles taking various institutional features of reform, macro control and fiscal and monetary policy into account.

fluctuations[2]. These considerations suggest that a synthesis type model like the IS-LM model could be a suitable candidate for studying economic fluctuations in a transition economy.

The empirical framework of this study is based on the SVAR model which has been widely used in both developed countries[3] and developing countries[4]. Similar formal empirical studies on the Chinese economy are very few. Three exceptions are Zhang and Wan (2004), Wang (2004) and Siklos and Zhang (2007). Zhang and Wan (2004) estimated an output-price VAR using quarterly data 1985Q2-2000Q4 in the traditional AS-AD model by assuming that only AS shocks have long-run effect on output (see, Blanchard and Quah (1989)). Their variance decompositions show that AS shocks are only slightly more important than AD shocks for accounting for short-run output fluctuations, whilst AD shocks account for almost all of the fluctuations in inflation. Wang (2004) constructed a three variable VAR model consisting of relative output, real effective exchange rate and relative prices to examine the sources of fluctuations in real exchange rate. By applying the restriction that nominal shocks do not have long-run effect on real exchange rate (see Clarida and Galí (1994)), they decomposed the changes in the three variables into components attributable to AS, real and nominal AD shocks. The results show

[2]There have been positive findings on the effectiveness of fiscal and monetary policies and the existence of money demand relationship in post-reform China. For example, the VAR studies such as in Xie (2004), Qin *et al.* (2005), Geiger (2006) and Dickinson and Liu (2007) have reported positive findings on the effectiveness of monetary policy. Few studies, e.g., Ducanes *et al.* (2006) and Jha *et al.* (2010) also find that there is effective fiscal policy in the Chinese economy. A strand of literature, e.g., Xu (1998), Huang (1994), Gerlach and Kong (2005) and Mehrotra (2006) have found empirical evidence that there exists a stable money demand function in the post-reform economy.

[3]Excellent examples can be found in Blanchard and Watson (1986), Blanchard and Quah (1989), Shapiro and Watson (1988), Galí (1992) and Clarida and Galí (1994) for studying the sources of business cycles in the post-war US economy. It has also been intensively used for studying the Great Depressions in the US economy (see e.g., Cecchetti and Karras (1994)) and in other developed countries (see e.g., Karras (1994) for Germany, France and UK). Recently, the SVAR model has also been used for generating stylized facts about the effects of monetary policy shocks (see e.g., Christiano, Eichenbaum and Evans (2005)), fiscal policy shocks (see e.g., Mountford and Uhlig (2009)) and technology shocks (see e.g., Galí (1999) and recently Galí and Rabanal (2004), Uhlig (2004) and Francis and Ramey (2005)) for contrasting theoretical models.

[4]A number of studies, e.g., Bayoumi and Eichengreen (1994), Morling (2002) and Omar H M N (2009) have employed SVAR models for investigating the responses of key macroeconomic variables such as output and prices to supply and demand shocks in developing countries. Many researchers have also used open economy SVAR models to analyze the impacts of external factors domestic fluctuations in developing countries. See e.g., Ying and Kim (2001) for detecting the sources of capital flows in Korea and Mexico; Dibooglu and Kutan (2001) for examining sources of real exchange rate fluctuations in Poland and Hungary; and Canova (2005), Mackowiak (2007) and Sato, Zhang and McAleer (2009) for studying the impacts of various US shocks on emerging economies.

a dominant role for AS shocks in causing output and inflation fluctuations, while changes in real effective exchange rate are mostly related to real AD shocks.

Siklos and Zhang (2007) conducted a similar analysis as in Zhang and Wan (2004) but also considered two extensions of the benchmark Blanchard and Quah identification: (i) Blanchard and Quah identification with correlated AS-AD shocks as in Cover, Enders and Hueng (2006); and (ii) Blanchard and Quah identification in a trivariate (output-price-money) VAR model as in Bordo and Redish (2003). They examined the sources of inflation and output fluctuations using quarterly data from 1990Q1 to 2004Q3. Their results show substantial differences depending on which identification scheme is used. There are several shortcomings of their strategies. The first point is that they did not justify the use of each strategy, with no empirical evidence to support correlated AS-AD shocks. Second, some long-run restrictions in their third strategy are unusual. For example, their third identification relies on the assumption that there is no long-run impact of demand shocks on prices which is only valid for small open economies as considered in Bordo and Redish (2003) but not for China[5]. Third, their empirical framework is still unable to provide a suitable basis for testing economic theory and analyzing the components of demand shocks such as fiscal and monetary policies.

Compared with the literature, this paper offers three main innovations for analyzing fluctuations in the Chinese economy. Firstly, this study represents the first attempt to further decompose AD shocks into money supply, money demand and IS shocks[6]. Long-run restrictions of Blanchard and Quah (1989) and short-run restrictions of Galí (1992) are applied to identify the economic disturbances as the four structural shocks found in the IS-LM model. This allows an evaluation of the consistency of fiscal and monetary effects with those predicted in market economies as a gauge of the progress of economic reform. Secondly, a relatively long sample size of high frequency data is used (quarterly data from 1980Q1 to 2009Q3). The advantage to the research is that the relatively long sample size better justifies the long-run restriction while the quarterly frequency justifies the use of short-run restrictions. Thirdly, there is a formal and complete analysis of the sources of economic fluctuations over the sample period. The overall importance of each shock is inferred from the variance decompositions and the contribution of each shock in different periods is learned from the historical decompositions. Due to the restriction of small sample size, the previous study, i.e., Zhang and Wan (2004) was only able to characterize part of the cycles recognized in the Chinese economy. Taking the advantage of the long sample size, we are able to provide the

[5]For example, this assumption is obviously at odds with the empirical studies mentioned earlier which support the existence of long-run money demand.

[6]Due to the lack of data on producing input of output such as employment, it is not possible to conduct further decomposition of supply shocks such as the one proposed in Shapiro and Watson (1988).

first complete characterization of all the five cycles from 1983 to 2009.

The remainder of this paper is as follows: Section 2 gives a brief description of the sources and construction of the data used in this study. Section 3 provides a short description of the institutional background of the Chinese economy. Section 4 describes the SVAR model and illustrates the identification schemes in terms of long- and short-run restrictions. Section 5 presents the empirical results of the estimated impulse responses to examine if the IS-LM fits the post-reform Chinese data. The importance of each economic shock is investigated in Section 6 by computing the variance decompositions and the historical decompositions for the period 1983-2009. Section 7 considers alternative measures of variables to check the robustness of results and an alternative specification of the VAR to examine the sources of the unit root in nominal variables. Section 8 concludes.

2 Data

2.1 Description of data

The data used for estimation includes[7]: quarterly real GDP, the consumer price index (CPI), the one-year bank lending rate and the nominal money ('money plus quasi-money') from 1980Q1 to 2009Q3[8].

Real GDP was chosen as a measure of the output since it is a more comprehensive index for measuring output than other related series such as industrial production or consumption. For example, these related series can not capture the changes in services which have gained substantial increases proportional to GDP in recent years. Moreover, data such as industrial production has missing values even in the 1990s.

The CPI is chosen as a index for the price level due to the fact that the data for GDP deflator has never been published in China. It is impossible either, to infer the implicit GDP deflator in our full data sample since the quarterly nominal GDP data is only available since 1992. Moreover, other price indices such as retail price index (RPI) and producer price index (PPI) also have much shorter data lengths.

The measure of nominal interest rate is the bank lending rate. The bank deposit rate will also be used in estimation but only as a robustness check.

The data of 'money plus quasi-money' is used as the measure of the nominal money holdings. The term 'money plus quasi-money' refers to a measure of money that is wider than M1 (currency plus checkable deposits) but narrower than M2

[7] Although high frequency data is preferred, it is not possible to use monthly data since it is of poor quality and suffers from missing values even for recent years.

[8] The sources and construction of data for each variable are provided in Appendix (9.1).

(currency plus overall deposits). It has been used by the People's Bank of China (the central bank of China, PBC, hereafter) since 1979. The possible alternative, the narrow money M1 alone is also considered at the end of this study as a robustness check.

One inevitable issue in the literature concerning the empirical research for the Chinese economy is the credibility of data. While doubts and criticisms on the official Chinese statistics can be found for example, in Rawski (2001), Young (2003) and Holz (2004), positive views have also been found in Chow (1985), Klein and Ozmucur (2002), Chow and Shen (2004), Holz (2005) and Chow (2006). To ensure the accuracy and consistency of the data, this study makes use of the most recent data from the database of the National Bureau of Statistics of China (NBSC, hereafter)[9]. The use of Chinese statistics are supported by the view in Chow (2006) that the Chinese statistics are 'by and large reliable'.

2.2 Preliminary tests

Some preliminary tests related to the long-run properties of data are required prior to the specification and estimation of the VAR model below. The data series to be tested are : the log of real GDP, y, the one-year lending rate, i, the log of the CPI in levels, p, the log of money plus quasi-money, m, the real interest rate, $ri = i - \triangle p$, and the log of real money, $rm = m - p$.

Following Engle and Granger (1987), the degree of integration of each data series and the existence of cointegration relationships must be examined so as to determine the order of differencing of data. Additionally, since the Chinese data at hand are not seasonally adjusted, we also need to seasonally adjust the data before conducting standard unit root tests. That is, unit root tests at seasonal frequencies are also required. In what follows, the preliminary tests are conducted in two steps.

Firstly, there is the test for the existence of unit roots at seasonal frequencies for quarterly data using the procedure proposed in Hylleberg, Engle, Granger and Yoo (1990) (HEGE, hereafter). There are four seasonal unit roots considered here for quarterly data $\{1, -1, \pm i\}$, at frequencies $\left\{0, \pi, \frac{\pi}{2}\right\}$. The ordinary least squares (OLS) regression which the tests are based on, takes the following form:

$$\varphi^* (L)\, s_{4t} = \pi_1 s_{1t-1} + \pi_2 s_{2t-1} + \pi_3 s_{3t-2} + \pi_4 s_{3t-1} + d_t + \beta t + \varepsilon_t \qquad (1)$$

where $\varphi^* (L)$ is the lag polynomial defined in HEGE equation (3.2), d_t and t are the seasonal dummies and the time trend respectively, and s_{1t}, s_{2t}, s_{3t} and s_{4t} are

[9] Given the intensive debates on the overestimation of real GDP growth rate during 1997-2002 and the underestimation of it from 2003 upwards, the NBSC has been revising its GDP statistics since 2004.

the four different seasonal differences of the original data x_t, i.e.:

$$\begin{aligned} s_{1t} &= \left(1 + L + L^2 + L^3\right) x_t \\ s_{2t} &= -\left(1 - L + L^2 - L^3\right) x_t \\ s_{3t} &= -\left(1 - L^2\right) x_t \\ s_{4t} &= \left(1 - L^4\right) x_t. \end{aligned}$$

The null hypothesis of the seasonality test is that there are unit roots at all frequencies. Therefore, the absence of unit root at any seasonal frequency requires that π_1, π_2, π_3 and π_4 are all different from zero. Moreover, since the third and fourth unit roots are complex numbers with the same root, a jointly test for π_3 and π_4 can be used. Therefore, the seasonal unit root tests involve two t tests with respect to the null hypothesis of $\pi_1 = 0$ and $\pi_2 = 0$ and a F test with the null hypothesis that both π_3 and π_4 are zero.

The results of the seasonal unit root tests are reported in Table 1A below. A seasonal dummy is always included in the OLS regression. Both cases with and without a time trend in the regressions are considered. The test statistics are then compared with the critical values taken from HEGE Tables 1a and 1b. It is shown that none of the data series can be considered as stationary since not all the seasonal unit root tests reject the null hypothesis of unit roots. If the focus is on seasonal frequencies π and $\frac{\pi}{2}$, only the nominal interest rate does not have any seasonal pattern. These results imply that all the data need to be seasonally adjusted except nominal interest rate. The program TRAMO-SEATS is used to seasonally adjust all the raw data except the nominal interest rate[10]. In the process of seasonal adjustment, a pre-test for the log/level specification is always used and the adjustment automatically detects for outliers and accounts for trading day and Leap year effects.

[10]The TRAMO-SEATS package is developed by Goez and Maravall (1996) for the Central Bank of Spain and has been widely used by the EU countries. Another popular program in seasonal adjustment is the X-12 which is used by the United States Bureau of Labor Statistics. It uses the X-12-ARIMA method to seasonally adjust data series. This study has applied both TRAMO-SEATS and X-12 to do the seasonal adjustment. The resulting series turn out to be very similar. Moreover, the results of the structural VAR analyses using the two different seasonally adjusted series are also very similar.

Table 1A: Seasonal Unit Root Tests
Sample Period: 1980Q1 to 2009Q3

Variable	Trend	π_1	π_2	F_{π_3,π_4}
Real GDP (y)	No	-0.52	-1.54	4.37
	Yes	-3.38	-1.60	4.10
Prices (p)	No	-2.06	-3.06^*	5.93
	Yes	-0.87	-3.05^*	5.86
Nominal Interest Rate (i)	No	-1.28	-3.74^*	17.11^{**}
	Yes	-2.15	-3.71^*	16.92^{**}
Real Interest Rate	No	-1.46	-2.53	6.58
($i - \triangle p$)	Yes	-2.08	-2.51	6.65
Nominal Money (m)	No	-1.22	-2.27	4.48
	Yes	-1.38	-2.28	5.15
Real Money	No	0.35	-2.62	4.48
($rm = m - p$)	Yes	-3.61^*	-2.78	5.15
Frequency of unit root		0	π	$\frac{\pi}{2}$

$*$ →Significant at the 5% level $**$ →Significant at the 1% level

After the seasonal adjustment, we check the adjusted data series again and test for the seasonality to make sure that all the seasonal patterns in data have been removed. These are reported in Table 1B:

Table 1B: Seasonal Unit Root Tests for Seasonally Adjusted data
Sample Period: 1980Q1 to 2009Q3

Variable	Trend	π_1	π_2	F_{π_3,π_4}
Real GDP (y)	No	-0.44	-4.36^{**}	21.61^{**}
	Yes	-3.52^*	-4.61^{**}	24.31^{**}
Prices (p)	No	-2.15	-3.77^{**}	26.34^{**}
	Yes	-0.86	-3.75^*	26.04^{**}
Nominal Interest Rate (i)	No	-1.28	-3.74^*	17.11^{**}
	Yes	-2.15	-3.71^*	16.92^{**}
Real Interest Rate	No	-1.88	-4.22^{**}	20.72^{**}
($i - \triangle p$)	Yes	-2.36	-4.19^{**}	20.39^{**}
Nominal Money (m)	No	-1.21	-3.94^{**}	14.06^{**}
	Yes	-1.68	-3.98^*	15.41^{**}
Real Money	No	0.28	-4.30^{**}	14.06^{**}
($drm = \triangle m - \triangle p$)	Yes	-3.86^*	-4.57^{**}	15.41^{**}
Frequency of unit root		0	π	$\frac{\pi}{2}$

$*$ →Significant at the 5% level $**$ →Significant at the 1% level

Table 1B shows that the seasonal components in the raw data have been successfully removed. All the statistical tests reject the null of seasonal unit roots at frequencies π and $\frac{\pi}{2}$ and almost all of them are significant at the 1% level. Moreover, since the seasonal adjustment only removes the unit root at seasonal frequency, most of the t tests for π_1 cannot reject the null hypothesis of unit root at zero frequency.

The second step is to test the unit roots at zero frequency for the seasonally adjusted data. Here we consider two types of tests, i.e., the augmented Dickey Fuller (ADF) test and the Kwiatkowski, Phillips, Schmidt and Shin (1992) (KPSS) test[11]. The former is based on a OLS regression of the form, $\triangle x_t = \alpha + \beta t + \phi x_{t-1} + \delta (1 - L) x_{t-1} + \varepsilon_t$ and tests the null hypothesis of unit root, $H_0 : \phi = 0$. The KPSS test on the other hand, tests the null hypothesis that a time series x_t is stationary. It starts with the regression: $x_t = \alpha + \beta t + \mu_t + \varepsilon_t$, with $\varepsilon_t \rightarrow I(0)$ and $\mu_t = \mu_{t-1} + \epsilon_t$, $\epsilon_t \backsim WN(0, \sigma_\epsilon^2)$. The construction of the KPSS statistic is then the Lagrange multiplier (LM) statistic for testing the variance of the random walk process being zero: $H_0 : \sigma_\epsilon^2 = 0$. The results of the ADF test and the KPSS test for the seasonally adjusted data series are shown in Table 2A (the last two columns). The results of the same tests for the first-differenced data series are shown in Table 2B (the last two columns). The length of the time lag we choose is 4 in both the ADF and the KPSS tests.

Table 2A: Unit Root Tests For Seasonally Adjusted Variables[12]
Sample Period: 1980Q1 to 2009Q3

Variable	Trend	ADF test	KPSS test
Log Real GDP (y)	No	-0.65	2.47^{**}
	Yes	-4.48^{**}	0.11
Log Prices (p)	No	-2.02	2.32^{**}
	Yes	-0.94	0.56^{**}
Nominal Interest Rate (i)	No	-1.31	1.13
	Yes	-2.08	0.39
Real Interest Rate	No	-2.75	0.72^{*}
($ri = i - \triangle p$)	Yes	-3.21	0.35^{**}
Log Nominal Money (m)	No	-1.26	2.47^{**}
	Yes	-1.00	0.54^{**}
Log Real Money	No	0.35	2.48^{**}
($rm = m - p$)	Yes	-4.47^{**}	0.10

$*$ →Significant at the 5% level $**$ →Significant at the 1% level

[11] Another widely used unit test, i.e., the Phillips-Perron test is not conducted in this study. Some researchers, e.g., Schwert (1989) point out that Phillips-Perron test is likely to be more biased than the ADF test when the data process takes an ARIMA representation.

[12] The critical values of the ADF test at the 1% and the 5% significance level are -3.49 and

Table 2B: Unit Root Tests For First-differenced Variables
Sample Period: 1980Q1 to 2009Q3

Variable	Trend	ADF test	KPSS test
Differenced Real GDP ($\triangle y$)	No	-3.62^{**}	0.099
	Yes	-3.55^{*}	0.073
Differenced Prices ($\triangle p$)	No	-3.28^{*}	0.70^{*}
	Yes	-3.87^{*}	0.11
Differenced Nominal Rate ($\triangle i$)	No	-4.09^{**}	0.15
	Yes	-4.09^{**}	0.11
Differenced Real Rate ($\triangle ri$)	No	-6.15^{**}	0.06
	Yes	-6.12^{**}	0.04
Differenced Nominal Money ($\triangle m$)	No	-2.91^{*}	0.68^{*}
	Yes	-3.32	0.18^{*}
Differenced Real Money	No	-4.12^{**}	0.05
($\triangle rm = \triangle m - \triangle p$)	Yes	-4.10^{**}	0.05

$*$ →Significant at the 5% level $**$ →Significant at the 1% level

The unit root tests for the seasonally-adjusted data in Table 2A suggest that real GDP is either difference-stationary or trend stationary. For example, the ADF test without trend in regression cannot reject the null of unit root and the KPSS test rejects the null of stationarity at 1% level. On the other hand, the ADF test with trend in regression rejects the null of unit root at the 1% level and the KPSS test cannot reject the null of stationarity. However, the trend-stationary results might be the Type I error. It can be seen from Table 2B that the unit root tests for the first-differenced real GDP reject the unit root at the 1% level for both with trend and without trend cases. If the true data process of real GDP was trend stationary, a first-differencing would introduce a unit root in it and thus should result in non-rejection of the ADF test and a rejection of stationarity in the KPSS test. However, this is obviously not the case. Therefore the conclusion is that the log of real GDP data, y, is $I(1)$. This is also consistent with the findings in literature (see for example, Zhang and Wan (2004) and Wang (2004)).

The results also suggest that the seasonally adjusted prices and nominal money are also $I(1)$ processes. The ADF tests for the two variables in level cannot reject the unit root while the ADF tests for the two variables in first-differences reject the null of unit root at the 5% level. The KPSS tests also come to the same conclusion. Given the stationarity in differenced nominal money and prices, the

-2.89 respectively when only constant is included in regressions. The same change to -4.04 and -3.45 respectively when both a constant and a time trend is included in regressions. On the other hand, the critical values of the KPSS test at the 1% and the 5% level are 0.74 and 0.46 respectively when only a constant is included in regressions. The same changes to 0.22 and 0.15 when both a constant and a time trend is included in regressions.

differenced real money should be also stationary, which is confirmed by the unit root tests for differenced real money in Table 2B.

Finally, the specification of the covariance stationary vector process then depends on the long-run property of the nominal and real interest rates. Apparently, the ADF and KPSS tests in Table 2A suggest that both nominal and real interest rates are not stationary. The same tests for the first-differenced data imply that the nominal and real interest rates are all $I(1)$ processes. However, these results should be rejected based on the following considerations. First, the nominal interest rate has been administratively fixed in the short-run. It is then adjusted with a shift to a new level according to the climate of economy. Although it still shows variations in the long-run, the short-term fixed feature amounts to introduce many structural breaks in both nominal and real interest rates. By consequence, the unit root tests might be biased in favor of a unit root process (Type II error). Second, the existence of a unit root in the real interest rate is hardly reconciled with economic theory which makes our analysis difficult to interpret. Given the identified $I(1)$ process for prices, the stationarity of real interest rate requires that the nominal interest rate is also stationary. Therefore, based on these two considerations both the nominal and real interest rates are treated as stationary processes.

Based on the discussions above, the plausible long-run properties of the data are given by: $y \rightarrow I(1)$, $m \rightarrow I(1)$, $p \rightarrow I(1)$ and $i \rightarrow I(0)$. Accordingly, the covariance stationary process would be $[\triangle y, i, \triangle p, \triangle m]$. Note that this specification has important implications for the long-run property of nominal variables. For example, the absence of unit root in the nominal interest rate means that there is no money-real interest rate relationship (thus an LM equation) in the long-run. Moreover, the stationary money growth implies that any monetary intervention is absent in the long-run.

3 Some Institutional Background

Prior to illustrating the structural model used in this study, this section provides an overview of the institutional background of the Chinese economy. In particular, since much of the work is on decomposing the demand shocks in the IS-LM framework, the focus will shift to the institutional changes in the financial and fiscal reforms and the conduct of monetary and fiscal policy.[13]. This section will serve two purposes. First, it helps to justify the methodology of this study, especially the identification strategy used for the SVAR model. Second, it provides a context

[13]It is argued that other aspects of the economic reform such as enterprise reform, labour reform and reform in trade and openness mainly have supply side effects on the economy through changing technological progress and efficiency. Thus, we do not provide a detailed review on these market reforms since we are not focusing on decomposing the supply shocks.

for understanding and interpreting the empirical results.

3.1 Financial reform and monetary policy

Since 1979, the financial market has been built and reformed to fulfil its function for allocating financial resources and for providing the environment for the conduct of monetary policy. Studies of the financial reform can be seen among others, in De Wulf and Goldsbrough (1986), Brandt and Zhu (1995) and Lardy (1998). Here we focus on three aspects of the financial reform which are closely related with our purpose: the emergence of the new banking system, the financial decentralization and the conduct of monetary policy.

A summary of the institutions of the financial market and the macro management in the pre-reform era is as follows. Before 1979, the allocation of financial resources was totally controlled by the central government. Accordingly, the conduct of monetary policy was in the form of credit plan mostly controlled by the central government. The credit was extended to enterprises in the form of budgetary grants. The decisions of amount, distribution and purpose of these funds, were made by the Ministry of Finance, a department of the State Council. On the other hand, the role of the PBC, currently the central bank of China, was only accommodating the central plan and issuing bank credit to enterprises for very specific production plans. Therefore, there was no 'market' or formal monetary policy replying on market in the pre-reform era.

After the economic reform in 1979, the government started to build a financial market where financial resources can be allocated by the market mechanism. The highly centralized financial system was reformed from 1979 to 1984 when a set of specialized commercial banks[14] were founded and the State Council assigned the PBC the function of a modern central bank. This resulted in a new banking system which has gained increasing importance for allocating financial resources. For example, the PBC issued bank credits to commercial banks which were then extended to enterprises. Although other financial markets were also established in the 1980s such as the bond market and the stock market, most of the allocation of financial resources had still been through the banking system. Today, the financial reforms are still ongoing. The incomplete reform makes the financial market different from those in industrialized countries. For example, the bank interest rates (deposit rate and lending rate) were fixed in the short-run. In fact, the interest rates were used mainly for attracting households' savings by the commercial banks which were then used for financing investment. Many observers (see for example, Naughton (1987)) have seen rapid increases in bank deposits since the 1980s.

[14] There were four specialized commercial banks established during 1979-1984: the Industrial and Commercial Bank, the Agricultural Bank of China, the People's Construction Bank of China and the Bank of Communications.

A key feature of the financial reform was the decentralization of decision-making. Due to the setup of branches of the PBC at the provincial level, the branches were granted the autonomy to decide how much credit to be extended to the state-owned commercial banks. The local branches of the state-owned commercial banks then in turn obtained the discretion in issuing loans to enterprises. For example, the commercial banks were allowed to retain some of their profits gained from lending money to enterprises. Also, they were also allowed to decide the distribution of loans between state and non-state sectors.

At the start of the 1990s, more decentralization occurred. The inter-bank market was established where a more flexible nominal interest rate was used to facilitate bank businesses between the commercial banks. The decentralization in financial system has been found to be crucial for the reallocation of bank credits across different sectors of the economy. In particular, many researchers (see for example, Chai (1997) and Brandt and Zhu (2000)) have observed that this financial decentralization has directed more funds from less productive state owned enterprises (SOEs) to more productive non-state owned enterprises (non-SOEs) and thus contributed to economic growth.

The newly-built banking system has also changed the way in which the monetary policy was conducted[15]. Although the target of the PBC has long been the stability of price level, the way it achieves this target has changed after the reform of the financial system. Compared with the monetary policy prior to 1979 when the allocation of financial resources were controlled by the state council through credit plan, now the PBC act as the central bank and sets monetary targets for the economy. This sort of bank credit is usually referred as the indicative plan since it relies mostly on the banking system itself rather than the administrative controls. Two characteristics are noteworthy. First, the monetary policy was not fully independent of the central government especially during the early reform period 1979 - 1998. Instead, the monetary policy had been characterized by both indicative credit plans and administrative controls[16]. This makes the monetary policy difficult to implement independently and effectively. In 1995, 'central bank law' was issued which stating the PBC as the independent institution for conducting monetary policy. As a result, the administrative credit plan has rarely been used since 1996. Instead, the indicative credit plan has played a more important role in the conduct of monetary policy. Second, unlike the monetary policy practice in

[15] Studies on the implementation of monetary policy during the post-reform period can be seen for example, in Chow (1987), Naughton (1987), Chen (1989), Yusuf (1994), McKinnon (1994) and Xie (2004).

[16] Typical examples of the government intervention were observed during economic overheating (such as in 1981, 1989-90 and 1993-94) where the government forced the PBC to apply tight monetary policy to restrict the amount and distribution of funds to the commercial banks. Declines in output and inflation in the following periods were observed.

market economies where central banks set interest rates, a fundamental feature of the conduct of monetary policy in China is that the PBC has targeted the money aggregate. For example, the PBC has announced clear monetary targets for money supply during the period 1998-2002 (see, Xie (2004)). The use of money aggregate rather than interest rate for monetary target is mainly due to the incomplete reform in financial market.

3.2 Fiscal reform

Another important factor in the changes in the public sector is fiscal reform. Compared with the vast studies on the financial reform and the monetary policy, there has been far less on fiscal reform in China.

Two features have been identified as worthy of interest. The first feature of fiscal reform is the fiscal decentralization recognized, among others, by Bell *et al.* (1993), Tseng *et al.* (1994), Hofman (1993), Lardy (1998) and Ma (1997). The central feature of the fiscal reform is the decentralization of decision-making between the central government and the local governments. For example, during the 1980s, the local governments were allowed to retain most of their revenues and make their own decisions on spending. The new tax system was adopted in 1994 to categorize the local tax revenues into central government tax revenues, local government tax revenues and revenues shared by both. The budget plan was also made according to different administrative levels. The intention of the fiscal decentralization was to enforce the control of the central government on tax and stimulating investment of local governments. However, it resulted in enormous decreases in the budget revenue of the central government. The fall in budget revenues has continued until 2000 when the government enforced fiscal centralization through the tax system.

The second feature of fiscal reform is that the central government has discriminated its policies between SOEs and non-SOEs. In particular, it is shown that the central government still has a commitment to the state sector due to the old tradition that it takes the majority of it's support from the workers in the SOEs. Thus maintaining employment and wage level in the SOEs is important for political considerations. Some researchers (see e.g., Brandt and Zhu (2000)) show that the central government has made transfers to the state sector during output growth. Moreover, when the tax revenue is not enough to finance the transfers, the central government has to collaborate with the PBC and finance the transfers through money creation. This in turn, affects inflation. Thus, the fiscal reform also has important influence on the macro economy.

4 The Structural VAR Model

The general approach of the SVAR model is to identify the economic disturbances from the residuals in an estimated VAR model by applying a set of economic restrictions. Specifically, this study applies the methodology used in Galí (1992) and adopts both long- and short-run restrictions in the IS-LM framework[17]. By applying Galí's approach, the economic disturbances in the VAR can be identified as the four structural disturbances as in the IS-LM model.

The long-run restriction that aggregate demand shocks do not have permanent effect on output is used to isolate the supply shocks from demand shocks. This long-run restriction was introduced by Blanchard and Quah (1989) and has been widely used in empirical studies such as Shapiro and Watson (1988), Bayoumi and Eichengreen (1994), Clarida and Galí (1994), Galí (1999), Christiano, Eichenbaum and Vigfusson (2003), Francis and Ramey (2004) and Galí and Rabanal (2004).

The three types of demand shocks, i.e., money supply shocks, money demand shocks and IS shocks as in the IS-LM model are identified by applying three short-run restrictions on the contemporaneous impact of the money shocks on output and the contemporaneous reaction of output and prices to money shocks. These short-run restrictions are built on the work by Blanchard and Watson (1986), Bernanke (1986) and Sims (1986) and more applications in Christiano and Eichenbaum (1992), Christiano, Eichenbaum and Evans (2005)[18].

It is noteworthy that Galí's approach provides an advantage that the long- and short-run restrictions are imposed in a sequential order and thus are independent of each other. That is, even if one or two restrictions fail to work, other restrictions are still valid in identifying other structural shocks. This also enables a comparison of the results in each step of the identification to the result found in the literature. The following will illustrate the main predictions of the IS-LM model, the specification of the SVAR and the implementation of the identifying restrictions.

4.1 The IS-LM model

Before estimating the SVAR, the main predictions of the Phillips Curve augmented IS-LM model are highlighted so that they can be compared with the estimated dy-

[17] This strategy of using both long-run and short-run restrictions has also been used in empirical studies such as Cechetti and Karras (1994) and Karras (1994) for their study of causes of US economic fluctuations during the Great Depression.

[18] Other identification schemes in literature include Kim and Roubini (2000) and Cushman and Zha (1997) for open economy SVAR and Uhlig (1999), Faust (1998), Canova and De Nicolo (2002) and Mountford and Uhlig (2005) for sign restrictions on the impulse response functions.

namics of the SVAR[19]. The structure of the basic IS-LM model can be summarized as:

$$\begin{aligned} y_t &= \alpha + \mu_{s,t} - \sigma\left(i_t - E_t\Delta p_{t+1}\right) + \mu_{is,t} && \text{(IS equation)} \\ m_t - p_t &= \phi y_t - \lambda i_t + \mu_{md,t} && \text{(LM equation)} \\ \Delta m_t &= \mu_{ms,t} && \text{(Money supply)} \\ \Delta p_t &= \Delta p_{t-1} + \beta\left(y_t - \mu_{s,t}\right) && \text{(Phillips Curve)} \end{aligned}$$

where y, i, m and p are the endogenous variables denoting the log of output, the nominal interest rate, the log of the money supply and the log of the price level respectively. The subscripted variables μ_s, μ_{ms}, μ_{md} and μ_{is} represent the four structural shocks in the economy, i.e., aggregate supply, money supply, money demand and government spending which are assumed to follow stochastic processes. The first difference operator Δ is used to calculate money growth Δm and inflation Δp. The real interest rate is given by $(i - E\Delta p_{t+1})$ where E is the expectations operator.

Although the IS-LM model has been criticized for missing micro-foundations (see e.g., Lucas (1976)) especially on the supply side, it is still useful in providing stylized predictions on the dynamics of the economy[20]. For example, the IS equation captures the negative relationship between the real interest rate and output, the latter is also positively affected by favourable supply side shocks and public spending. The LM equation defines how the money demand for real balances is satisfied given output and nominal interest rate. The money supply equation assumes that monetary authority conducts monetary policy by controlling the money aggregate. While this is unlikely the case in most of the developed countries, it is a good description of how monetary policy is conducted in China. Finally, the IS-LM model is complemented with a Phillips Curve to reveal how prices in the short-run evolve along with the output gap, i.e., the difference between output and its potential value, μ_s.

With this structure in place, the following predictions relating to the money-interest-output transmission mechanism are of particular interest:

[19]The IS-LM model is proposed by Hicks and its Phillips Curve augmented extensions are made by Dornbusch (1990), Romer (2000) and Taylor and Moosa (2002).

[20]Recent developments in macroeconomics (either in terms of the Real Business Cycle (RBC) model or the New Keynesian model) have built a new consensus which is broadly related to this framework. For example: (i) the evolution of output gap in the New Neo-Classical Synthesis (NNCS) maps with the IS curve; (ii) the demand for real balances maps with the LM curve; and (iii) the traditional Phillips Curve evolves to the New Keynesian Phillips Curve (NKPC). Some authors (see for example, Carlin and Soskice (2005) and Benigno (2009)) also show that the NNCS has a graphical exposition as in the traditional IS-LM-PC model. Galí (2000) suggests that recent development of NNCS as a return of the IS-LM-PC framework.

- Aggregate demand shocks can have short-run effects on real variables due to nominal rigidities such as slow adjustments of prices.
- The money-real interest rate - output channel - Money shocks change real interest rate given price rigidity, which in turn affect output.

Examining the empirical validity of the above predictions is crucial for understanding roles of demand and supply shocks and how they generate aggregate fluctuations.

4.2 Specification of the SVAR

The SVAR can be represented in its moving average form as:

$$\mathbf{x} = \mathbf{C}(\mathbf{L})\boldsymbol{\varepsilon} \tag{2}$$

where $\mathbf{x}$ is a $n \times 1$ covariance stationary vector which contains the dependant variables of interest, $\boldsymbol{\varepsilon}$ consists of a $n \times 1$ vector of structural disturbances which are serially uncorrected and $\mathbf{C}(L) = C_0 + C_1 L + C_2 L^2 + ...$denotes the $n \times n$ matrix of the current and lagged effects of structural disturbances on dependant variables with L as the normal lag operator. For simplicity, the time script has been suppressed.

To make the SVAR comparable with the IS-LM model discussed above, we consider four structural shocks in $\boldsymbol{\varepsilon}$: aggregate supply, money supply, money demand and IS. The matrix $\mathbf{x}$ contains the transformed variables of output, real or nominal interest rate, prices and money with the type of transformation depending on the data property. It is noteworthy that the inclusion of the real or nominal interest rate in the VAR might cause problems due to the fact that the nominal interest rate in China has been administratively fixed in the short-run. Nonetheless, we still stick with the four-variable VAR specification due to several considerations. First, although the nominal interest rate is fixed in the short-run, it is flexible in the medium- and long-term. In fact, it has been adjusted by the PBC based on different conditions of the economy. For example, during economic overheating, the PBC usually tightens the money supply to raise interest rates, providing that higher nominal interest rate increases the borrowing cost of bank loans. Second, some recent studies (see for example, Koivu (2009)) find that the Chinese macroeconomic variables have become increasingly responsive to changes in the real interest rates. These suggest that the changes in nominal interest rate might correctly reflect economic conditions, which can be examined in our SVAR framework. Finally, the inclusion of the real interest rate provides a four-variable VAR that is suitable for distinguishing money supply from money demand shocks using short-run restrictions as in Galí (1992). It is impossible, on the other hand, to

identify the two money shocks in the IS-LM model using alternative VAR models with less than four variables.

Based on the data analysis in section 2, we adopt the following specification as the benchmark case[21]:

$$\begin{pmatrix} \Delta y \\ i \\ \Delta p \\ \Delta m \end{pmatrix} = C(L) \begin{pmatrix} \varepsilon_{as} \\ \varepsilon_{ms} \\ \varepsilon_{md} \\ \varepsilon_{is} \end{pmatrix} \tag{3}$$

where Δy denotes the growth rate (log-difference) of output, i is the nominal interest rate, $i - \Delta p$ represents the real interest rate and $\Delta m - \Delta p$ is the growth rate of real balances of money holdings. The disturbances ε_{as}, ε_{ms}, ε_{md} and ε_{is} are the aggregate supply, money supply, money demand and IS shocks respectively. According to the IS-LM model, the two money shocks and the IS shock are together categorized as aggregate demand shocks.

4.3 Blanchard-Quah and Galí identification scheme

Since the structural disturbances are not observable, the structural model in (3) and the polynomial matrix $\mathbf{C}(\mathbf{L})$ can not be directly estimated from data. One can then estimate the reduced form VAR model which, in moving average form, is given by:

$$\mathbf{x} = \mathbf{B}(\mathbf{L})\,\mathbf{v} \tag{4}$$

where $\mathbf{B}(\mathbf{L}) = B_0 + B_1 L + B_2 L^2 + ...$ is the $n \times n$ matrix of polynomial lag of the estimated coefficients and $\mathbf{v}$ is the $n \times 1$ residual matrix. Once $\mathbf{B}(\mathbf{L})$ is known, one needs to identify $\mathbf{C}(\mathbf{L})$ so that the structural impacts of shocks in $\boldsymbol{\varepsilon}$ on $\mathbf{x}$ can be also found. To do this, substitute the reduced form moving average process (4) back into the structural moving average process (2) to obtain,

$$\mathbf{B}(\mathbf{L})\,\mathbf{v} = \mathbf{C}(\mathbf{L})\,\boldsymbol{\varepsilon}. \tag{5}$$

To proceed, note that the unknown structural disturbances in $\boldsymbol{\varepsilon}$ are assumed to be linear combinations of the reduced VAR residuals in $\mathbf{v}$:

$$\mathbf{v} = \mathbf{S}\boldsymbol{\varepsilon} \tag{6}$$

where $\mathbf{S}$ is a $n \times n$ full rank matrix. Substituting above result back into (5) yields,

$$\begin{aligned} \mathbf{B}(\mathbf{L})\,\mathbf{S}\boldsymbol{\varepsilon} &= \mathbf{C}(\mathbf{L})\,\boldsymbol{\varepsilon} \\ &\Rightarrow \mathbf{C}(\mathbf{L}) = \mathbf{B}(\mathbf{L})\,\mathbf{S}. \end{aligned} \tag{7}$$

[21] The analysis based on the alternative specification allowing a unit root in nominal variables will be conducted below in Appendix 9.3 using the same identification strategy.

Now the identification of the structural coefficients matrix $\mathbf{C}(\mathbf{L})$ is transformed to the identification of the matrix $\mathbf{S}$.

To find the $n \times n$ matrix $\mathbf{S}$, one needs to find $n^2 = 16$ equations to exactly identify its 16 elements. A first set of equations can be naturally obtained from the assumption that the four structural disturbances are not correlated[22] and therefore their covariance matrix is an identity matrix, $\boldsymbol{\varepsilon}\boldsymbol{\varepsilon}' = I$. This can be achieved by taking the variance of both side of equation (6):

$$\mathbf{v}\mathbf{v}' = \mathbf{S}\boldsymbol{\varepsilon}\boldsymbol{\varepsilon}'\mathbf{S}'$$

where

$$\widehat{\boldsymbol{\Sigma}} = \mathbf{S}\mathbf{S}'$$

is the covariance matrix of the VAR residuals which is also known after estimation. Since this covariance matrix $\widehat{\boldsymbol{\Sigma}}$ is symmetric, it provides $n(n+1)/2 = 10$ equations for identifying $\mathbf{S}$. Therefore an additional number of $n(n-1)/2 = 6$ restrictions are needed to just identify $\mathbf{S}$.

This study applies the identification scheme in Blanchard and Quah (1989) and Galí (1992) to provide six additional restrictions concerning both the long-run and short-run behavior of the structural shocks. The design and implementation of the IS-LM identification is carried out as follows. First, following Blanchard and Quah (1989), we use a long-run restriction that demand shocks do not affect long-run output to identify aggregate supply shocks from aggregate demand shocks, i.e.:

- **Restrictions 1-3:** None of the three demand shocks has long-run effect on the level of output. As a result, three long-run restrictions are put on the matrix $\mathbf{C}(1)$ which governs the long-run dynamics of the model: $\mathbf{C}_{12}(1) = \mathbf{C}_{13}(1) = \mathbf{C}_{14}(1) = 0$. Given $\mathbf{B}(\mathbf{1})\mathbf{S} = \mathbf{C}(\mathbf{1})$, these restrictions imply that:

$$\begin{aligned}
\mathbf{B}_{11}(\mathbf{1})S_{12} + \mathbf{B}_{12}(\mathbf{1})S_{22} + \mathbf{B}_{13}(\mathbf{1})S_{32} + \mathbf{B}_{14}(\mathbf{1})S_{42} &= 0 && (8)\\
\mathbf{B}_{11}(\mathbf{1})S_{13} + \mathbf{B}_{12}(\mathbf{1})S_{23} + \mathbf{B}_{13}(\mathbf{1})S_{33} + \mathbf{B}_{14}(\mathbf{1})S_{43} &= 0 && (9)\\
\mathbf{B}_{11}(\mathbf{1})S_{14} + \mathbf{B}_{12}(\mathbf{1})S_{24} + \mathbf{B}_{13}(\mathbf{1})S_{34} + \mathbf{B}_{14}(\mathbf{1})S_{44} &= 0 && (10)
\end{aligned}$$

  which amounts to restricting a set of sums of structural coefficients. This long-run restriction is controversial. For example, since the coefficient matrix $\mathbf{B}(\mathbf{1})$ is estimated with error, deriving the elements in $\mathbf{C}(\mathbf{1})$ using above equations might not be accurate (see for example, Hansen and Sargent (1991), Faust and Leeper (1997) and Cooley and Dwyer (1998)). Moreover, many demand disturbances do have long-run impacts on output. Examples include the changes in the social saving rate (stemming from changes in the

[22] See for example, Cover, Enders and Hueng (2006) for a discussion of the restrictions allowing correlated aggregate demand and aggregate supply shocks.

discount rate of household or the investment rate of the government) which affect the long-run level of capital stock and thus of output. This is the case for many overlapping generations models. In the case of China, a consideration that deserves attention is that a large proportion of GDP is fixed investment. The changes in fixed investment may also have long-lasting effects on output through the accumulation of capital. However, as Blanchard and Quah (1993) argue, even if these permanent demand shocks exist, their effects are expected to be small. Also, we use near 30 years quarterly data so that most of the long-lasting impacts of demand disturbances die out sooner or later. Therefore, we consider the long-run restrictions as reasonable.

Second, Galí (1992) further puts three short-run restrictions to identify the three components of the demand shocks. To separate IS shocks from the two money shocks, two assumptions on the contemporaneous effects of money shocks on output are imposed, i.e.:

- **Restriction 4:** No contemporaneous effect of money supply shocks on output;
- **Restriction 5:** No contemporaneous effect of money demand shocks on output.

Since the short-run contemporaneous relationship between the structural shocks and the variables of interest is given by

$$\begin{pmatrix} \Delta y_t \\ i_t \\ \Delta p_t \\ \Delta m_t \end{pmatrix} = C(0) \begin{pmatrix} \varepsilon_{as,t} \\ \varepsilon_{ms,t} \\ \varepsilon_{md,t} \\ \varepsilon_{is,t} \end{pmatrix}, \tag{11}$$

this set of short-run restrictions actually concerns $\mathbf{C}(0)$ which is the matrix of the contemporaneous coefficients of structural shocks on the dependant variables. Particularly in our case, $\mathbf{C}(0)$ is equal to $\mathbf{S}$ and these two short-run restrictions imply that,

$$S_{12} = 0 \tag{12}$$

$$S_{13} = 0. \tag{13}$$

These two restrictions are a result of the 'outside lags' assumption that aggregate demand is not affected in the short-run if the money shocks do not change the financial conditions such as real interest rate and real exchange rate. Supportive evidence of this short-run restriction on money shocks has been found in developed

countries[23]. Although there is no such evidence for China, it is argued that this restriction is also reasonable. This is based on two considerations. First, it is argued that for a financial market in reform, money shocks take even more time to affect output due to the inefficiency of the financial transmission channels. Second, it is true that, during the early stage of reform, the PBC has occasionally employed direct administrative controls on the supply and demand of money. However, it is still very likely that even these direct controls also need time to take effect on output. Also, the use of these direct controls have greatly decreased over the data sample. These discussions imply that the short-run impact of money shocks is expected to be very small. Thus, these two short-run restrictions are justified.

There is one last restriction left to separate the two money shocks. Following Galí (1992), we consider three possible short-run restrictions that concern the contemporaneous impacts of dependant variables on structural shocks, i.e.:

- **Restriction 6:** Contemporaneous prices do not enter the money supply rule (thus restricts the monetary authority not to respond to short-run prices changes);
- **Restriction 7:** Contemporaneous GDP does not enter the money supply rule (thus restricts the monetary authority not to respond to short-run GDP changes);
- **Restriction 8:** Contemporaneous prices do not enter the money demand rule (thus imposes homogeneity in the money demand function).

Since these restrictions deal with the contemporaneous impacts of dependent variables on structural shocks, we rewrite the system in (11) to obtain,

$$\mathbf{C}(0)^{-1}\begin{pmatrix}\Delta y_t\\ \Delta i_t\\ \Delta p_t\\ \Delta m_t\end{pmatrix}=\begin{pmatrix}\varepsilon_{as,t}\\ \varepsilon_{ms,t}\\ \varepsilon_{md,t}\\ \varepsilon_{is,t}\end{pmatrix}. \tag{14}$$

These three restrictions then concern the inverse of the matrix $\mathbf{C}(0)$,

$$\mathbf{C}(0)^{-1}=\mathbf{S}^{-1}=\overline{\mathbf{S}}$$

where $\overline{\mathbf{S}}$ denotes the inverse of the matrix $\mathbf{S}$. For restriction 6 where the relationship between Δp_t and $\varepsilon_{ms,t}$ is considered, it implies that,

$$\overline{S}_{23}=0. \tag{15}$$

[23]Supportive evidence in the developed countries can be found from the effect of money shocks on investment as in Shapiro (1986) and also on the effect of exchange rate on trade flows as in Wilson and Takacs (1979).

For restriction 7 where the relationship between Δy_t and $\varepsilon_{ms,t}$ is considered, it implies that,

$$\overline{S}_{21} = 0. \tag{16}$$

Finally for restriction 8 where the relationship between Δm_t, Δp_t and $\varepsilon_{md,t}$ is considered, it implies that,

$$\overline{S}_{33} + \overline{S}_{34} = 0. \tag{17}$$

Employing any restriction from 6-8 together with the restrictions 1-5 discussed above will provide 16 equations to just-identify S.

The choice of restrictions 6-8 deserves a further discussion. The first two restrictions, i.e., R6 and R7 are associated with the 'inside lags' of the PBC in response to changes in the economy. Thus, the choice of restrictions R6-R7 depends on which one is more consistent with the monetary policy practice in China. In fact, R6 and R7 concern how much weight the government has put on output gap and inflation in the short-run. Unfortunately, it is difficult to choose between R6 and R7 given the monetary practice in China. On one hand, the government has used both indirect economic and direct administrative tools to control the bank loans and money supply during an inflation hike. This indicates that using R6 to identify the money shocks might be risky[24]. On the other hand, China as a developing country has also put much emphasis on GDP growth rate every year. Thus it is also risky to use R7 to identify the two money shocks. In an attempt to further understand the implications of these restrictions we conducted an empirical analysis using both R6 and R7. The results show that both R6 and R7 failed to distinguish money supply shocks from money demand shocks (see Appendix (9.2) for details). Therefore, we discard R6-7 and turn to R8.

Now we turn to R8 which amounts to assuming that changes in demand for nominal money move one-for-one with changes in prices. This assumption is usually to imply that there is no cost of adjusting nominal money holdings. This assumption of homogeneity in money demand seems to be supported by a number of empirical studies on money demand in China (see e.g., Hafer and Kutan (1994)). In fact, recent studies on money demand in China (see e.g., Xu (1998) and Mehrotra (2006)) often impose the homogeneity assumption directly. We then use R8 to conduct the analysis. The results turn to be more plausible with theory than the results obtained using R6 and R7. Based on the above discussion, the following will proceed with R8 to identify the two money shocks in our SVAR.

[24] Besides, the awareness of the danger of price volatility (such as the Tiananmen Square Incident) leads the government to issue the Central Bank Law in 1995 which states the price stability as the primary objective of the PBC.

4.4 General issues with specification and identification of SVAR

Although the restrictions discussed above enable us to mathematically solve for the unknown structural coefficients, the accuracy of this methodology in correctly estimating the effects of economic shocks has been questioned in literature. While early criticism on the identification technique can be found on the misuse of long-run restrictions discussed above, some more general issues have been acknowledged in the literature. Recent work by Chari, Kehoe and McGrattan (2005) claims that the structural VAR models are likely to be misspecified. Their estimated impulse response functions of hours to technology shocks using structural VAR based on the simulated data from the Real Business Cycle model are at odds with the theoretical ones. However, Christiano, Eichenbaum, and Vigfusson (2006) also makes use of the RBC model as data generating process but arrive in the opposite conclusion that although the long-run restriction generate wider confidence intervals than short-run restriction due to bigger sampling uncertainty, it is still accurate as long as the technology shock accounts for at least one percent variance in hours worked. Particularly, Gali and Rabanal (2004) re-examined the critics in Chari, Kehoe and McGrattan (2005) and pointed out that their striking results are due to misspecification and misidentification in their use of the structural VAR, not to the flaws of the technique itself. The structural VAR is still extremely useful in identifying responses of economic shocks and discriminating theoretical models.

Some researchers have investigated the performance of structural VARs in a more general way. For example, Ravenna (2007) evaluated the performance of the finite order VAR approximations to the exact infinite order VAR representation of a theoretical model. It is found that even if there is no identification bias, the truncated VAR can still deliver largely inconsistent estimates of the structural coefficients. The problem lies in the fact that finite order VAR is truncated VAR approximation that might not be the appropriate approximation of the infinite order VAR representation of the theoretical model. To overcome this problem, one way is to include more variables in the finite truncated VAR (see, e.g., Erceg, Guerrieri and Gust (2005)) and test the robustness of the results. To do such a robustness check, more data is required (which might be a difficulty in the case of China) and the identification scheme illustrated above needs to be revised accordingly. While this has not been undertaken in the current thesis, this deserves a further examination in future work.

5 How well does the IS-LM model fit post-reform Chinese data?

The next two sections report the empirical results of the SVAR model specified in Section 4. Firstly there are the estimated impulse response functions which generate model dynamics that can be compared with the predictions in the IS-LM model. This is used as a way to examine the fit of the theoretical model to the Chinese data. Following, the standard forecast error variance decomposition was calculated in Section 6 to examine the contribution of each economic shock to output fluctuations over the data sample. Additionally the historical forecast error decomposition is presented together with the recognized economic events so as to answer the question that how the role of each economic shock changes over time.

Firstly the question is how successful the IS-LM model is in explaining the Chinese data. This is done by comparing the estimated effects of economic shocks on the economy with those predicted by the IS-LM model summarized in Section 4.1. The estimated impulse response functions are presented which describe how the variables of interest react to a one period change in the structural shocks. For example, from the moving average form of the structural model (3), the impact of a particular structural shock on a particular dependant variable is given by:

$$\mathbf{x}_{i,t} = \mathbf{C}_{i,j}\left(\mathbf{L}\right)\boldsymbol{\varepsilon}_{j,t} \tag{18}$$

where $i, j \in 1, 2, 3, 4$ correspond to the four dependant variables in $[\triangle y, \triangle i, ri, \triangle rm]$ and the four structural shocks in $[as, ms, md, is]$ respectively, and they select the (i, j) entry of the $\mathbf{C}\left(\mathbf{L}\right)$ matrix. Expressing above result explicitly and leading it h period ahead gives:

$$\begin{aligned}
\mathbf{x}_{i,t} &= \mathbf{C}_{i,j}(0)\boldsymbol{\varepsilon}_{j,t} + \mathbf{C}_{i,j}(1)\boldsymbol{\varepsilon}_{j,t-1} + \mathbf{C}_{i,j}(2)\boldsymbol{\varepsilon}_{j,t-2} + ... \\
\mathbf{x}_{i,t+1} &= \mathbf{C}_{i,j}(0)\boldsymbol{\varepsilon}_{j,t+1} + \mathbf{C}_{i,j}(1)\boldsymbol{\varepsilon}_{j,t} + \mathbf{C}_{i,j}(2)\boldsymbol{\varepsilon}_{j,t-1} + ... \\
\cdots &= \cdots \\
\mathbf{x}_{i,t+h} &= \mathbf{C}_{i,j}(0)\boldsymbol{\varepsilon}_{j,t} + \mathbf{C}_{i,j}(1)\boldsymbol{\varepsilon}_{j,t+h-1} + ...\mathbf{C}_{i,j}(h)\boldsymbol{\varepsilon}_{j,t} + ...
\end{aligned}$$

which implies that the impulse responses of $\mathbf{x}_{i,t+h}$ to the structural shock $\varepsilon_{j,t}$ is given by:

$$\mathbf{x}_{i,t+h} = \mathbf{C}_{i,j}(h)\boldsymbol{\varepsilon}_{j,t} \tag{19}$$

which is the general result for calculating the impulse response functions for variables in levels such as the real interest rate. For variables in first difference, such as the real GDP, it is easily to show that the impulse response function is just the

cumulative sum of the (weighted) structural shock which is given by:

$$\mathbf{x}_{i,t+h} = \sum_{l=1}^{h} \mathbf{C}_{i,j}(l)\boldsymbol{\varepsilon}_{j,t}. \tag{20}$$

The impulse responses of different variables of interest to the four structural shocks considered in the IS-LM framework are reported below.

5.1 Impulse responses - Supply shock

The impulse responses of variables to a favourable one-standard deviation aggregate supply shock are shown in Figure 1. The initial impact of aggregate supply shock on GDP is about 0.62 percent which roughly matches the one estimated in Galí (1992) for US data. The increase in output growth grows larger in the following 10 quarters and stabilizing around 2 percent, double of the same for US data. As the economic theory predicts a favourable supply shock dampens prices. An initial 0.15 percent fall in prices is observed. This decrease in prices is small and short-lived - vanishing after three quarters. From the fourth quarter, the impact of the initial supply shock becomes inflationary. Prices continue to climb up and reach a peak 8 quarters after the shock. After that, the inflation takes more than four years to disappear.

The marked surges of money supply observed are largely responsible for the mid- to long-run inflationary impacts of the supply shock. It is shown that, the nominal money responds by an over 0.5 percent increase in its growth rate, which is large. This explains the small decrease in prices in the first three quarters. As found in many developed countries, this can be seen as a monetary accommodation by the central bank as a way to offset the falling prices. However, as shown in Figure 1, the demand for money seems to be soon 'over' accommodated - the increase in money growth remains large and persistent (although shows some irregular variations) in the following two to four years. This soon gives rise to inflationary pressures and induces a long-lived inflation.

The responses of the nominal interest rate are considerable with substantial persistence. Since the adjustments in prices are relatively small, the responses of the real rate display similar pattern with the nominal interest rate. However, the dynamics of the nominal interest rate and the real balances are largely consistent with the LM equation: their adjustments within four quarters show a different shape with output since the nominal rate decreased considerably. After six quarters when the output gradually stabilizes, the adjustments of real balances and nominal rate show adverse directions. The embedded estimate of the income elasticity of real balances, φ, varies over time. Its short-run value is about 1.1, bigger than the

same estimate for the US, 0.3. Its the long-run value is about 0.9, smaller than the same estimate for US, 1.5.

Compared with similar studies of responses of variables to supply shocks, two features in our results are noteworthy. First, as discussed above, the reaction of output after a supply shock in the medium-run is about twice as big as the one estimated in Galí (1992) for US. Although this is not surprising given China as a developing country, it does highlight the importance of economic reforms in China. It implies that the efficiency improvement through economic reform is crucial for the development of the economy. This point has been commonly acknowledged in the developing economies literature and will be further discussed in the next section by calculating the importance of supply shocks.

The second important feature in the Chinese economy regarding the results in Figure 1 is the exceptional large monetary 'over' accommodation. The money supply goes up together with output growth after a supply shock. The reason for this behavior deserves a further discussion. That is, what has induced the large and persistent monetary responses? As mentioned above, the discussion of institutional background in Section 3 might shed light on this issue. It suggests that institutional factors related with the economic reform and the conduct of monetary policy must account for the odd monetary responses. In fact, there have been attempts of researchers which explain macroeconomic performance with these institutional factors[25]. Among these attempts, the explanation of Brandt and Zhu (2000) seems to be most suitable for understanding our results. Brandt and Zhu (2000) argued that the money creation and inflation can be a natural result of two institutions in China: the decentralization and the commitment of the government to the state sector. Economic decentralization allows more productive non-SOEs access more resources and thus contribute to economic growth. However, as the gap between the SOEs and the non-SOEs becomes large, the government has to make fiscal transfers to the SOEs due to its commitment to the latter and its inability of redirecting bank credit to the state sector under the decentralized banking system. Since its fiscal revenue is declining due to the fiscal decentralization, the fiscal transfers have to rely on money creation which causes inflation. This explanation fits the result well. The observed significant and persistent increases in money growth just reflect the dilemma of the government - the faster the output grows, the more gap of productivity and wage between SOEs and non-SOEs and thus more need to compensate the less productive state sector and to increase money supply. This situation continues, until the economy is overheating with rising inflation. The government has to adopt strict administrative controls on bank credit and cuts money supply. This cools both the output growth and inflation

[25] Examples of these attempts include Yusuf (1994), Naughton (1995), Imai (1996), Yu (1997), Oppers (1997), Fung *et al.* (2000), Qian and Roland (1998) and Brandt and Zhu (2000).

down.

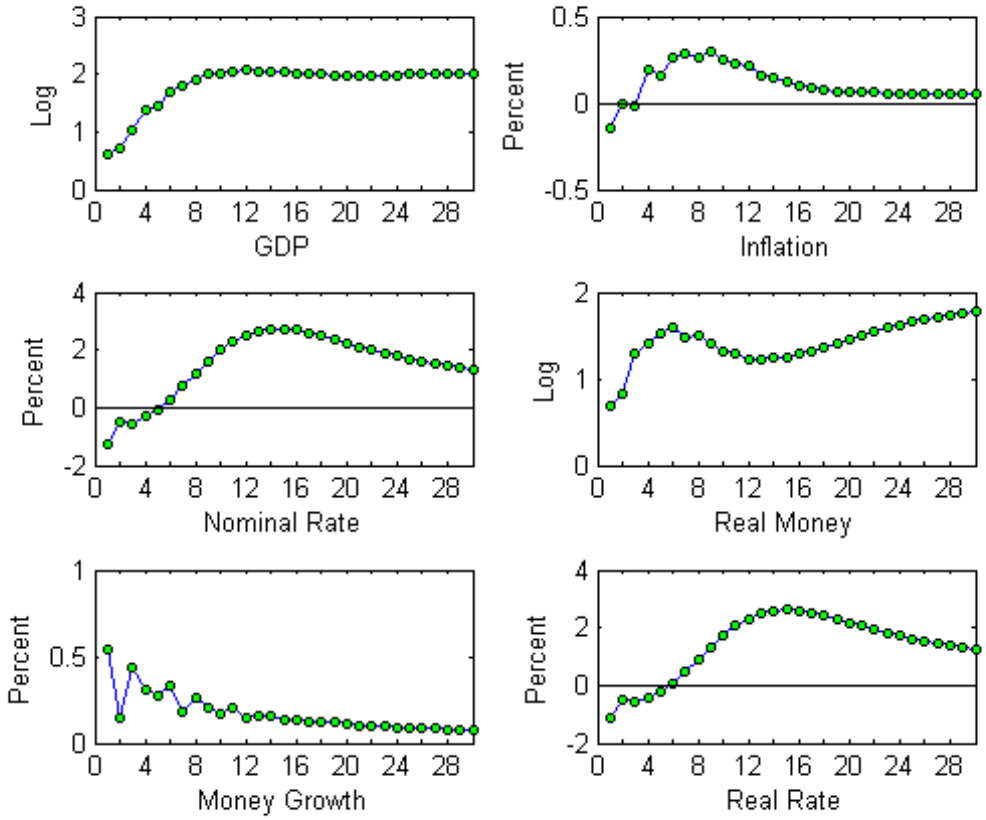

Figure 1: Impulse Responses - Supply Shock

5.2 Impulse responses - Money supply shock

Figure 2 shows the responses of different variables to a one-standard deviation shock in money supply. We first observe an initial jump of 0.75 percent in nominal money, followed by some irregular behavior in the same variable which eventually returns to its initial value. The money-real interest rate-output transmission mechanism in the IS-LM model works well: the increase in money growth induces an immediate increase in real balances since the increase in inflation is less. Both nominal and real interest rates fall considerably, indicating that the liquidity effect[26] far outweighs the Fisher effect due to smaller adjustment of prices. Output,

[26] Considering the fact that the nominal interest rate is administratively fixed in the short-run, this liquidity effect might reflect the fact that the PBC cuts interest rate to reduce the borrowing

although assumed not to respond to demand shocks in the first quarter, gradually goes up due to lower real interest rate in a way consistent with the IS equation. However, compared with the substantial drop in real interest rate, the effect on output is very small, indicating that the real interest rate effect is weak in China. As output growth increases, inflation and nominal interest rate also go up in a way consistent with the Phillips Curve and the LM equation. It is noteworthy that the adjustment of nominal interest rate is quite fast. It becomes positive only after 4 quarters, and so does the real interest rate since the increase in prices remain small. In consequence, output growth slows down and turns slightly negative after 12 quarters, leading inflation to gradually return to zero.

Since there is no unit root in nominal variables under this specification of the model, inflation, nominal rate and money growth eventually return to their initial values in the long-run. Accordingly, the LM equation which measures the relationship between the real balances and the real interest rate finally disappears after infinite horizons. However, since the adjustments of the two variables are slow, it is still possible to measure the short- to mid-term LM equation: the point estimate of the interest-semi-elasticity, λ, is about 0.5 in 12 quarters and is close to 0.9 after 29 quarters. In the long-run, only the real balances are permanently affected (since the level of money is lower than the price level in the long-run). The working of the IS-LM transmission mechanism of money supply shock is one of the most striking results of this study. This indicates that as economic reform goes deep, market mechanisms gain more importance. This gives the monetary authority more room to conduct its policy and reply more on the working of the market mechanism. This finding is consistent with the observation that the PBC has adopted more and more indirect instruments than direct controls in the post-reform period.

The responses of output and inflation to the money supply shock in Figure 2 can be compared with the those to the supply shock in Figure 1. It is shown that the impact of the money supply shock on output in Figure 2 is much smaller than the increase in output growth observed in Figure 1: The maximum of response of output to money supply shock is 0.22 and it soon vanishes and even turns negative after 12 quarters. On the other hand, the impact of the money supply shock on inflation in Figure 2 is much bigger than the jump in inflation in Figure 1: The maximum response of output to money supply shock is almost double of the same in supply shock case and it persists for 12 quarters. Taking the results together, it is concluded that the responses of output in Figure 1 is mostly caused by supply shocks while the induced money expansion is mainly responsible for the increases in inflation.

The estimated impulse responses of variables after a money supply shock show

cost of the commercial banks and enterprises when an expansionary policy is implemented.

various differences with the estimates for the US data. The biggest difference lies in that the effect of the money supply shock on output is much smaller in the case of China while the effect on prices is much bigger. In other words, a positive money supply shock leads to smaller increases in GDP and is more likely to cause inflation. This has been reflected in the estimates of the medium to long-run interest-semi-elasticity. For instance, the estimate for λ after 29 quarters for US data is close to 2, much bigger than the estimate as in Chinese data. This difference in the impact of monetary expansion has important implication. It indicates that there are still obstacles in the Chinese economy which prevents the monetary transmission mechanism from working fully. This is not difficult to understand given the incomplete reform in financial markets and the conduct of monetary policy discussed in the institutional background section 3.1.

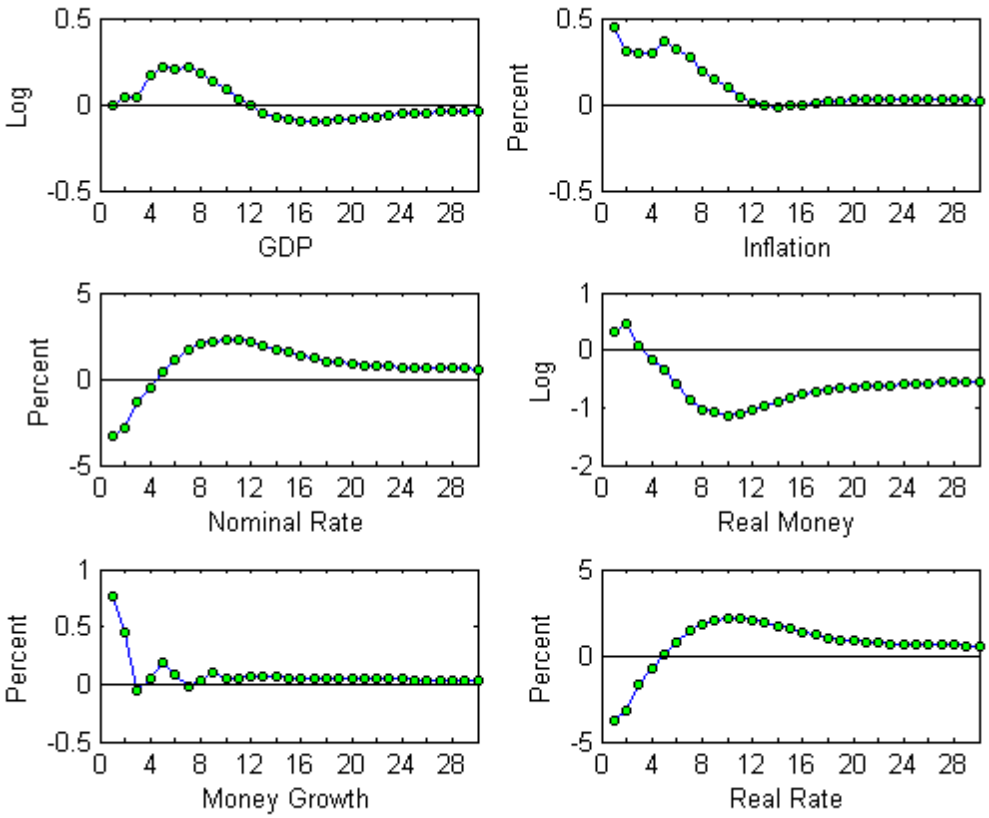

Figure 2: Impulse Responses to Money Supply Shock

5.3 Impulse responses - Money demand shock

The responses of variables to an one-standard deviation increase in real balances demanded are shown in Figure 3. At a first glance, they appear qualitatively as a mirror image of the impulse responses to the money supply shock. There are two noteworthy exceptions. The first exception is that the responses of output within 8 quarters take an erratic pattern. There appears a short term positive correlation between output and real interest rate, which is thus inconsistent with the IS equation. It disappears after 8 quarters and is replaced by a negative relationship between output and real interest rate consistent with the IS equation. The second exception concerns the observed inflation instead of deflation as would be predicted by general equilibrium models. This is due to the strong monetary accommodation to the increase in money demand: Money growth increases 2 percent which is even more than the increase of the same variable to a money supply shock. The vast liquidity seems to induce excess demand over supply, entailing a jump in prices. Since the jump in money supply is one-off, the jump in inflation is also short-lived. It is important to note that, the positive correlation between output growth and inflation suggests that the Phillips Curve is still valid. Overall, the responses of variables to money demand shock still favors the reasonableness of the IS-LM model.

In the long-run, only the real balances are permanently affected. Although prices adjust quickly after the jump, the slow adjustment of the nominal interest rate (again, due to its short-run 'fixed' feature) leads to large persistence in real interest rate and thus a long-lived effect on output.

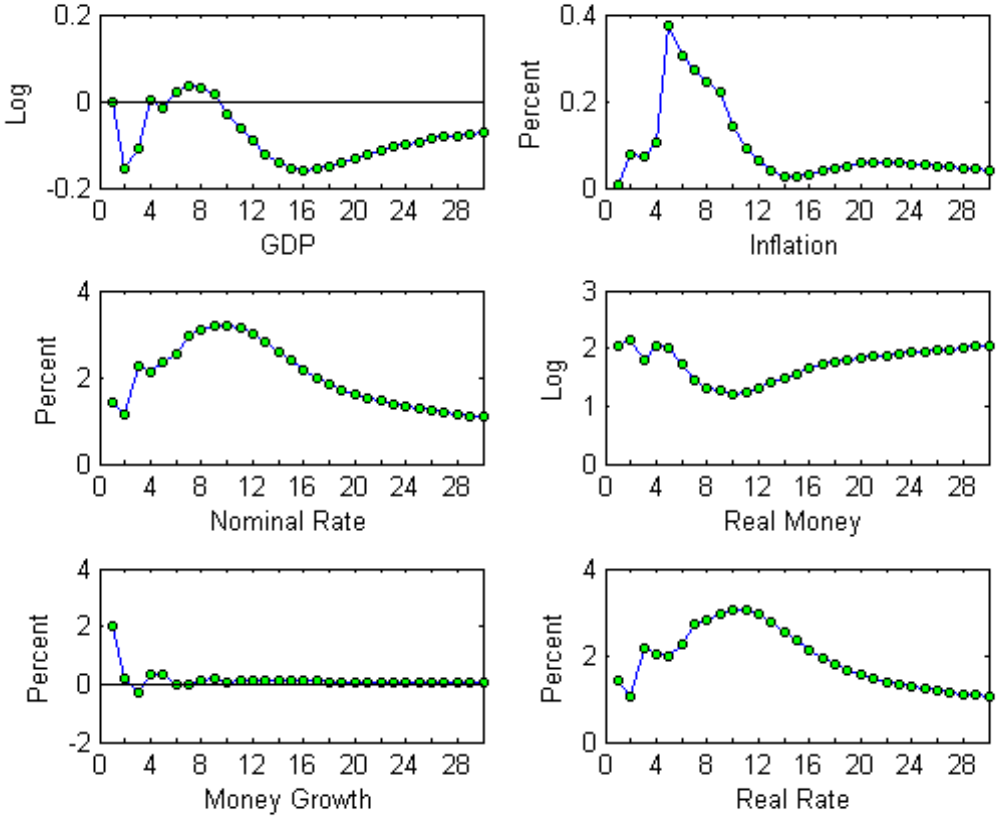

Figure 3: Impulse Responses to Money Demand Shock

5.4 Impulse responses -IS shock

The effect of a positive one-standard deviation shock in public spending is shown in Figure 4. The results vividly display the dynamics of the nominal and real variables and the interaction between the fiscal and monetary policies. Firstly, the fiscal expansion leads to an immediate increase of 0.3 percent in real GDP. The nominal interest rate goes up considerably in a way consistent with the LM equation. Prices also respond fast but moderately. As a result, the real interest rate jumps up in a shape similar with the nominal interest rate. The quick response of the real interest rate dampens the increase in output in a way consistent with the IS equation. The downward pressure of output and inflation however, is not only from the crowding-out effect - the monetary authority cuts money supply in response to the increase in fiscal spending. Real balances immediately go negative after the monetary contraction, generating more upward pressure on real interest

rates. After the real interest rate reaches a peak in 7 quarters, output falls and the positive impact of the initial fiscal spending dies out. As a result, the positive impacts of fiscal expansion on output disappear after 8 quarters.

In the long-run, money growth by assumption returns to zero. All the variables except for the real balance variable return to their initial values. The estimated semi-elasticity of real interest rate in the LM equation, λ, is 1.5 in 12 quarters and is about 3.3 in 20 quarters. These estimates are higher than in the case of money supply shock.

The result of the estimated responses of variables to an IS shock highlight two interesting findings. First, it turns out that the monetary policy is complementary with fiscal policy. This is clearly an important difference compared with the result for the US where money supply increases together after an IS shock. This might have reflected the fiscal policy design of the Chinese government probably in fear of overheating problem in the Chinese economy. The latter again can be due to institutional reasons. Second, since nominal money is assumed to be $I(1)$, there is no monetary intervention in the long-run. In many developed countries, the intention of raising money supply in the medium and long-run of the monetary authority usually lead to inflation in the long-run. In the case of China however, there is no such attempt and therefore no inflation in the long-run.

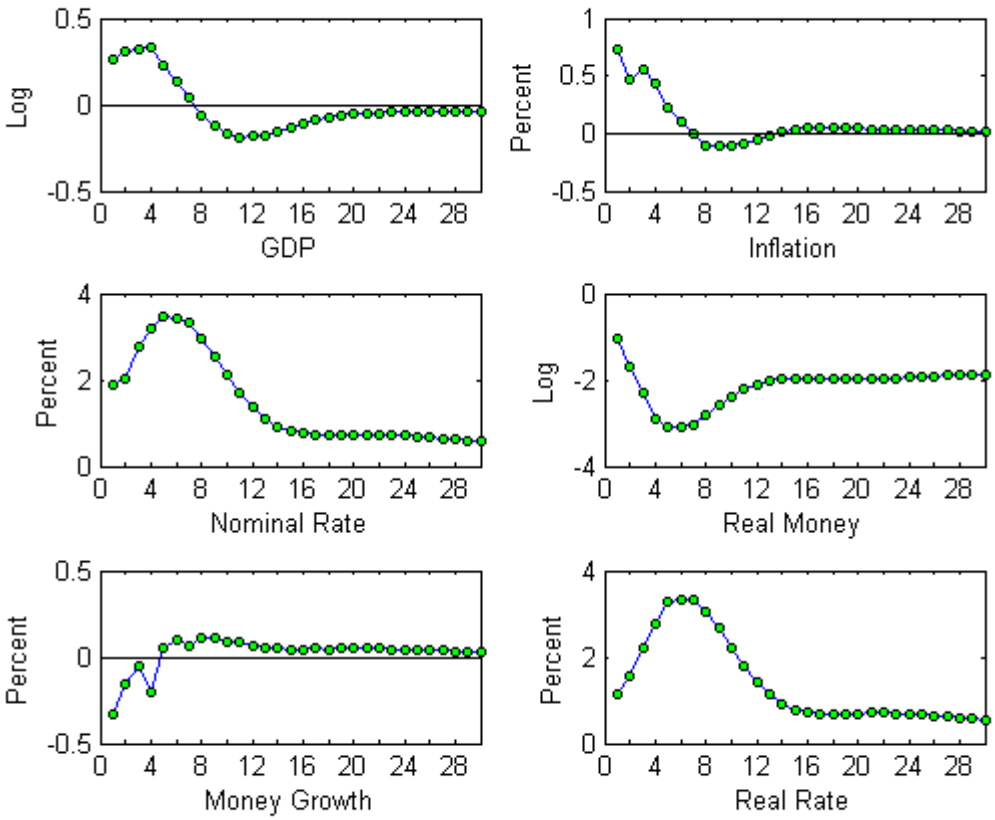

Figure 4: Impulse Responses - IS Shock

In summary, the estimated responses of variables to the four structural shocks are all consistent with the dynamics predicted by the IS-LM model. This implies that the market mechanisms during economic reform are gaining increasing importance. Not only are supply shocks such as changes in technology and efficiency work in consistent with the theory, but also that the fiscal and monetary policies work more through market channels. The results confirm the positive changes in the economic structure in the post-reform Chinese economy. This is one of the most important findings in this study.

6 Sources of China's post-reform business cycles

6.1 Variance decompositions

Another important question is that of the sources of output fluctuations. One might have inferred the importance of each structural shock from the magnitudes

of the responses of variables to different shocks discussed above. To bolster the inferences two more standard examinations were conducted, i.e., the forecast error variance decomposition (FEVD) and the historical forecast error decomposition (HFED) to precisely gauge the contribution of each structural shock to output fluctuations. The FEVD assigns the output variance over the data sample to proportions accounted by the four structural shocks and thus can be considered as reflecting the overall importance of each shock in accounting for output variations. The HFED decomposes the time series of the variations in output into structural shocks components providing a historical view on the importance of each shock.

To see the derivation of these two decompositions, note that the forecast error of variables in $\mathbf{x}$ based on the estimated SVAR is given by:

$$\begin{aligned} & \mathbf{x}_{t+h} - \widehat{\mathbf{x}}_{t+h} \\ = \; & \mathbf{C}(L)\boldsymbol{\varepsilon}_{t+h} \\ = \; & \sum_{l=0}^{\infty} \mathbf{C}(l)\boldsymbol{\varepsilon}_{t+h-l} \end{aligned} \tag{21}$$

where $\mathbf{x}_{t+h}$ is the matrix consists of the realizations of the variables of interest, $\widehat{\mathbf{x}}_{t+h}$ is the fitted value based on the estimated structural coefficient matrix $\mathbf{C}(L)$ and h is the forecast horizon. The historical decomposition of this forecast error with respect to each structural shock is then given by:

$$\mathbf{x}_{i,t+h} - \widehat{\mathbf{x}}_{i,t+h} = \sum_{l=0}^{h-1} \mathbf{C}_{i,j}(l)\boldsymbol{\varepsilon}_{j,t+h-l} \tag{22}$$

where as defined before the subscripts i and j correspond to the ith variables in $\mathbf{x}$ and jth shock in $\boldsymbol{\varepsilon}$ and they select the (i, j) entry of the structural matrix $\mathbf{C}(L)$. Again it is noteworthy that the above calculation is for variables in first difference such as the real interest rate. The calculation for variables in levels such as the output is slightly different and is given by:

$$\mathbf{x}_{i,t+h} - \widehat{\mathbf{x}}_{i,t+h} = \sum_{l=0}^{h-1} \mathbf{D}_{i,j}(l)\boldsymbol{\varepsilon}_{j,t+h-l} \tag{23}$$

where $\mathbf{D}_{i,j}(l)$ is now a cumulative sum, $\mathbf{D}_{i,j}(l) = \sum_{s=0}^{l} \mathbf{C}_{i,j}(s)$.

The results of the FEVDs for the four dependant variables are reported in Table 3 and plotted in Figure 5. These results confirm the findings in the previous impulse responses analysis. Aggregate supply shocks account for an average of

89% of the short-run (two years) real GDP fluctuations[27]. After twenty quarters, almost all of the GDP fluctuations are due to supply shocks. The demand shocks on the other hand, only account for a small part of GDP fluctuations. Specifically, the fiscal spending shock accounts for about 17% of GDP fluctuations in the first quarter and 10% in the first year. Its impact vanishes quickly in two years. Also, although the impulse responses of output under all shocks are affected by the responses in money growth, the contributions of the two money shocks on GDP fluctuations are almost negligible. The result of the dominant contribution of supply shocks to output fluctuations is much larger than those found by Zhang and Wan (2004) and Silkos and Zhang (2008)[28]. This result is also consistent with the findings for developed countries (for example, Blanchard and Quah (1989) and Galí (1992) for US data).

It is very useful to compare the results of the FEVDs with those estimated for other developed and developing countries. For example, early studies using similar VAR specification and identification strategy (e.g., Shapiro and Watson (1988) and Galí (1992)) found smaller fraction (around 70%) of output contributable to supply shocks in the short-run for the US economy. However, recent studies using only long-run restrictions (e.g., Galí (1999), Galí and Rabanal (2004), Francis and Ramey (2005), Chari, Kehoe and McGrattan (2005) and Christiano, Eichenbaum and Vigfusson (2006)) have found this fraction to be substantially smaller (from 7% to 37%, overall not over 40% in all VAR specifications). Also, similar structural VAR studies for the european countries (e.g., Karras (1994)) also found much smaller (not over 45%) importance of supply shocks. On the other hand, the dominant role of supply shocks are consistent with the findings in most developing countries. For example, the study of Morling (2002) using Blanchard and Quah identification reported a average fraction of 87% of supply components for developing countries in Asia, Africa, Middle East and Western Hemisphere. Some other studies using alternative identification schemes (e.g., Du Plessis *et al.* (2008) and Sato, Zhang and McAleer (2010)) also found quite high percentage of output fluctuations due to supply shocks.

The above discussion seems to suggest that supply shocks play dominant role in developing countries. This finding has important implications. First, the dominant role of supply shocks highlights the importance of economic reforms undergone de-

[27] Note that the monetary expansion along with the supply shock also plays an important role in driving the dynamics of the economy. However, as discussed in Section 5.2, its impact is mainly on inflation while its impact on output is very small.

[28] Possible reasons why these researchers obtain smaller role of supply shocks might be that Zhang and Wan (2004) use a two-variable VAR model, which might ignore the supply-induced money effect on output. Moreover, their data length is also smaller. Silkos and Zhang (2008) apply a different identification strategy where supply and demand shocks are correlated, which might assign a large portion of supply side effect to demand side.

veloping countries. For developing countries, the efficiency improvement is another source of economic growth besides technolgical progress. Second, given this dominant role of supply shocks, diagnosing the sources of supply shocks is critical for understanding economic fluctuations. A further decomposition is very meaningful. Applying another identification scheme (see example, Shapiro and Watson (1988)) to further investigate the components of supply shocks requires data for the producing inputs of output such as employment. However, this is not possible for China since the supply side data are not available, especially at quarterly frequency. This leaves areas for future research once more data becomes available. Third, the dominance of supply shocks for causing economic fluctuations also has important implication for macroeconomic modeling. It indicates that theoretical models for explaining the working of the Chinese economy should mainly build on real side of the economy. In this sense, modeling paradigm starting from a real business cycle (RBC) model would be preferred. Fourth, in the case of China, despite the working of the fiscal and monetary policies shocks analyzed in the impulse responses, the overall contributions of them to economic fluctuations are small. This indicates that the incomplete reform and related institutional structures discussed before might have built obstacles for monetary shocks to affect the economy. In other words, the working of the fiscal and monetary policies might have still partially replied on non-market channels such as credit controls. Thus, further reforms are needed to allow the financial market to work fully.

Finally, although the emphasis of this study is on output fluctuations, the FEVDs for other variables are also summarized as follows. The fluctuations in nominal interest rate are mainly accounted by IS shocks and money supply shocks in the short-run. For, the long-run, fluctuations are caused by all of the four shocks with more important responsibility given by money supply shocks and IS shocks. This again confirms that, all of the shocks are sources of unit root in nominal variables. Nonetheless, the FEVDs further reveal that money supply shocks and IS shocks are most responsible. The short-run fluctuations in inflation are most accounted by the money supply and the IS shocks. However, money demand shocks and supply shocks gain increasingly importance over time. The former becomes the main source of inflation fluctuations in the long-run. The variations in money growth are mainly determined by money supply shocks. In the long-run, all the shocks are responsible for inflation fluctuations with money demand shocks playing the most important role.

Table 3: Decomposition of Forecast Error Variance

Component:	Supply	Money Supply	Money Demand	IS
GDP				
1 quarter	0.83	0.00	0.00	0.17
4 quarters	0.88	0.01	0.01	0.10
8 quarters	0.96	0.01	0.00	0.03
12 quarters	0.97	0.01	0.00	0.02
20 quarters	0.98	0.00	0.01	0.01
Nominal Rate				
1 quarter	0.03	0.26	0.00	0.71
4 quarters	0.00	0.27	0.01	0.72
8 quarters	0.02	0.36	0.08	0.54
12 quarters	0.09	0.39	0.13	0.39
20 quarters	0.19	0.36	0.17	0.28
Inflation				
1 quarter	0.09	0.61	0.11	0.19
4 quarters	0.04	0.35	0.21	0.40
8 quarters	0.3	0.20	0.30	0.47
12 quarters	0.10	0.2	0.35	0.35
20 quarters	0.21	0.19	0.34	0.26
Money Growth				
1 quarter	0.09	0.61	0.11	0.19
4 quarters	0.04	0.35	0.20	0.41
8 quarters	0.03	0.20	0.30	0.47
12 quarters	0.09	0.21	0.35	0.35
20 quarters	0.22	0.18	0.34	0.26

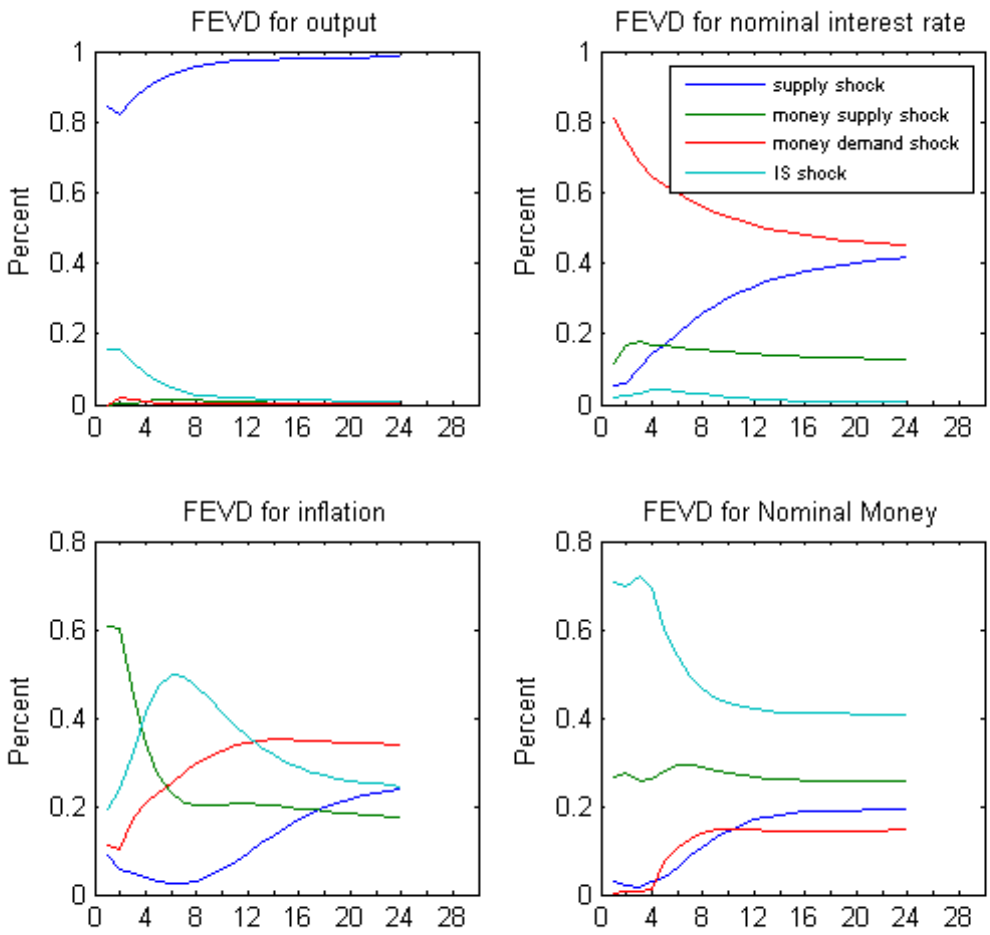

Figure 5: Decomposition of Forecast Error Variance

6.2 Are business cycles all alike?

The above discussion of the FEVDs can be considered as an exposition of the *overall* contribution of each structural shock in accounting for fluctuations. It does not tell us however, the importance of each shock at a specific time. Although the variance decompositions implies that the historical contributions of the three demand shocks on average are also small, a historical examination might tell different stories. Therefore, this section presents the HFED of the real GDP series and examines the sources of the business cycles in the sample period 1983Q1-2009Q3[29].

[29] The first three years, 1980-1982, are lost due to differencing variables (one year lost for first-differencing and two years lost due to the two-year forecast horizon).

The calculation of the FEVD is very similar. The FEVD is measured as the ratio of the contribution of a particular structural shock to the variance of h-step forecast error of a given variable over the variance of the h-step forecast error of this variable. Since the variance-covariance matrix of the structural shocks is just identity matrix, the variance of the forecast error is just given by:

$$\sum_{l=0}^{h-1} \mathbf{C}(l)\mathbf{C}(l)'$$

and the decomposition of this variance according to each structural shock is given by:

$$FEVD_{i,h} = \frac{\sum_{l=0}^{h-1} \mathbf{C}_{i,j}(l)^2}{\sum_{l=0}^{h-1} \mathbf{C}(l)\mathbf{C}(l)'} \tag{24}$$

where the subscripts i, j as defined before represent the contribution of the jth shock on the variance of the forecast error of the ith variable. They select the (i, j) entry of the structural matrix $\mathbf{C}(L)$. This representation is for variables in level such as the nominal rate. For variables in first difference such as output, the FEVD is given by:

$$FEVD_{i,h} = \frac{\sum_{l=0}^{h-1} \mathbf{D}_{i,j}(l)^2}{\sum_{l=0}^{h-1} \mathbf{D}(l)\mathbf{D}(l)'} \tag{25}$$

where $\mathbf{D}_{i,j}(l)$ is now a cumulative sum, $\mathbf{D}_{i,j}(l) = \sum_{s=0}^{l} \mathbf{C}_{i,j}(s)$.

Before starting the analysis, we characterize the chronology of China's business cycles from 1983Q1 to 2009Q3 by examining the de-trended series derived by the HP filter (Hodrick and Prescott (1997)) plotted in Figure 6. The figure demonstrates broad co-movement between detrended GDP and inflation (i.e., the peaks and the troughs) roughly map each other, implying that the occurrences of economic overheating over the sample period. Another significant feature is that both the amplitudes of the fluctuations in GDP and inflation decrease after 1996. This feature is usually referred as the 'soft landing' given that prices are largely reduced at a small cost of output reduction. The swings of GDP and inflation emerge again from 2004 but the amplitude of inflation fluctuation is much smaller than previous periods. After an inspection of the output fluctuations, we classify

five business cycles for Chinese economy[30]: 1983Q1—1985Q4, 1986Q1—1989Q4, 1990Q1—1997Q4, 1998Q1—2004Q3 and 2004Q4—2009Q3.

For illustration purpose, a green (solid) line is used to represent a peak in real GDP and a red (dashed) line to indicate a trough. The period starting from a red line and ending with a green line represents an expansion. The period starting from a green line and ending with a red line refers to a recession or downturn[31]. The time periods where two red lines appear in the downturns (such as 1988Q4-1989Q4, 1997-1998 and 2008Q3-2009Q3) indicate severe recessions.

The first four cycles are roughly consistent with the ones identified in literature (for example see, Khor (1992), Yu(1997), Oppers (1997), Zhang and Wan (2004) and Laurenceson and Dobson (2008)). The first three cycles and the last cycle are quite complete, in the sense that they start from a trough, then reach the peak and then end with another trough. The fourth cycle on the other hand, only displays small fluctuations around the trend, representing a great stability of the economy.

[30] We depict a cycle that begins with increasing output and ends with decreasing output after a peak.

[31] Obviously, our terminology 'recession' refers to deviations below the HP-trend rather than negative output growth.

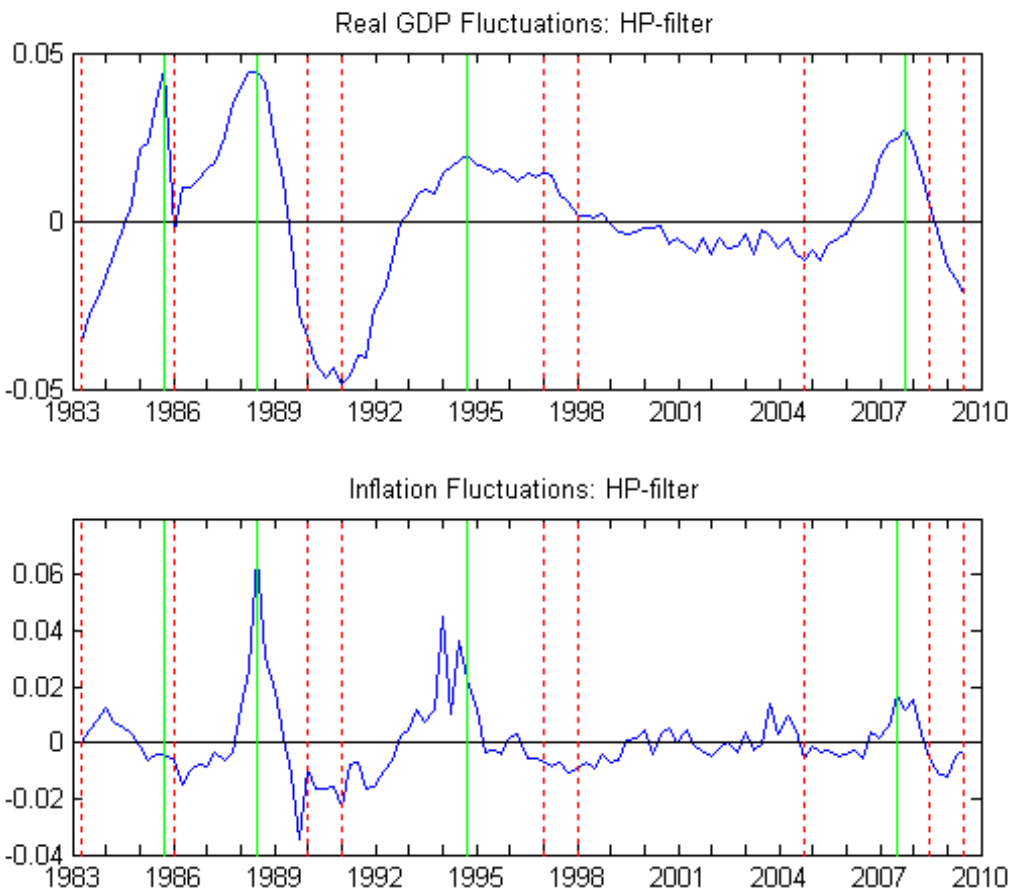

Figure 6: China's Business Cycles: 1983Q2 - 2009Q3

By using a forecasting horizon of 8 quarters, the following will discuss the sources of business cycles in the five sub-periods by using the HFED of real GDP. These results of the HFED are shown in Figure 7A and 7B. For the analysis of each sub-period, a description of the contribution of each shock based on our decompositions. The results are associated with the historical events such as the economic reforms there to better understand the sources of these disturbances.

a. 1983Q1—1985Q4.

AS-AD decomposition: The first cycle starts with significant surges in aggregate demand components. Then the supply components also go up with a magnitude that gradually becomes much bigger than the demand components and thus mainly account for the boom of the economy in 1984 and 1985. The demand components on the other hand, show a considerable drop during 1985Q4-1986Q1,

bearing the responsibility for the recession. It is also noteworthy that, the demand components move ahead with a direction that the supply components follow.

IS-LM decomposition: The movements of the IS components dominate other demand components. In particular, the main source of the surge in demand components which is crucial for the recovery of the economy is related with the IS shocks. The IS components also account for the sharp decline of demand in 1986. The money supply moves inversely with the IS components. The role of money demand is very limited.

Events: The main event in the 1983Q1-1984 period is the ongoing economic reform. Key elements of the reform include: The 12th Plenum of the Communist Central Committee in 1984 announced the plan to push the reform to a new phase; successful reforms in both rural (setup of rural exchange market) and urban areas (enterprises reform giving more autonomy and incentives to managers); development of non-SOEs which created more job opportunities and attracted more labour forces flowed from rural area to urban area; prices liberalizations; increased imports (73 percent in 1984) resulting in a significant trade deficit. The economic reform has both demand and supply side effects. On the one hand, it improves the efficiency in production and gives positive supply shocks. Our results show that these supply shocks due to reform have fast impact on the economy and contribute the most to the boom. On the other hand, the economic reform also releases the demand of people suppressed during the central planning era. The initial swing in aggregate demand confirms this. This demand is accommodated only gradually in the following years.

The key events in the remaining time of this subperiod were the economic overheating showed up in 1985 and the tightened economic policies in late 1985. These events have negative demand effects which are confirmed by the observed immediate substantial drop of demand especially the IS component.

b. 1986Q1—1990Q4.

AS-AD decomposition: Aggregate demand bears the full responsibility of the recovery of the economy from in 1986. Both supply and demand components are responsible for the boom in 1987 and the recession during 1989-1990, with the contribution of the former five times larger than the latter.

IS-LM decomposition: The recovery and the peak of demand components again emphasize the role of the IS components. The large decline in demand components in 1989 are due to a sharp decrease in IS components while the money supply components are increasing. Both the roles of money supply and money demand are very limited except that the further drop of demand components in 1990 is largely due to the large decline in money supply.

Events: The central government decided to launch further reform following the bad economic situation in 1985-86. More reforms were conducted in SOEs,

banking system and trade system. The price liberalization was implemented in April 1988, resulting in climbing prices of consumption goods. As a result, an increase in aggregate supply components was also observed during this period. At the same time, the bank credit and monetary policy were eased again, resulting in rapid growth of broad money (30 percent in the first three quarters of 1987). Consequently, a surge in aggregate demand was observed around 1988 due to this proactive monetary policy. In June 1989, the economic heating plus the corruption problem of the government induced the 'Tiananmen Square Incident'. It resulted in a drop in hours and production. Meantime, the government tightened the monetary policy in 1989 and postponed the economic reform. As a result, both aggregate supply and demand went downhill, bearing the responsibility of the recession in 1989.

c. 1991Q1—1997Q4.

AS-AD decomposition: The supply components continued to gain significant developments from 1991 to 1995, bearing the responsibility for the recovery of the economy. In contrast the demand components only fluctuate around the trend. The period from 1993Q2 to 1995Q1 represents an exception where the demand components contribute to almost all of the increases in real GDP while the supply components experience a decline. However, the demand components soon jump down in 1994Q4, bearing the responsibility for starting the downturn. The supply component jump again in 1995Q4 but soon start the decline from 1996. Both supply and demand components are responsible for the recession during 1996-1997. However, the decline in real GDP is quite moderate compared with the downturns of the previous two cycles. Since the prices are largely reduced at a small cost of output reduction, this downturn in 1996-1997 has been referred as the 'soft landing' from previous overheating years.

IS-LM decomposition: The money supply components account for most of the increases in demand components at the beginning of this cycle. The short-lived decline in demand in 1993 is caused by the money demand. There would have been a further decline of demand in 1995 following by the jump in IS components, if there were no increase in money supply. The money supply and IS components are responsible for the large decline of demand components in 1996 and in 1997 respectively. It is noteworthy that the overall volatility of the IS components has greatly reduced in this cycle.

Events: The economic downturn and the political pressure did not lead the government to turn back to central planning. Rather, several further reforms were undertaken to cure the recession. The key aspects include further price liberalization, deeper reform in SOEs, establishment of more commercial banks and the reform in trade sector to promote export (trade balance turned to surplus

in 1990 after a depreciation of the currency in the same year). A marked historical event was the Deng Xiaoping's Southern Tour and the 14th National Congress of the Communist Party held in 1992 which set the backbone for deeper reforms and the aim to build a socialist market economy. These events sent significant signals of deeper reform to people. As can be seen in the Figures, they generated large increases in aggregate supply components responsible for the recovery of the economy.

The fiscal and monetary policies during 1992-1993 were very proactive, leading to an investment boom. That corresponds to the surges of supply and IS shocks during 1992-1993. There was then a short period in 1993 where the authorities slowed down the reform and tightened the monetary policy, however, both fiscal and money policy became loose again in early 1994. The Chinese currency was greatly depreciated in late 1994, leading to significant increases of trade surplus and marketable inflows of foreign direct investment (FDI). As a result, although the money demand dropped in 1993 probably due to high prices, the increases in IS and supply components maintain output at a high level. Thus, the soft landing of the economy might be due to the moderate decline in supply and IS components. Possible reasons for this moderate declines might be the continued effect of the reform, the moderate changes in monetary and fiscal policy and the increasing trades surplus and the inflow of FDI.

From late 1994, the PBC had adopted tight monetary policy in fear of economic overheating. The Asian Currency Crisis occurred in 1997 and added more downward pressure on the economy. These result in the quick and large decline of aggregate demand (i.e., money supply and IS components) during 1996 - 1997.

d. 1998Q1—2004Q3.

AS-AD decomposition: Both supply and demand components bottom out in 1998Q3. However, supply components take the following six years to return to the trend, whilst demand components return to their trend faster. The overall volatility of both supply and demand components is much smaller than for the previous cycles. Especially, the movements of demand components in the following years in 2001-2005 are extremely smooth. In fact, this sub-period has not shown a standard business cycle but rather macroeconomic stability. It is noteworthy that, the movements in supply components and demand components seem to be on the opposite during this period. Thus they equally contribute to the fluctuations in real GDP.

IS-LM decomposition: The money demand and IS components are very stable during this cycle. Only the money supply components show some small variations. It is noteworthy that at the end of this sub-period until mid 2004, the jumps in the two money components are mainly responsible for the increase in GDP growth rather than the supply and IS components.

Events: The most important feature of events during 1998-2002 is the moderation of both economic reform and policy. For example, as a policy reaction to the economic downturn in 1997 and to overcome the negative impact of the Asian Currency Crisis, the tight macroeconomic management now is replaced by an moderately expansionary monetary and fiscal policies. Meantime, the overall speed of reform has been slowed down compared with the last decade. The only significant reform is the SOEs structure reform proposed by Zhu Rongji, the new premier of the State Council. The moderation in reform and policy seems to affect the economy in the same way. The overall volatility of both supply and the three demand components is much smaller than for the previous cycles as summarized above. Given the slow development in the supply side[32], the moderate monetary and fiscal policies explain the macroeconomic stability during this period.

There are two other important events occurred during this subpeirod: China became a member of the World Trade Organization (WTO) in November 1999 and the Severe Acute Respiratory Syndromes (SARS) occurred in 2003. However,

Since the recovery of the economy has been slow and is still below the trend, the expansionary policy continued until early 2004. However, as the results show, their effects on the economy have been very limited and short-lived.

e. 2004Q4—2009Q3.

AS-AD decomposition: From 2004Q4, output entered a new boom with the main contribution coming from the supply components. Demand components respond negatively in the next two years and then increase in 2006Q3 following the same pattern of the supply components. The peak in 2007Q3 was not long-lived with the recession starting from 2007Q3 to 2009Q3. The demand components are as important as the supply components in driving the economy to the recession. Overall, the supply and demand components move in the same direction.

IS-LM decomposition: The increases in demand components in the beginning of this cycle are due to the two money components. However, the boom of the demand components in 2007 is due to the IS shocks since the money supply components on the other has been falling from 2005 to 2008Q3. The IS components then fall considerably during 2008Q3 - 2009Q3, bearing the responsibility for the recession together with the supply components. Over this period, the money demand components have continued its smoothness since last cycle and have hardly moved.

Events: The monetary policy became loose and loose from 2004 to early 2005, maybe due to the relative stability of the economy during the last subperiod. The

[32] Retrieving to the institutional discussion in Section 2, the restructure of the state-owned enterprises reduces the burden of the central government. Less fiscal transfer and money expansion are needed to subsidize their deficits, which also helps macroeconomic stability.

government has committed to a neutral fiscal policy before 2007. The Olympic Games were successfully held in August 2008. The loose economic policies and the pre-Olympic investment tide explain the boom of the economy in 2007.

The economic reform on the other hand, entered a phase with no significant changes in economic structure or institutions. Therefore, the surge in supply components might not related with efficiency improvement in reform but related with other factors. These factors might include technological progress gained during the reform and openness and also the delayed supply effects of joining the WTO.

In 2007, monetary policy was tightened. The outbreak of the International Financial Crisis occurred in 2008Q3. The government launched a set of fiscal and monetary measures from December 2008 to combat the recession[33]. By consequence, the International Financial Crisis has greatly affected output, indicating that the Chinese economy has been more integrated with the world economy. The stimulus package of the government helps the recovery of the economy. Our results show a turning point of the demand components in 2008Q4 and a turning point of the supply components in 2009Q2. A further detection shows that the expansionary policies lifted money components first, then came the IS components and finally reached the supply components. This reflects that the proactive fiscal policy has been effective not only in expanding aggregate demand but also supply. This may be due to the fact that most of these stimulus packages have been spent on basic industries such as infrastructure and health care, which benefit production. It is also noteworthy that the money supply components has not increased much compared with the IS components during the recovery from 2009Q1. This might indicate that the monetary policy has been quite moderate.

[33]The key elements of these measures include a 4000 billion RMB stimulus package, a 500 billion RMB tax-cut package and an 850 billion RMB package on health care. The stimulus package has been financed by the fiscal revenue of the central government, by selling bonds and by utilizing the revenues from the local governments.

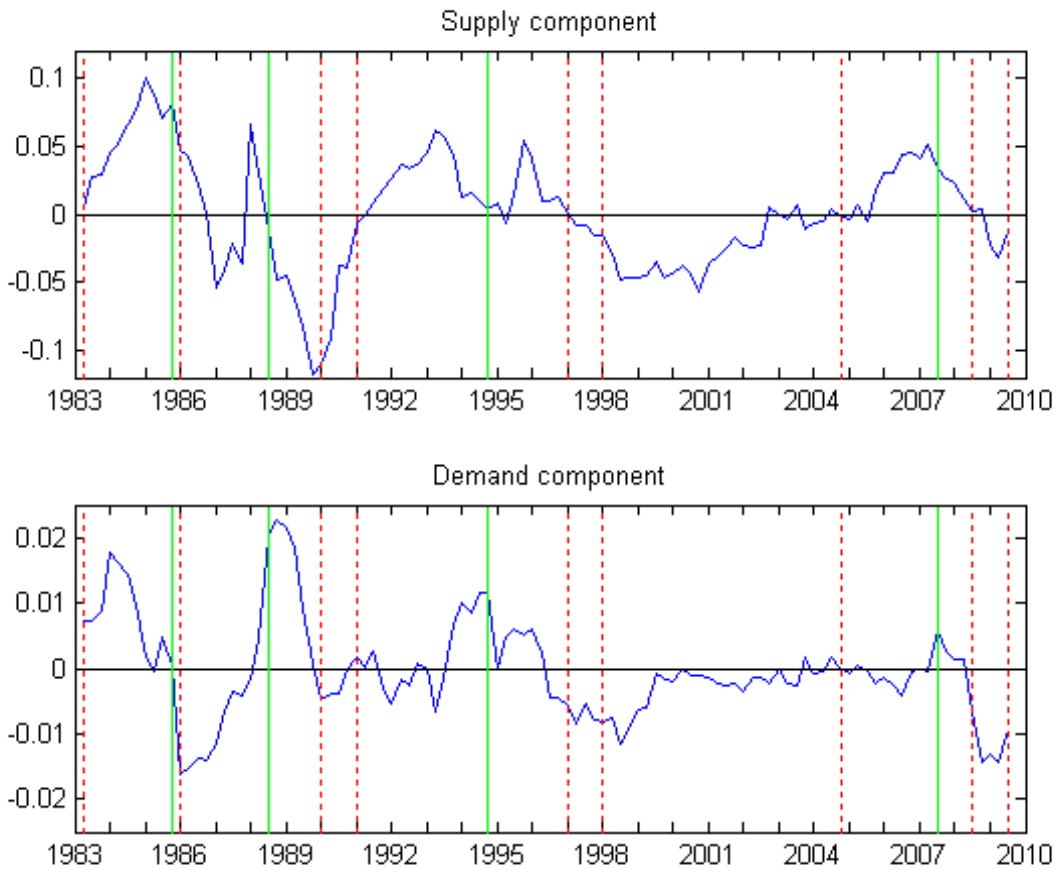

Figure 7A: Historical Decomposition of GDP Series

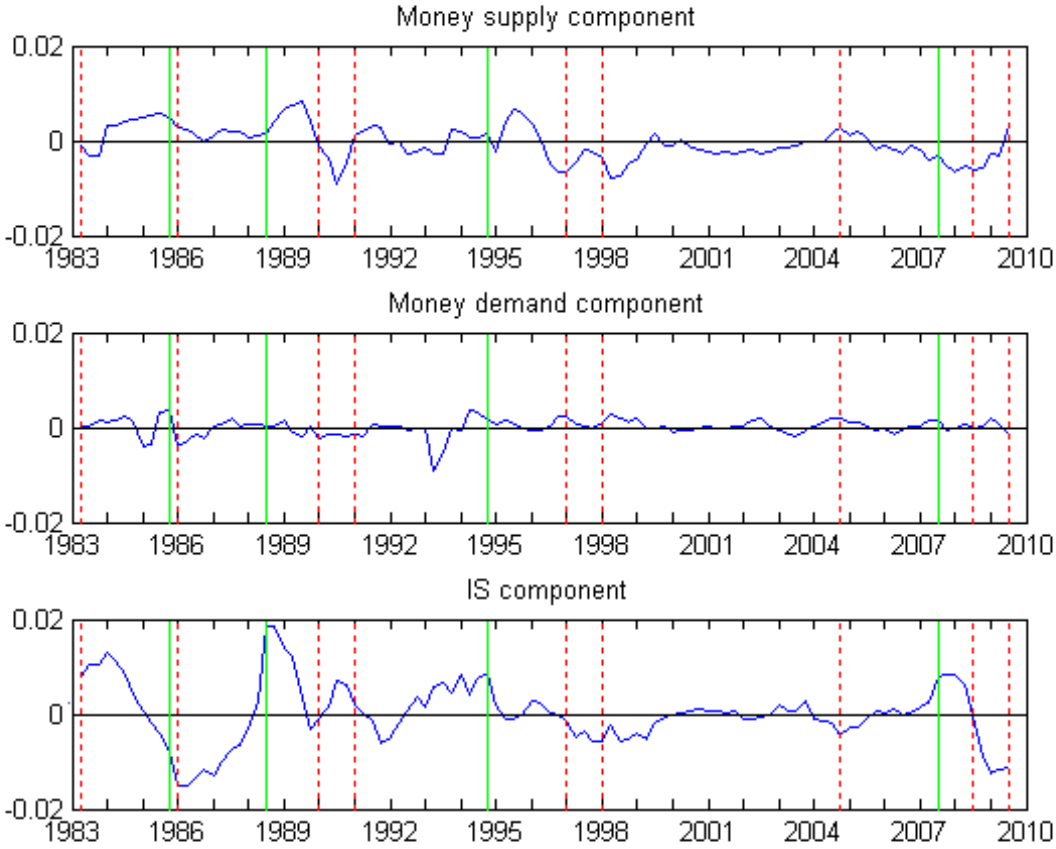

Figure 7B: Historical Decompositions of GDP series

7 Robustness of results

To check the robustness of the evidence above, the same empirical analysis was made using other choices of the dependant variables in the VAR model. In particular, the alternatives included using 'money' rather than 'money & quasi-money' and using deposit rate rather than lending rate. The results are presented in Appendix (9.3).

7.1 Deposit rate

The main finding is that when lending rate is replaced with deposit rate, all the results above (i.e., the impulse responses, the variance decomposition and the historical decomposition) remain similar. The only slight differences are quantitative,

not qualitative. For example, the responses of real interest rates to supply and IS shocks are higher than in the benchmark model. The responses of money growth and inflation to IS shocks are also higher. For the variance decomposition, a lower proportion of GDP fluctuations are accounted for by supply shocks whilst a greater proportion is accounted by the IS shocks. The historical decomposition changes very little. The conclusion, therefore, is that the results discussed in previous sections are robust to alternative measure of interest rate.

7.2 Narrow money

When the series of 'money' is used in estimation, the impulse responses to supply remain qualitatively identical. However, the responses of variables to money shocks are sensitive to the choice of money measures. In particular, the response of money growth to a money supply shock is negative in the first quarter. Furthermore, even in the short-run, the LM equation is violated in the money supply shock case. This might imply that the money shocks are incorrectly identified. The reason for this might be that the narrow money is not adequate for identifying the effect of monetary policy.

In recent years the PBC has announced targets for broad money growth rather than narrow money growth. Therefore, the narrow money might not be a suitable choice of dependant variable in our VAR analysis. Interestingly, the results of the variance decomposition and the historical decomposition do not show significant differences with the benchmark case. Therefore the results of the estimated decompositions, discussed in the main context can be considered as particularly robust.

7.3 Alternative specification and the sources of the unit root in nominal variables

The specification of the VAR relies on the unit root tests where all the nominal variables, i.e., nominal interest rate, money growth and inflation, are stationary. This implies that impacts of the structural shocks on nominal variables only exist in the short-run. However, it is well-known that, in general, unit root tests have low power. For example, Schwert (1987) argued that the ADF test is biased if the data series takes an ARIMA representation with large (negative) MA coefficient. Also, the above unit root tests perform poorly when the true data process is high persistent and close to being $I(1)$. In fact, the unit root tests do not show a 1% rejection of unit root in the first-differenced inflation and money growth series. Given the small sample size available, the stationarity of inflation and money growth might not be guaranteed. Based on these discussions, it is possible

to consider the alternative specification that a unit root is present in nominal variables. This allows an examination in the adjustments of nominal variables in longer horizons. Since the results found that the responses of the real variables are very similar (and qualitatively identical) under both specifications, the following will focus on the responses of nominal variables.

7.3.1 Supply shock

The impulse responses of variables to a favourable aggregate supply shock under the alternative specification are shown in Figure 8. The responses of GDP and real balances show little difference with the benchmark specification. However, the release of the stationarity of nominal variables results in substantial and sustainable increases in money growth and inflation. Therefore, the supply shock is responsible for the unit root in nominal variables. Since the nominal interest rate still adjusts slowly in the short-run, the surge in prices results in a small decrease in interest rate. As a result, the long-run level of output is a little higher than the same under the second specification.

Two important features remain unchanged. The first feature is that the dynamics of the nominal rate and real balances are still consistent with the LM equation, not only in the short-run, but also in the long-run. The estimated short- and long-run income elasticity, ϕ, is 1.4 and 0.5 respectively. Also, as output increases, it creates upward pressure on inflation in a manner consistent with the Phillips Curve. Secondly, the substantial changes of output and inflation are mixed effects of the supply shock and the monetary expansion. Again, they can be explained by the hypothesis of institutional accounting of fluctuations[34].

[34] Note that, for example, according to Brandt and Zhu (2000), a positive supply shock usually occurs when the government adopts a loose indicative credit plan with less resort to money creation. Thus the negative correlation between aggregate supply and money growth is possible when output growth is low.

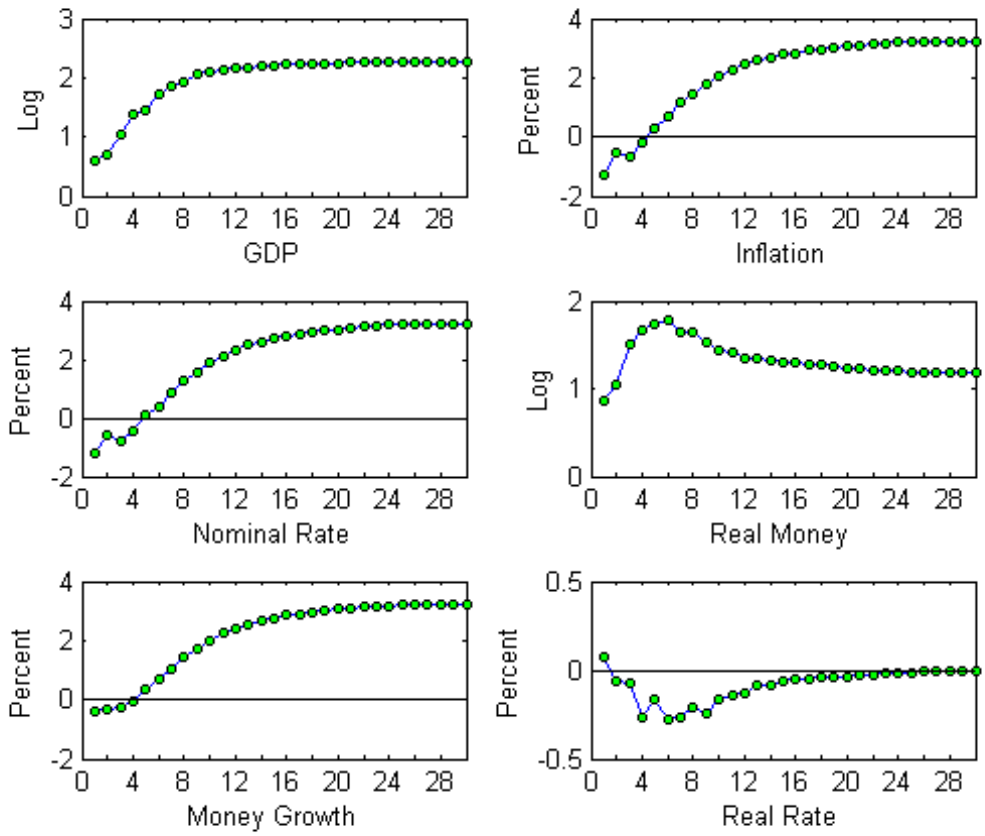

Figure 8: Impulse Responses - Supply Shock

7.3.2 Money supply shock

Figure 9 shows the responses of different variables to a money supply shock. The dynamics of real variables are again similar, while the responses of nominal variables make the differences. Money supply only increases slightly and then becomes negative for two quarters. The same variable then gradually increases and reaches a much higher level after 12 quarters. The institutional background provides an insight into the small and even negative response of money growth in the initial periods: The money supply is raised normally when output growth is high and prices are temporarily low. In fact, the negative response of money growth is indeed related to the drop of prices within the first 3 quarters, as shown in Figure 6. As money growth increases and output growth rises, prices go up. Therefore, it seems that the money supply shock is also one source of unit root in nominal variables.

The money-interest rate-output transmission mechanism in the IS-LM model now works both in the short-run and in the long-run. The estimated semi-elasticity of nominal interest rate, λ, is 0.7 and 0.2 respectively. Again, the effect of the money supply shock on output is still very small compared with the supply shock. The decrease in interest rate is much smaller than the same in the second specification. This indicates that the money expansion itself is not effective in raising output due to small changes in interest rate. On the other hand, the money supply shock has substantial impact on prices. The magnitudes of changes in money growth and inflation in Figure 9 also match strikingly well with those in the case of the supply shock in Figure 8. Therefore, it could be argued that the output increases in Figure 8 are mainly due to the supply shock, while the increases in inflation are mostly accounted for by the induced money expansion.

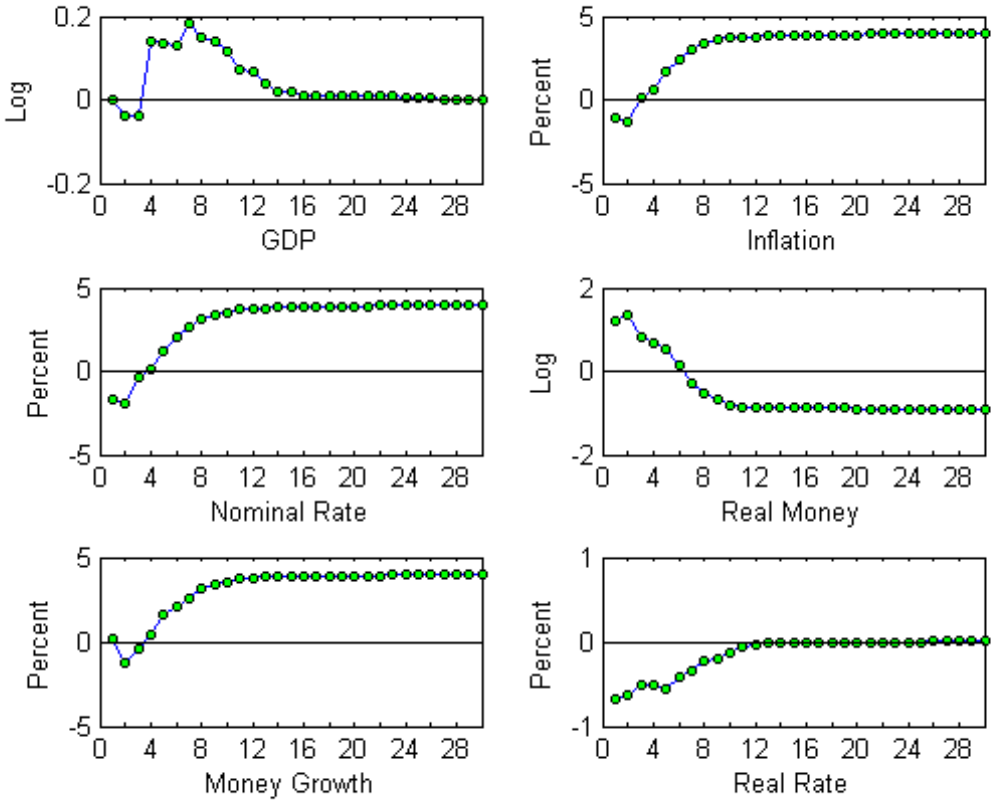

Figure 9: Impulse Responses to Money Supply Shock

7.3.3 Money demand shock

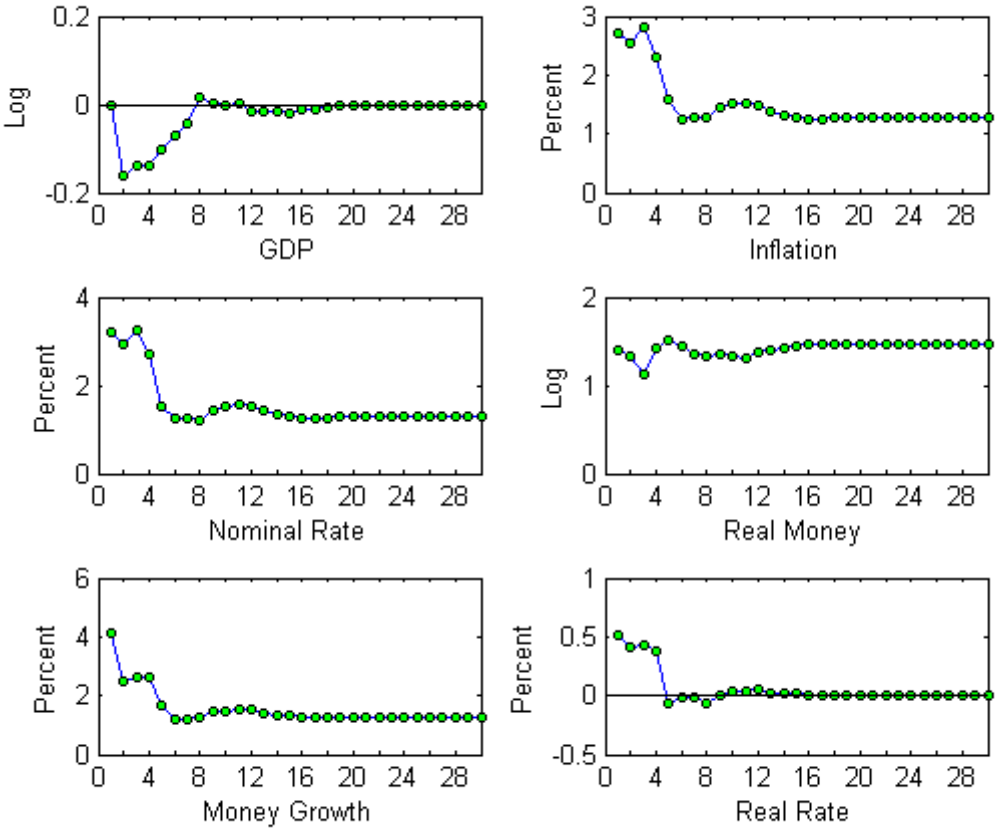

Figure 10: Impulse Responses to Money Demand Shock

The responses of variables to a money demand shock shown in Figure 10 appear as the qualitative mirror image of the results in Figure 9 in the case of a money supply shock. The differences come from the rapid adjustment of prices, interest rates and output. Moreover, the results here are almost qualitatively identical with the same under the second specification in Figure 3. The difference is again in the speed of adjustments of nominal variables and, additionally, in their long-run values. Here all nominal variables are permanently raised up, suggesting that the money demand shock is another source of the unit root in nominal variables.

7.3.4 IS shock

The responses of variables to a fiscal spending shock are given in Figure 11. At first glance, all the variables show identical responses except the money growth

and the initial responses of the interest rate. In fact, the monetary policy is no longer complementary to fiscal policy. Since the nominal rate is raised up through the LM equation, the PBC seems to raise the money supply to dampen the upward pressure on the nominal interest rate. However, since the inflation jumps higher than the nominal interest rate, the interest rate jumps down about 0.5 percent. As a result, the initial increase in output is higher than the same in the benchmark specification. In mid-term, from 5 to 12 quarters, the interest rate goes up and the crowding-out of the fiscal expansion drives output down in a way consistent with the IS curve. Nominal rate and inflation also decrease in a manner consistent with the LM equation and the Phillips Curve. The estimated short-run and long-run interest elasticity, λ, is 0.7 and 3.1 respectively. The short-run estimate is nearly the same as the one obtained in the money supply shock case, while the long-run estimate differs significantly. The non-stationarity of money growth seems to indicate that the PBC adopts the monetary accommodation again after 13 quarters to avoid recession. As a result, money growth remains positive in the long-run with permanent increases in nominal rate and inflation. Only output and interest rate therefore return to zero in the long-run. The IS shock appears as another source of the unit root in nominal variables.

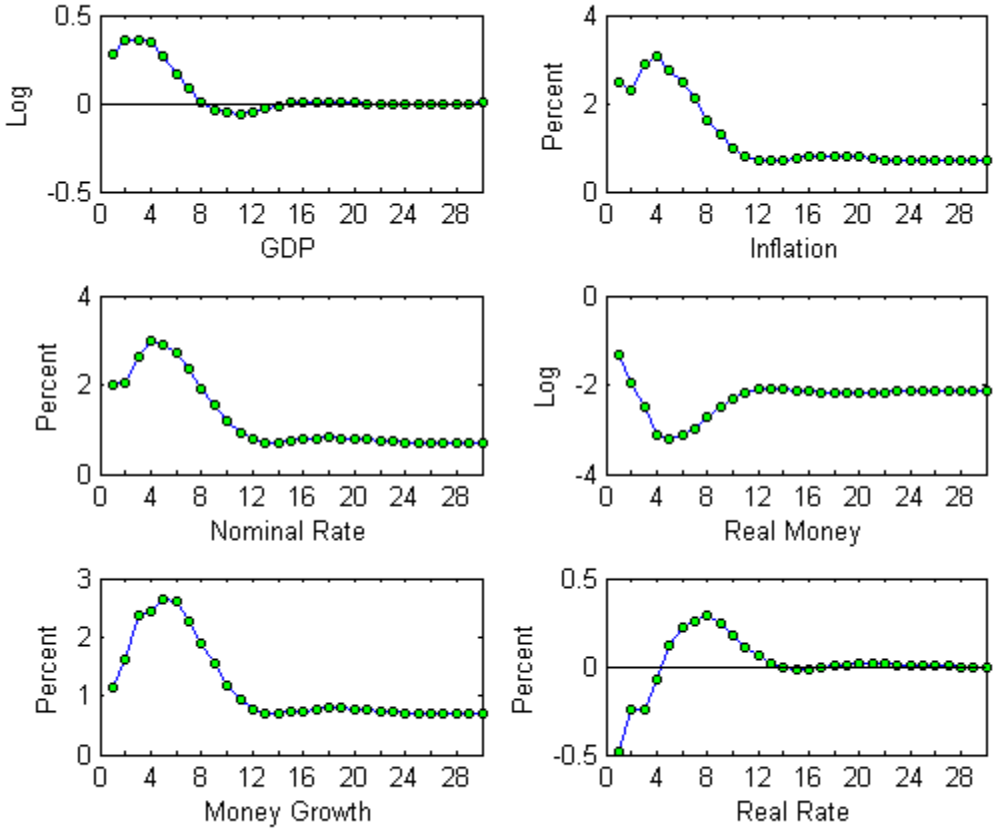

Figure 11: Impulse Responses - IS Shock

The main finding of the above examination is that all four structural shocks are responsible for the unit root in nominal variables. This is confirmed in the plot of the joint responses of nominal variables, i.e., inflation, money growth and nominal, in Figure 12. In the long-run, the impact of money supply shock is the biggest while the same of IS shocks is the smallest. However, as discussed above, since the permanent changes in nominal variables under supply and money demand shocks coincide with the induced money growth, it can be concluded that the contribution of the unit root in nominal variables is mainly due to the fiscal spending and the active monetary policy.

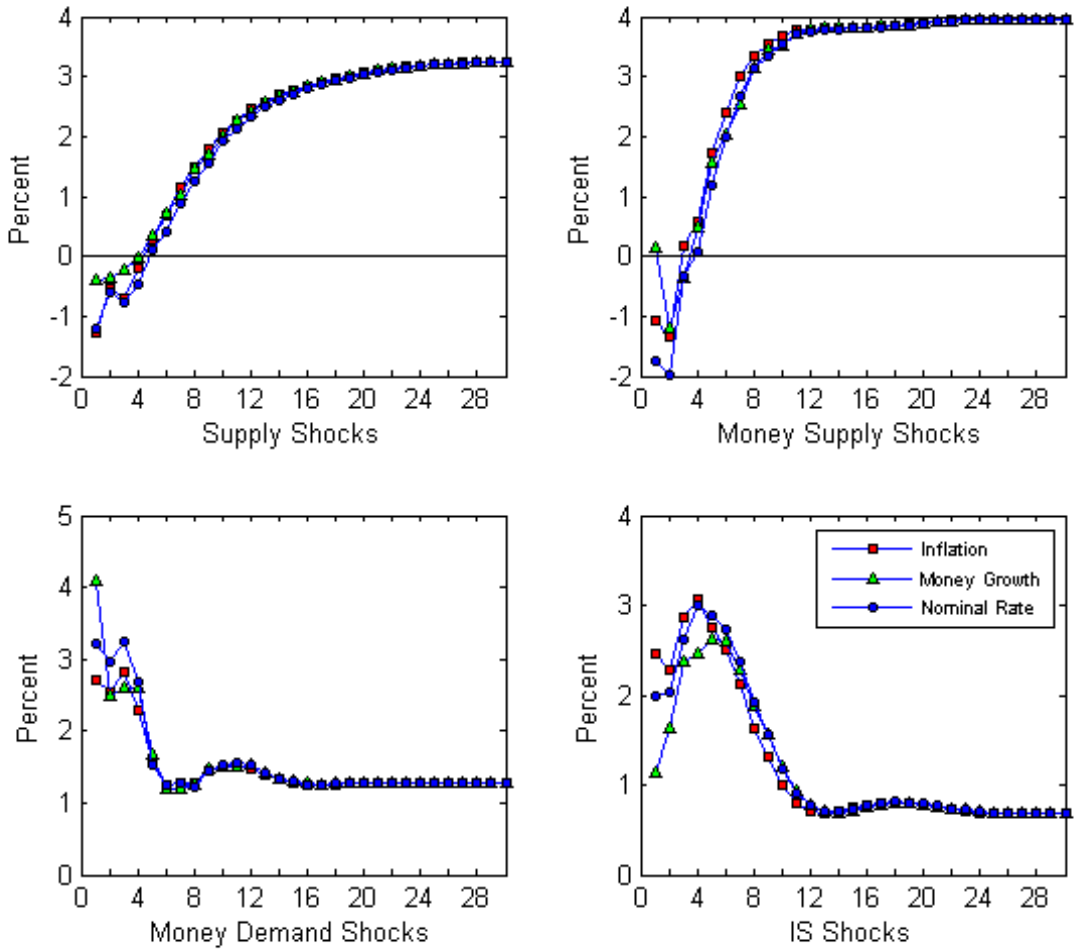

Figure 12: The Unit Root in Nominal Variables

8 Concluding remarks

The present study examines the sources of China's economic fluctuations in the post-reform period 1980-2009. Based on the popular IS-LM model, the sources of fluctuations are accounted for by the four driving forces, i.e., aggregate supply shocks, money supply shocks, money demand shocks and IS shocks. The joint behaviors of GDP, prices, money and interest rate are then estimated in a four-variable VAR model using quarterly data. By applying the identification strategy proposed in Galí (1992), four structural shocks are identified so that they can be interpreted as the four driving forces in the IS-LM model. This is achieved by adopting economic restrictions relating to different long-run and short-run dynamics of the economy. After the identification, the estimated effects of the structural shocks are compared with those predicted in the IS-LM model.

The results show that first, the estimated responses of variables to all the four structural shocks in the SVAR model match strikingly well with those predicted by the IS-LM model. In particular, the working of the three types of demand shocks are evidence that as reforms goes deeper and deeper, the market mechanism has gained growing importance, allowing the market channels to work in terms of fiscal and monetary policies. The fit of the IS-LM model for explaining the Chinese economy and the consistent responses of the economy to the three demand shocks are new findings. Second, there is strong evidence from the variance decomposition that supply shocks associated with technology progress, efficiency and institutional changes in reform account for almost all fluctuations in output. This suggests that the role of fiscal and monetary policy shocks are minor. Whist this is not a surprising result for China as a transition economy, it might also suggest that the working of fiscal and monetary policy might be through non-market mechanisms such as direct management and other administrative controls found in literature. This implies that further reform in economic structures and institutions, such as financial liberalization, are needed to remove the obstacles for a workable economic policy. It is shown that the above results are robust to alternative measures of interest rate and money and the alternative model specification which allows a unit root in norminal variables.

This study also provides a historical decomposition of the forecast error of the SVAR model to examine the sources of GDP fluctuations in the five business cycles over the post-reform period, 1983-2009. This is performed not only from a traditional AS-AD perspective but also a decomposition of the forecast error related to the three demand shocks. Our findings show that supply shocks are the main sources of output fluctuations while demand shocks, especially the fiscal forces, can play important roles in different sub-periods.

The main contribution of this study is that it provides a first attempt to examine the fit of this influential theoretical model to the Chinese economy and the

sources of demand-side contributions to fluctuations. In particular, the working of the IS-LM model, especially in the case of fiscal and monetary shocks, are new findings. This also has important implications as of a gauge of the progress of the reform and the growing of market mechanisms. Secondly, this study has used high frequency data with long sample size and thus has two important advantages. The first advantage is that both long- and short-run restriction assumptions are properly justified when using high frequency data. The second advantage is that it makes our study a first attempt to empirically examine the underlying sources of fluctuations for the whole post-reform period. For example, the data sample has allowed us to shed light on issues relating to the possible explanations for the macro-stability of the Chinese economy during 1998-2003, the Asian Currency Crisis 1997-1998 and the Financial Crisis from 2008 to date.

Given the dominant role of estimated supply shocks in generating output fluctuations, a further decomposition of the components of the supply shocks is particular interesting. There are several possible components in supply shocks recognized by researchers: technology shock, capital utilization shock, labour input shock and reforms and institutional shocks. There have been studies using long-run restrictions to identify non-reform related shocks. For example, Shapiro and Watson (1988) specified a output-hours-price-interest rate VAR model and applied the restriction of exogeneity of long-run labour input to isolate technology shocks from labour input shocks. However, empirical framework designed to identify reform related supply shocks have not been developed well in the literature. Given that reforms play crucial role in developing countries like China, it is particularly interesting to devise a econometric model and a identification scheme to disentangle different supply shocks. This might be done by introducing more variables characterizng the effect of reforms. To develop an appropriate identification scheme, one can make use of long-run restrictions as in Shapiro and Watson (1988) but can also restrict short-run behaviour of particular variables of interest. Of course, short-run restrictions reply on using high frequency data which might not be available in the case of China. In all, a further decomposition of supply shocks is a promising direction for future research.

Some limitations also apply to this study. For example, since the Chinese economy has been in transition during the sample period, the economic structure and the conduct of economic policies might have also changed. It is thus constructive to estimate a time-varying VAR analysis. Second, VAR models are subject to the Lucas's Critique (Lucas (1976)). Thus it would be useful to construct a theoretical model with micro-foundations for China. Given the dominant role of supply side disturbances, it is suggested that theoretical models explaining Chinese economic fluctuations should be built on the real side of the economy. In this sense, the line of Real Business Cycle models would be a potentially appropriate direction.

Moreover, if the sources of supply shocks were identified, it would provide useful guidance on how to add properly market imperfections to theoretical models to account for the progress of the economic reform. This would gain important insights on understanding and modeling the Chinese economy.

9 Appendices

9.1 Sources and construction of data

The main sources of the quarterly data are the databases of the National Bureau of Statistics (NBSC) and the International Financial Statistics (IFS). The former is the official agency directly under the State Council for statistics and economic accounting in China. The latter is a database founded by the International Money Fund (IMF). The sample period of the quarterly data is from 1980 Quarter 1 to 2008 Quarter 3. The sources and the construction of data for each of the four variables used in this study are described below.

9.1.1 Real GDP

There are two difficulties in constructing Chinese quarterly real GDP data. The first difficulty is that neither nominal nor real GDP data is available until 1992. One needs to estimate the quarterly GDP data using annual GDP data for the period 1980-1991. Secondly, there is no data for GDP deflator in China ever since. One might overcome this problem by instead using another price index to deflate the nominal GDP. However, as found by other researchers, deflating the nominal GDP data by other price indices such as the Consumer Price Index (CPI) or the Producer Price Index (PPI) does not give the correct real GDP data that match the official figures. Based on this situation, we construct our real GDP data by two sequences: The first sequence of real GDP data from 1980Q1 to 1991Q4 is taken from the estimated real GDP data reported in Abeysinghe and Rajaguru (2004). In their estimation, the real GDP growth rate was interpolated using the Chow and Lin method based on annual real GDP growth rate data and taking money stock M1 and trade as related series. The real GDP data in levels were then recovered by taking 1997 as the base year (since they found the quarterly real GDP growth rate and nominal growth rate are the same in 1997). The second sequence of real GDP data from 1992Q1 to 2008Q3 is calculated using the cumulative year-on-year real GDP growth rate data which is available from the NBSC. We believe the real GDP growth rate data from NBSC is the most reliable data, since the NBSC has adjusted the real GDP growth rate since 2004 for consistency of data. For example, there have been debates on the overestimation of real GDP growth rate during 1997-2002 and underestimation of it from 2003 upwards. The NBSC has adjusted these possible biases based on economic surveys, such as the National Economic Census in 2004.

9.1.2 Prices

The quarterly Consumer Price Index data from 1987Q1 to 2008Q3 is taken from the IFS database. This data has the best possible length compared with other price indicators and we have crossed checked its accuracy by comparing the recent CPI data published in other sources including the NBSC. One particular issue is that the quarterly CPI data from IFS (or other sources that were checked) is year-on-year rate of change in CPI. Therefore, to recover the prices in level, we need to find a base year where the quarter-to-quarter CPI data can be compared. Fortunately, the month-to-month CPI data is available from 2001 with the price level in 2000 as the base year. Therefore, we first calculated the month-to-month prices in level in such a way that the resulting price level in 2000 is equal to 100. Following this, we derived the quarter-to-quarter prices in level for 2001 by taking a seasonal average from the calculated month-to-month prices. After this, the other price levels from 1987Q1 to 2000Q4 and from 2002Q1 to 2008Q3 can be obtained using the quarter-to-quarter CPI data taken from the IFS database.

The quarterly CPI data from 1980Q1 to 1986Q4 is unfortunately unavailable. Therefore, we interpolated these missing values by following the Chow and Lin method using annual CPI data, taking the money stock M1 as related series. The sample size of the interpolation regression is from 1980Q1 to 2008Q3 and we have checked the quality of the interpolated data by comparing the overlapping period between the interpolated values and the true observations. Finally, with the estimated price levels from 1980Q1 to 1986Q4 and the prices calculated above using IFS data, the whole series of prices from 1980Q1 to 2008Q4 can be constructed.

9.1.3 Nominal interest rate

The interest rate data are the bank lending rates taken from the IFS. The same data taken from the NBSC was found to be the same. Better interest rate data such as the inter-bank rate or the bank reservation rate are only available from the late 1990s.

9.1.4 Money stock

The data for the common statistics of money such as M0, M1 and M2 is/was not available since the PBC has used different measures of money until 2006. Therefore the data for money used in our study is the 'money plus quasi-money' data taken from the IFS database. It is a measure of money that is wider than M1 but narrower than M2. We believe this is a good measure of money that provides information that is no worse than M1 and M2. Moreover, at the conclusion of our study, we also considered the data of 'money' (seasonally adjusted) from the IFS

database, which is close to M1. The results show that the two money measures make little change in the SVAR estimation.

9.2 Results under restriction 6 and 7

9.2.1 Impulse responses

The results of impulse responses to supply and IS shocks are the same across restrictions, so only the results in the case of the two money shocks are presented.

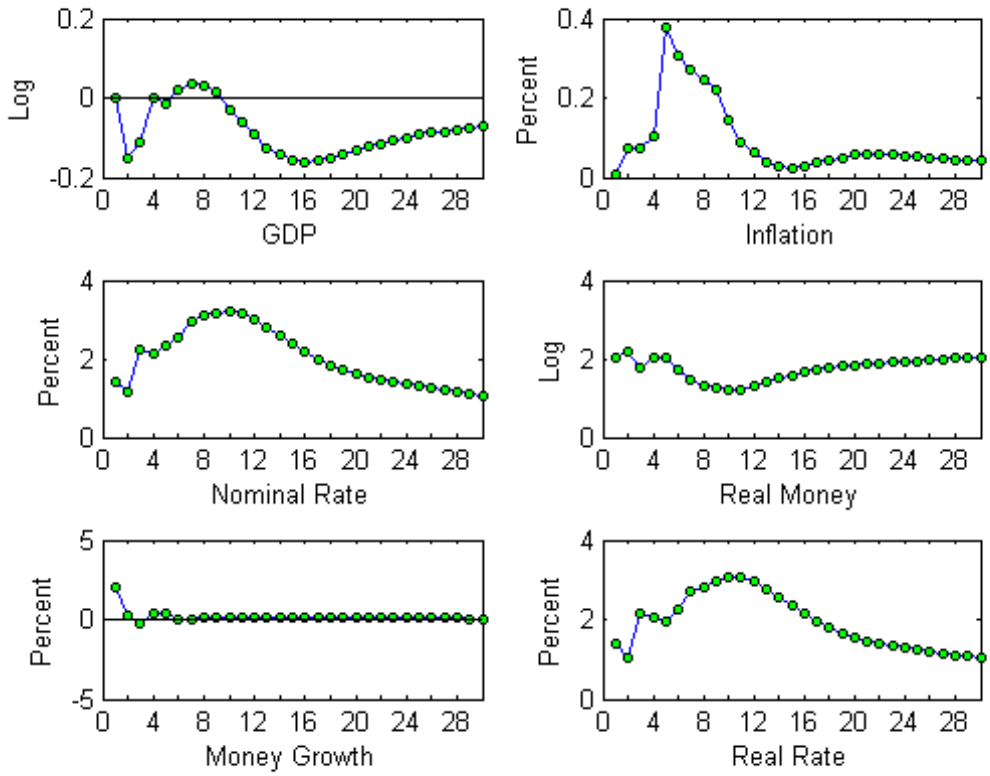

Figure 13: Impulse Responses to Money Supply Shock - R6

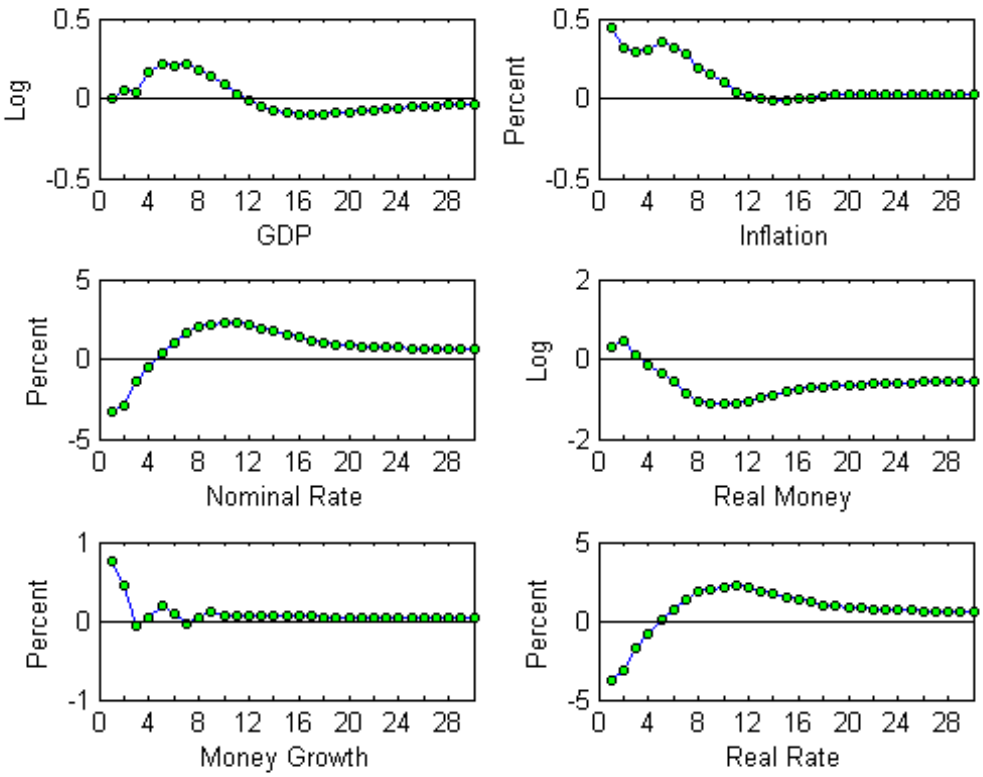

Figure 14: Impulse Responses to Money Demand Shock - R6

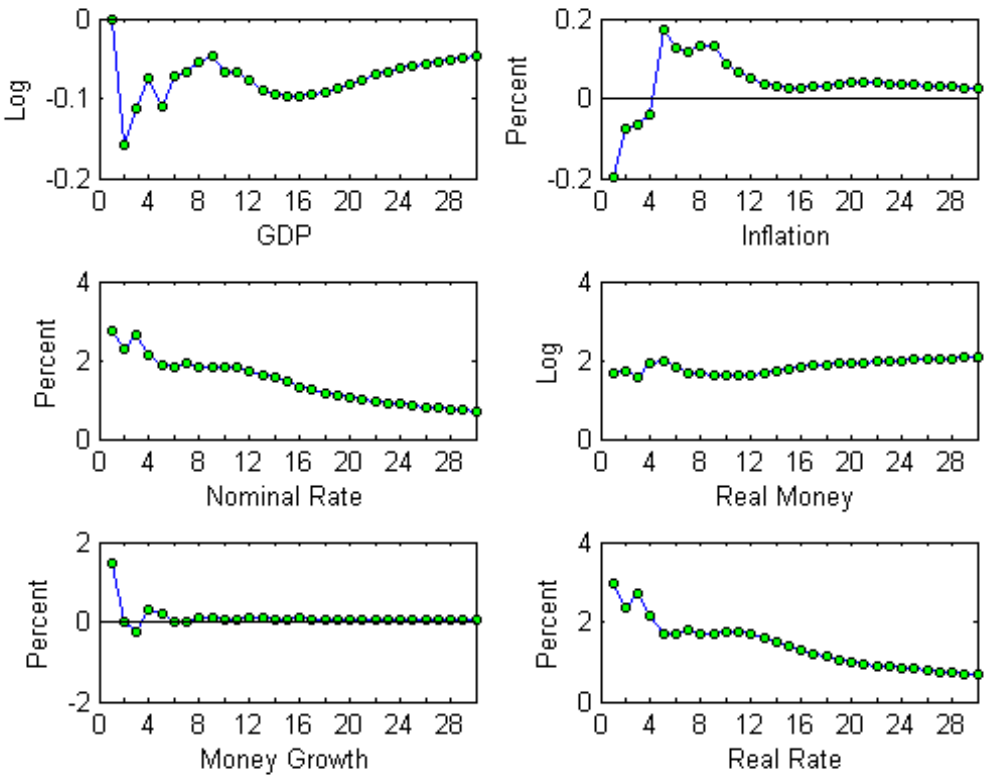

Figure 15: Impulse Responses to Money Supply Shock - R7

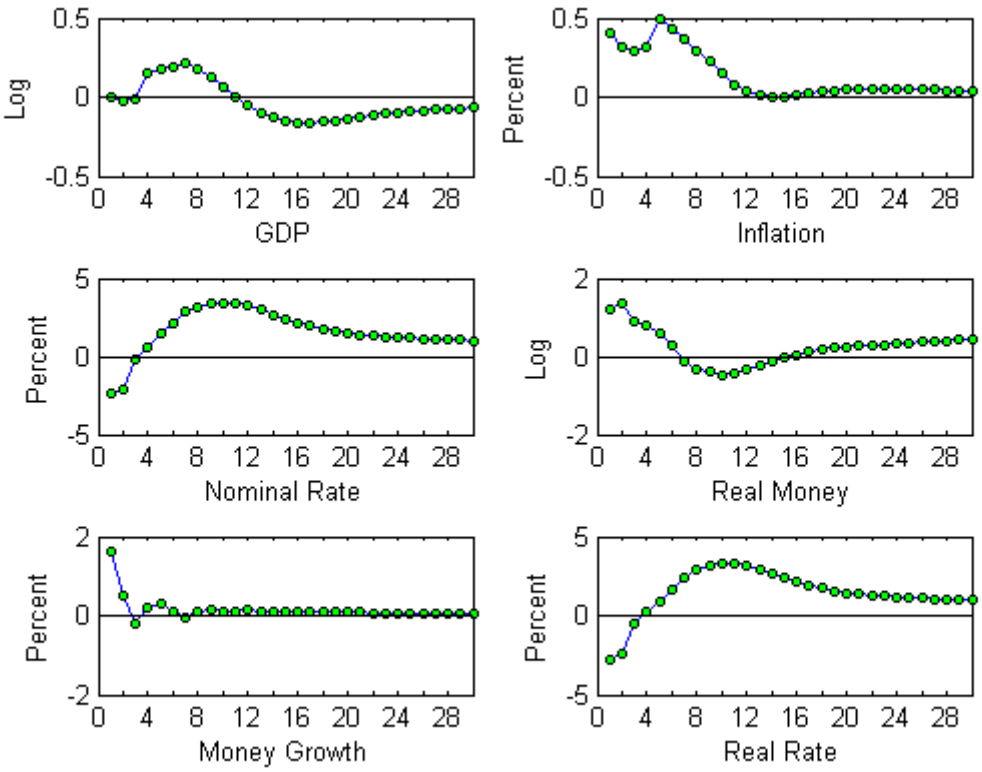

Figure 16: Impulse Responses to Money Demand Shock - R7

9.2.2 Variance decompositions

The results of decompositions of forecast error to supply and demand shocks are the same across restrictions, so here only present the decompositions with respect to the three types of demand shocks.

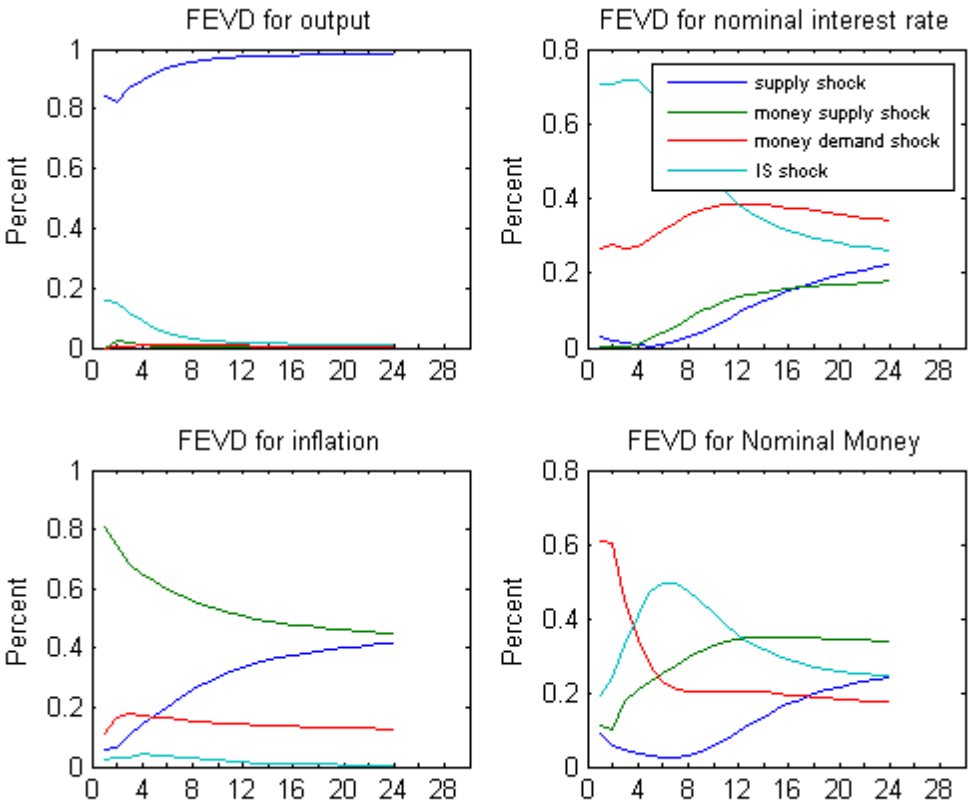

Figure 17: Decomposition of Forecast Error Variance - R6

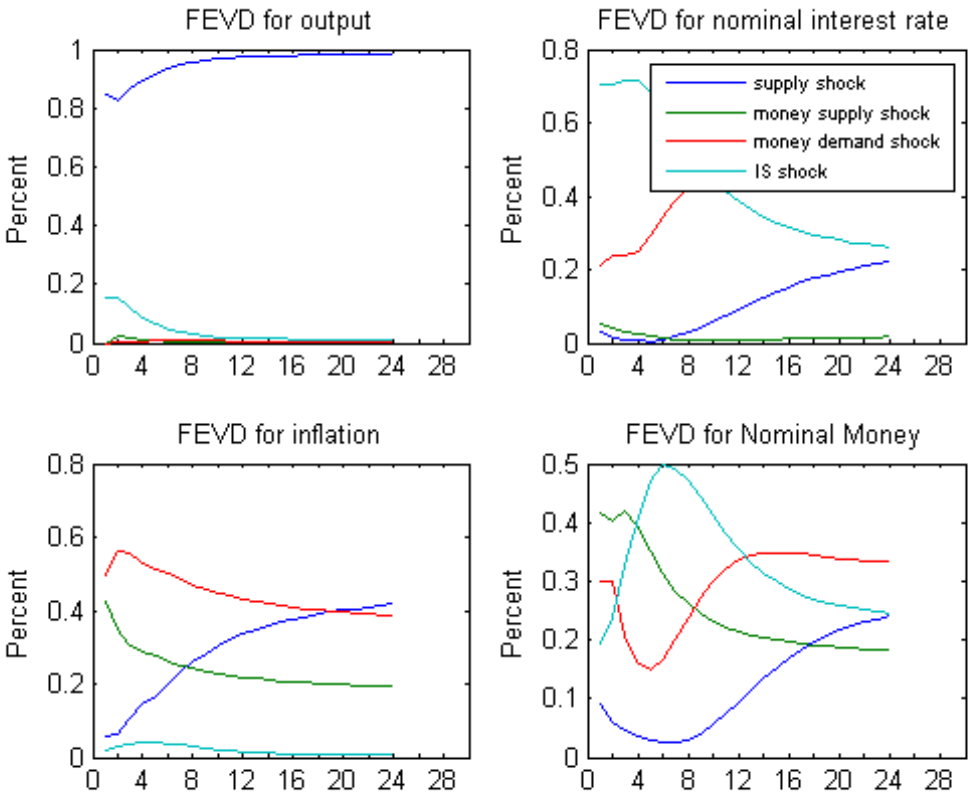

Figure 18: Decomposition of Forecast Error Variance - R7

9.2.3 Historical decompositions

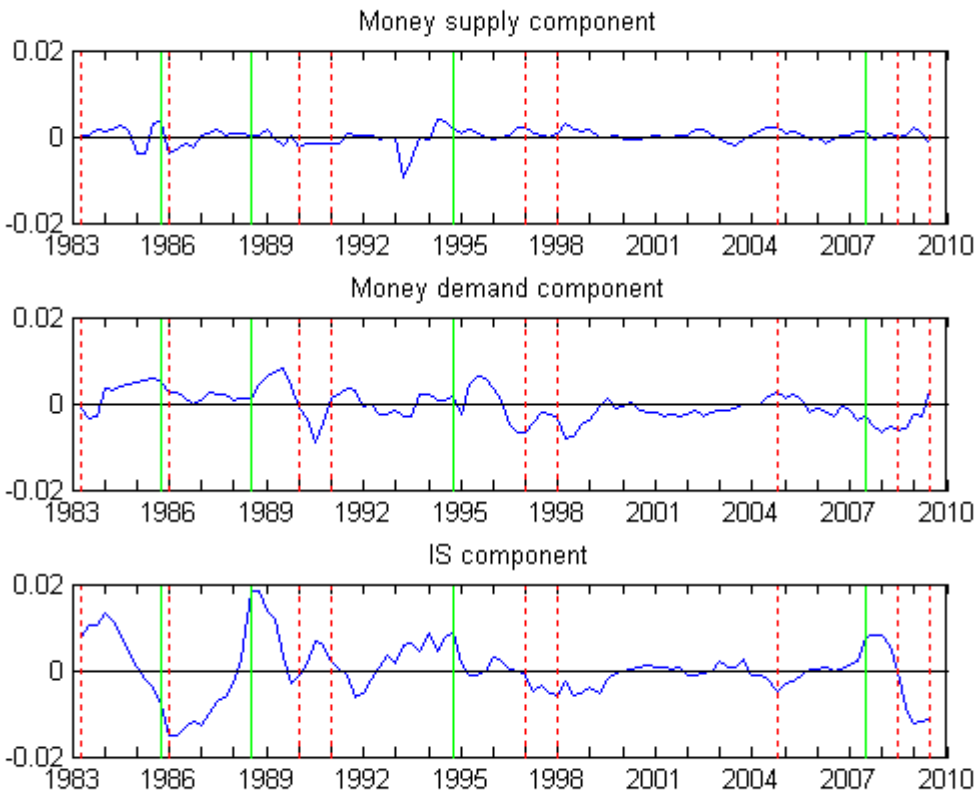

Figure 19: Historical Decompositions - R6

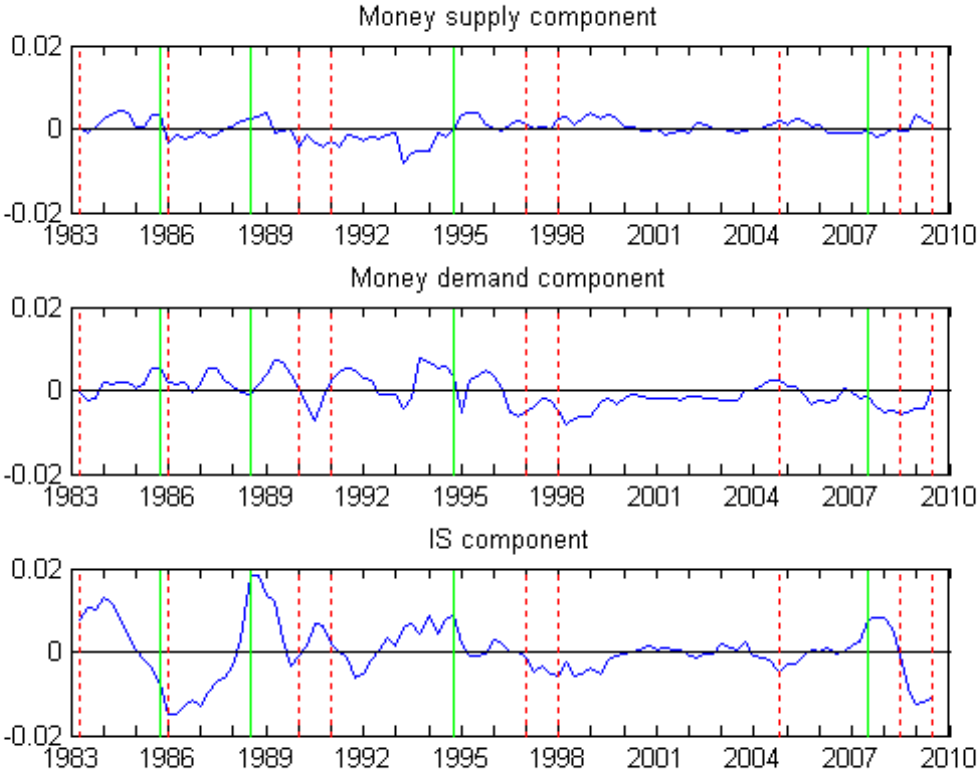

Figure 20: Historical Decompositions - R7

9.3 Results using alternative choice of dependent variables

9.3.1 Deposit rate

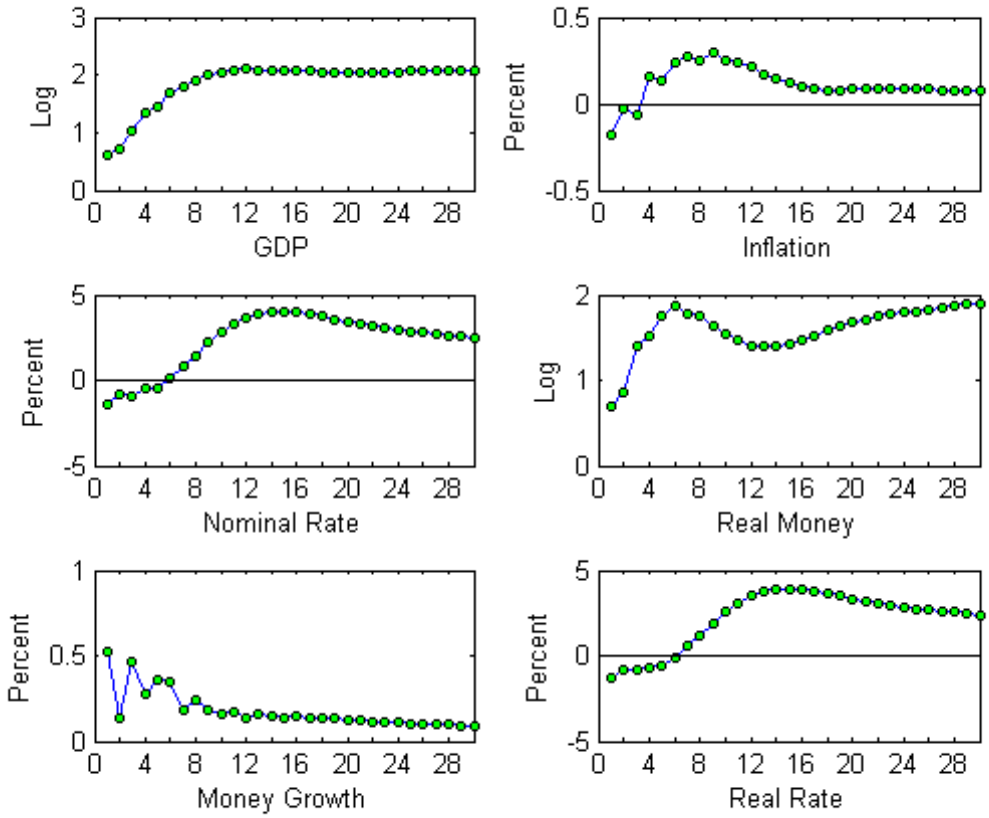

Figure 21: Impulse Responses to A Supply Shock

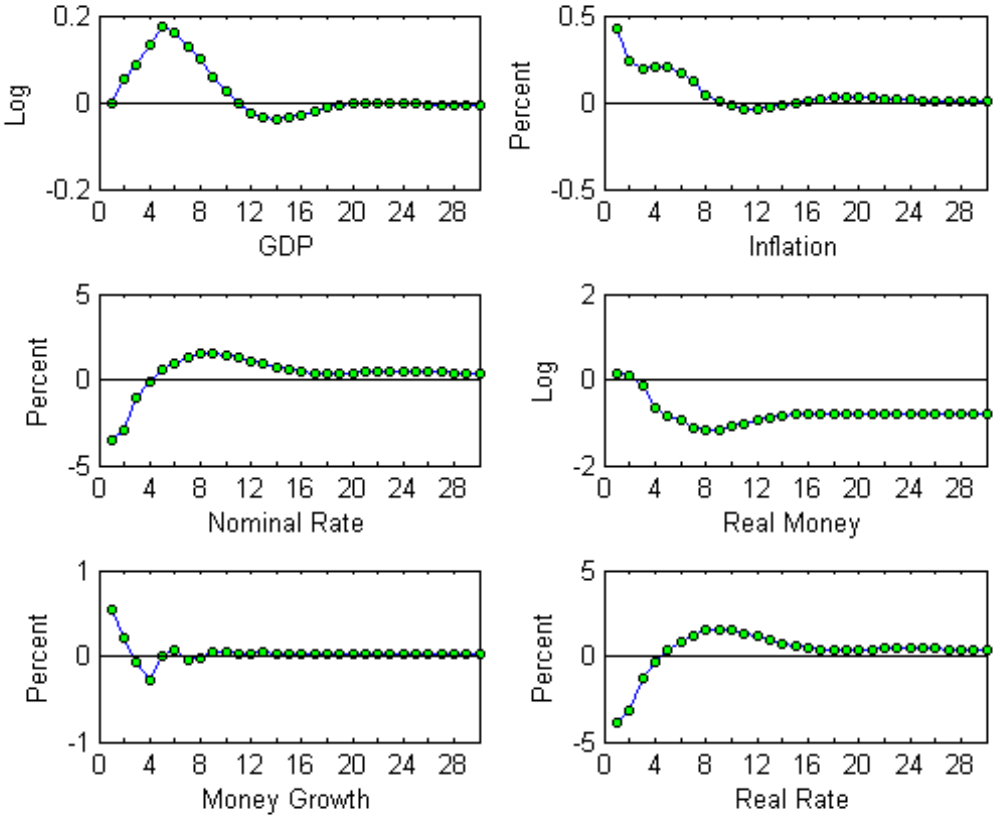

Figure 22: Impulse Responses to A Money Supply Shock

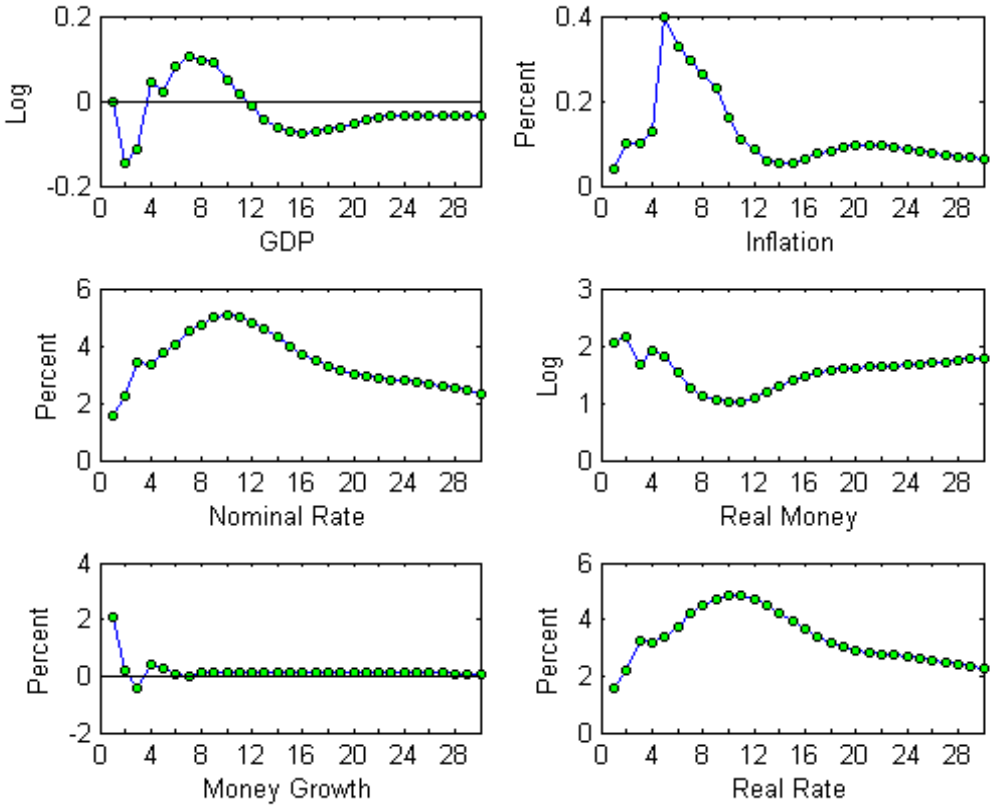

Figure 23: Impulse Responses to A Money Demand Shock

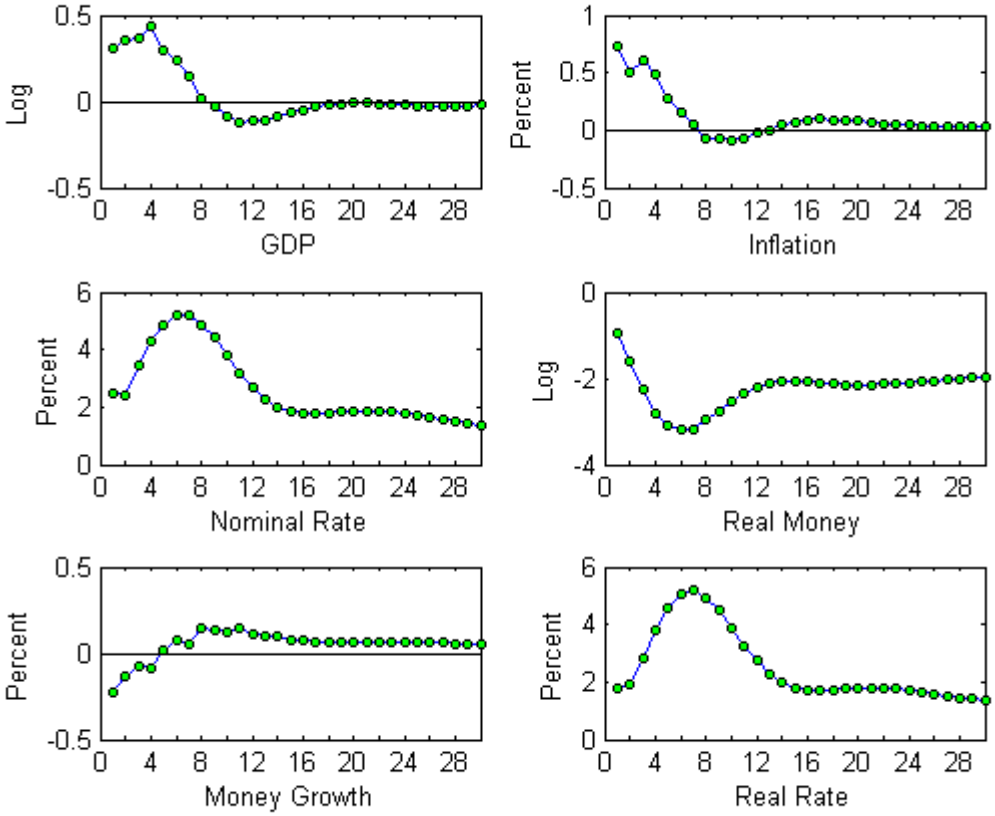

Figure 24: Impulse Responses to An IS Shock

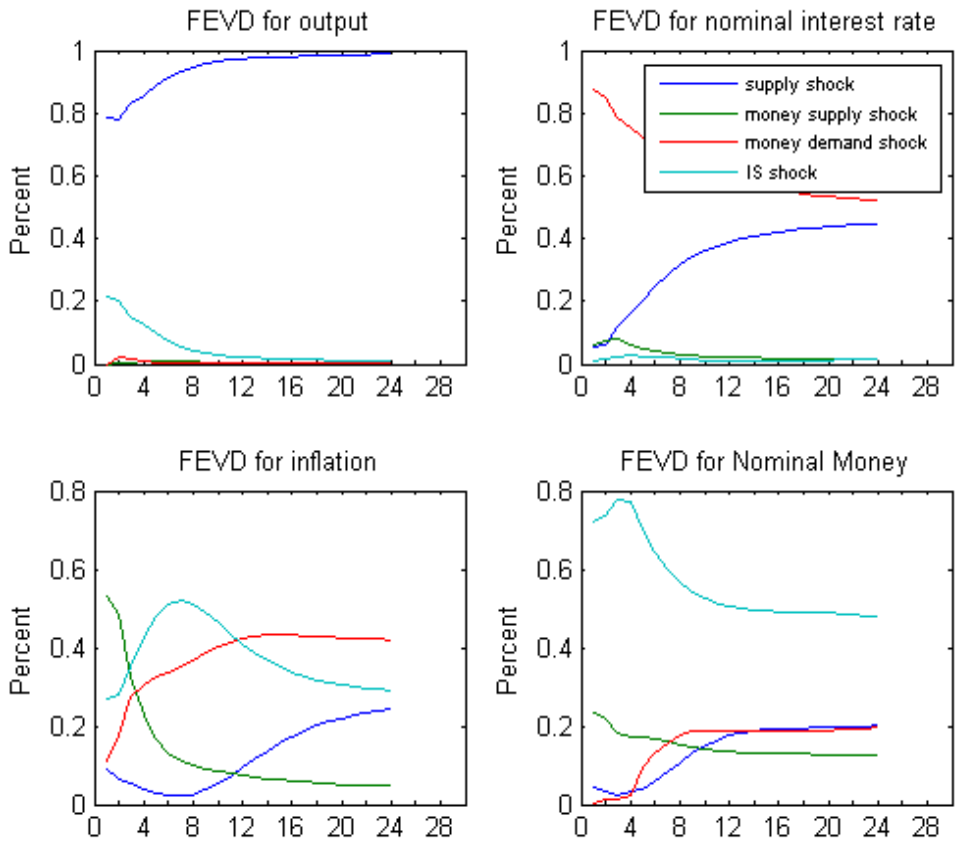

Figure 25: Decomposition of Forecast Error Variance

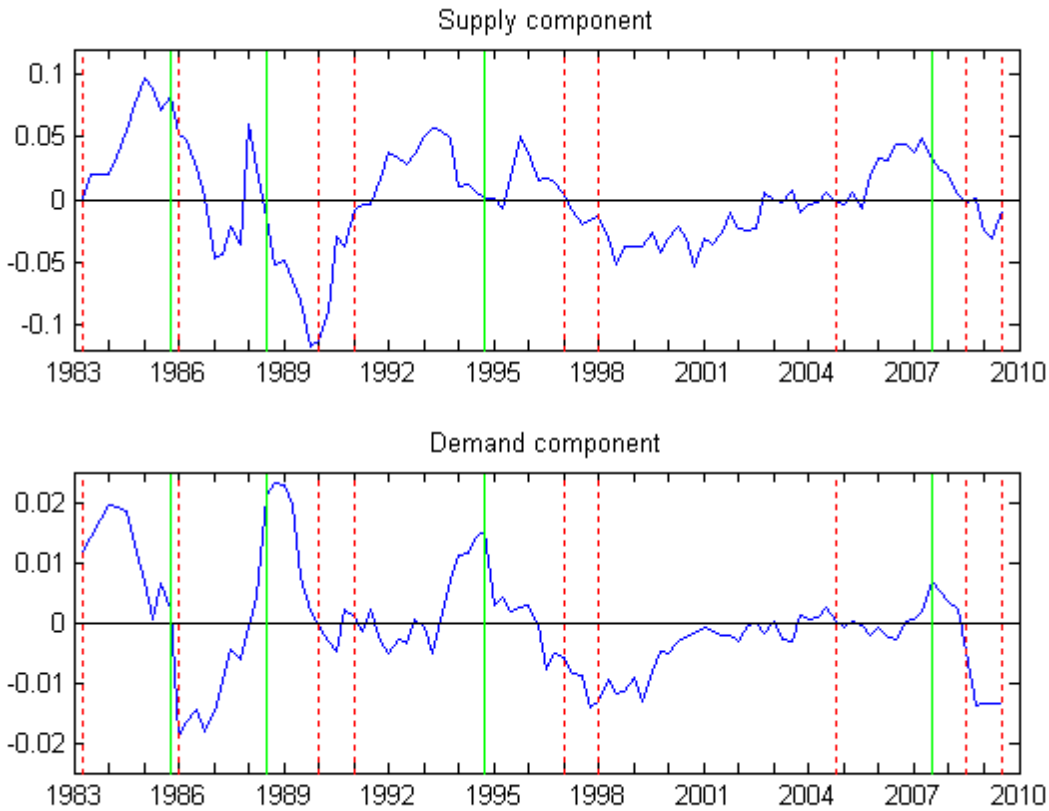

Figure 26: Historical Decomposition of Forecast Error

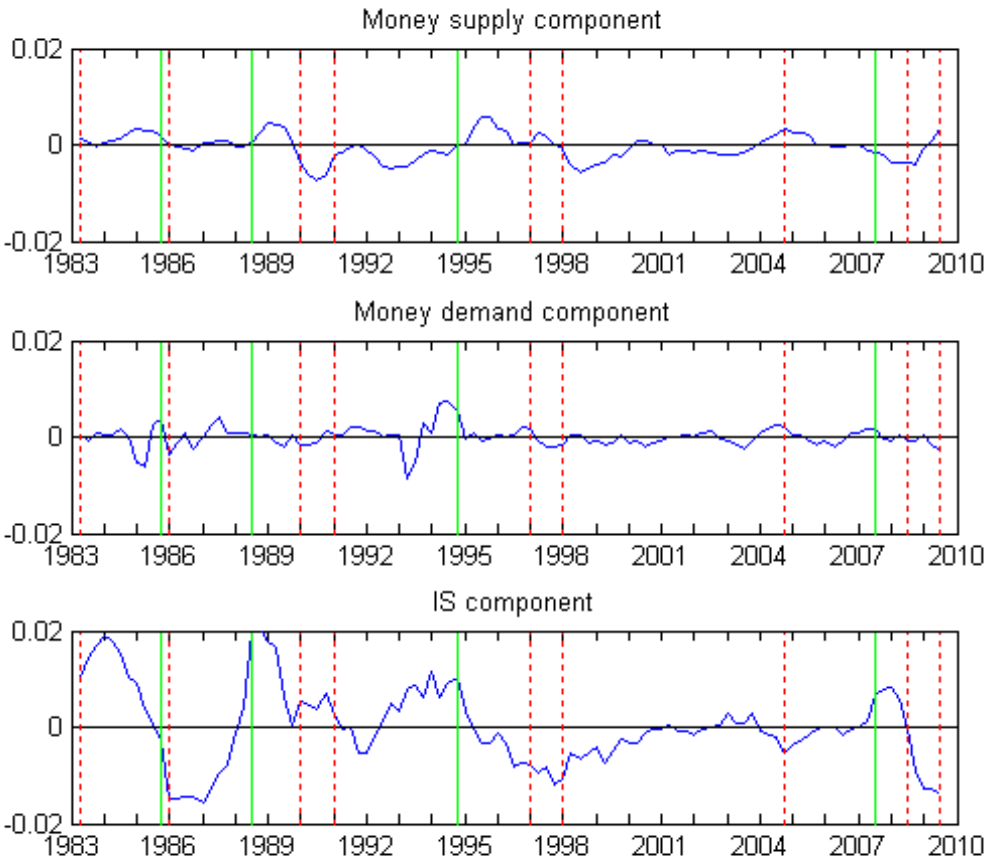

Figure 27: Historical Decomposition of Forecast Error

9.3.2 Narrow money

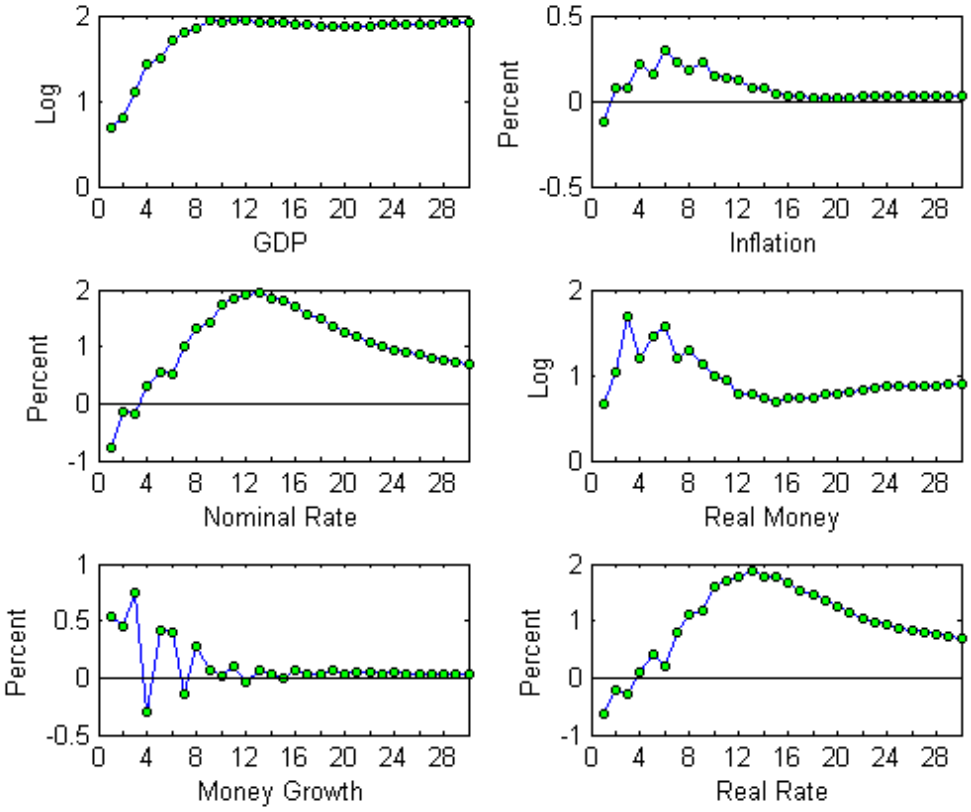

Figure 28: Impulse Responses to A Supply Shock

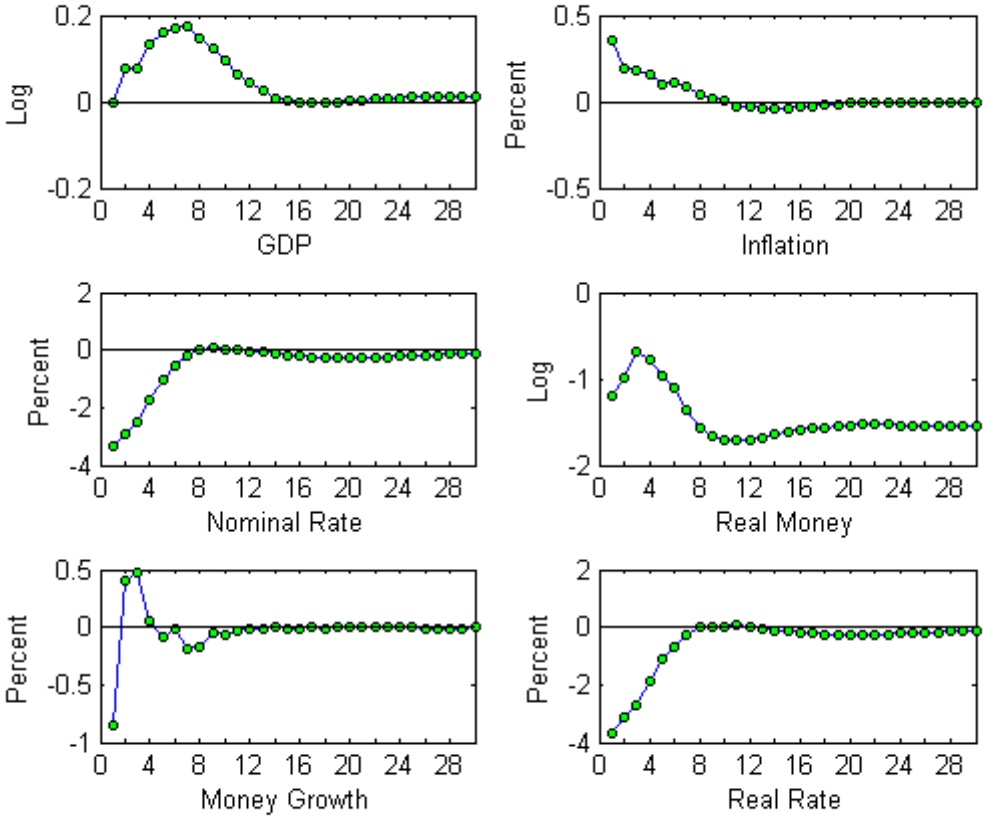

Figure 29: Impulse Responses to A Money Supply Shock

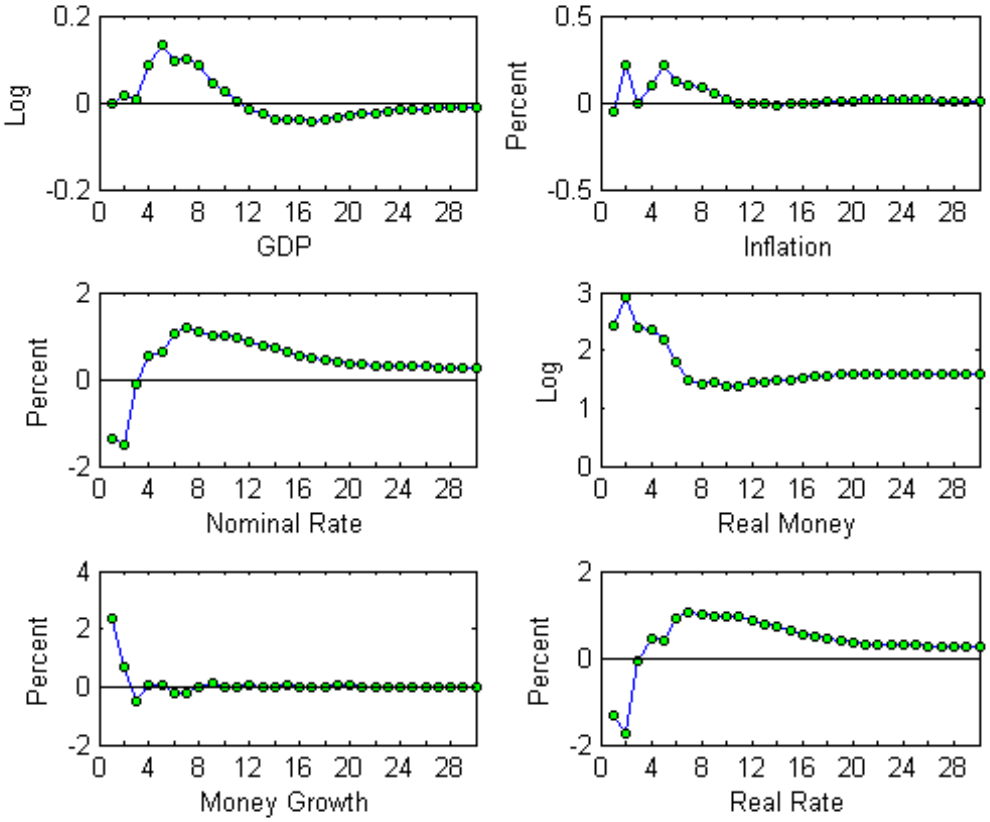

Figure 30: Impulse Responses to A Money Demand Shock

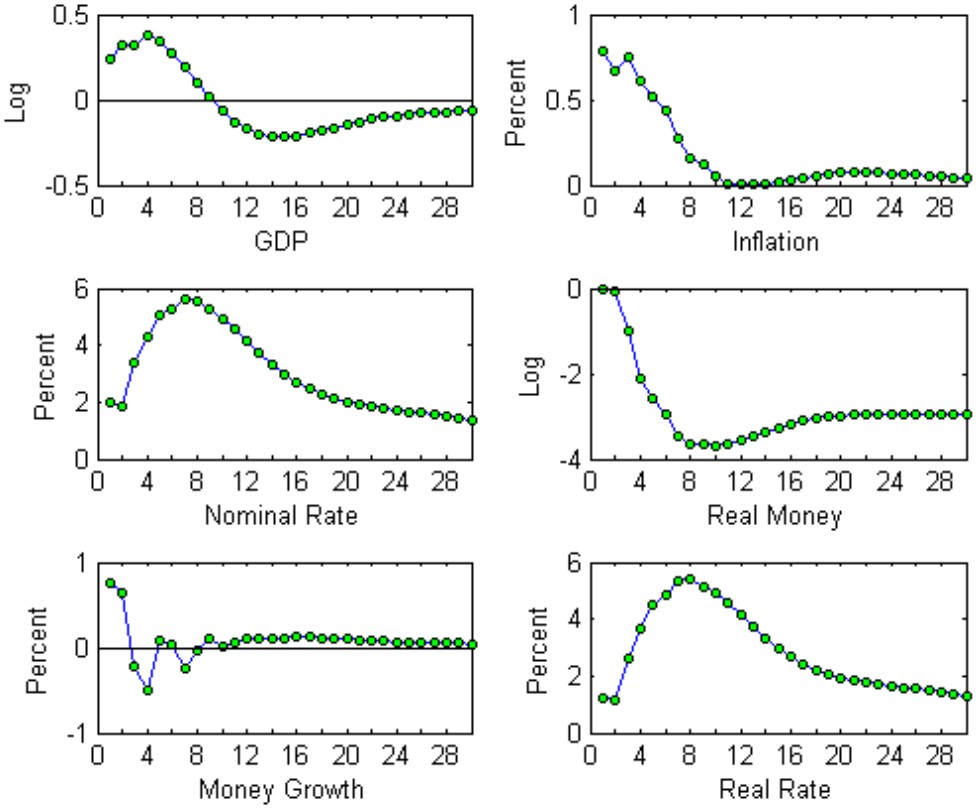

Figure 31: Impulse Responses to An IS Shock

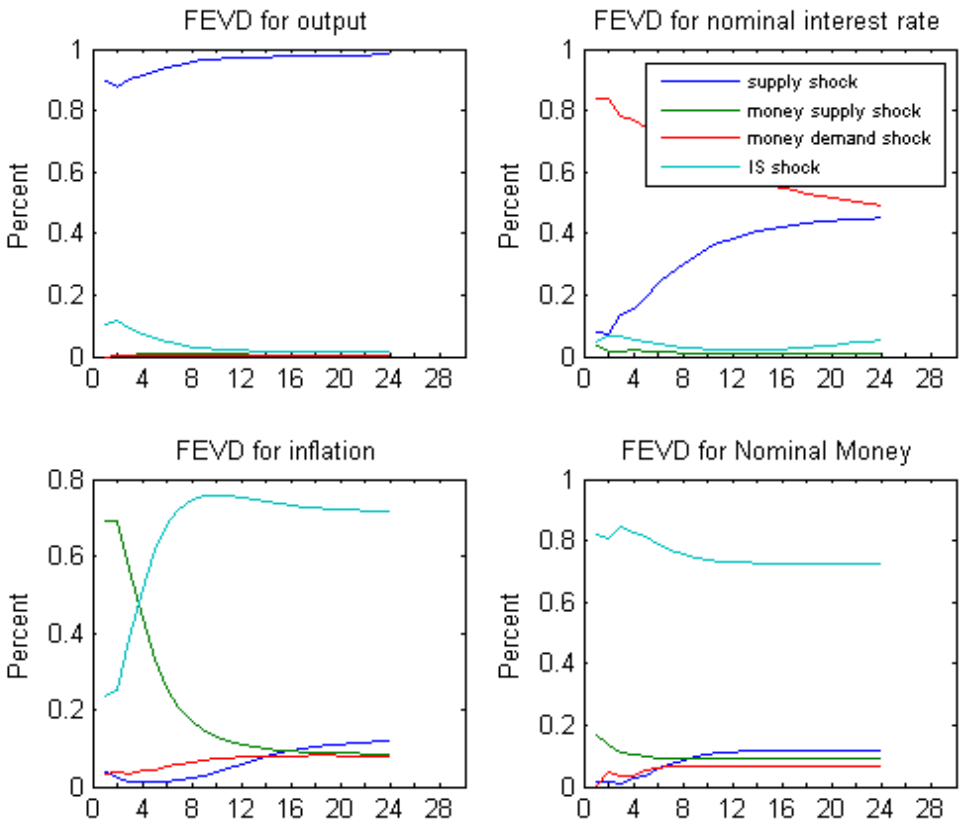

Figure 32: Decomposition of Forecast Error Variance

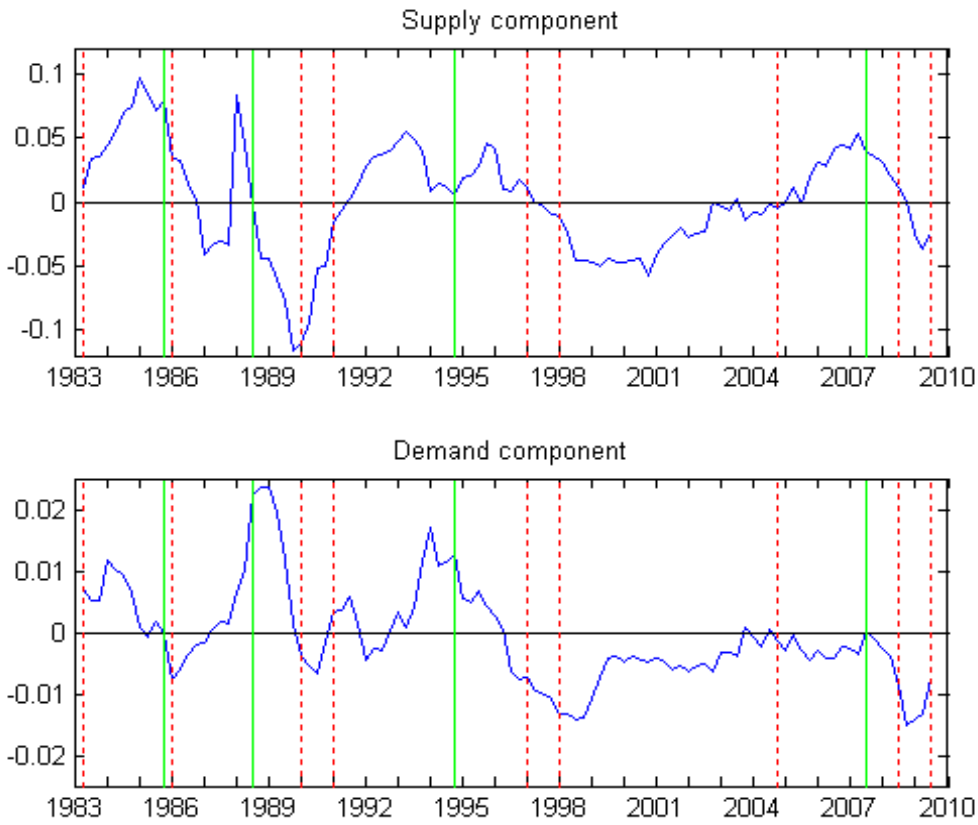

Figure 33: Historical Decomposition of Forecast Error

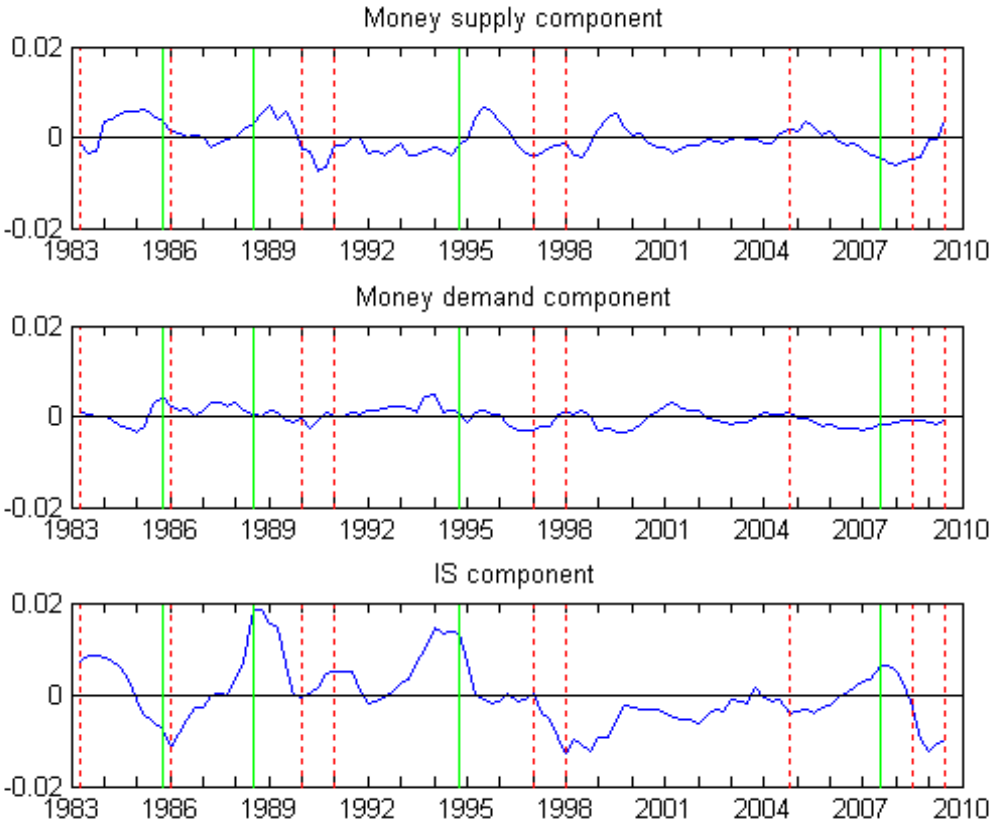

Figure 34: Historical Decomposition of Forecast Error

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