Chapter 2:

Are Currency Appreciations Contractionary in China?

JIANHUAI SHI

Peking University

Chapter 2:

Are Currency Appreciations Contractionary in China?*

Introduction

In recent years, the renminbi (RMB) exchange rate and China's exchange rate policy have received extensive attention from the international community. Is the RMB undervalued? If so, by how much it is undervalued? Should the RMB be allowed to appreciate? These questions have caused fierce debate both at home and abroad. Though there is no unanimous agreement as to how much the RMB is undervalued, researchers are unanimous that the RMB is undervalued. For example, Goldstein (2004) estimates that the RMB was undervalued by 15%-30% in 2003, according to a simple fundamental equilibrium exchange rate (FEER) model. Frankel (2004) uses a modified purchasing power parity method to estimate that the RMB was undervalued by 35% in 2000 and judges that it is undervalued by at least that much at present. Shi and Yu (2005) use a behavior equilibrium exchange rate (BEER) model to conclude that the RMB was undervalued by about 12% on average during 2002-2004. Coudert and Couharde (2005) also use a FEER model to estimate that the RMB was undervalued by 23% in 2003.

No matter whether a currency is under- or overvalued, exchange rate misalignment certainly results in a distortion that exerts a negative impact on the structure and macroeconomic performance of an economy. For example, in recent years, the Chinese economy has been in a state of obvious external and internal imbalance, which certainly has something to do with undervaluation of the RMB.[1] According to the Swan Diagram, a classic framework for analyzing macroeconomic policy in an open economy, allowing the RMB to appreciate is a direct and effective method for resolving imbalances of the Chinese economy, but the Chinese

---

* Acknowledgement: First published as Jianhui Shi, 2008, "Are Currency Revaluations Contractionary in China?" Takatoshi Ito and Andrew K Rose (eds.), *International Financial Issues in the Pacific Rim*, University of Chicago Press, Chicago. © 2008 by the National Bureau of Economic Research.
This is a revision of a paper presented at the 17th Annual East Asian Seminar on Economics on "International Financial Issues around the Pacific-Rim", Hawaii, June 22-24, 2006, organized by the National Bureau of Economic Research. I thank Ashvin Ahuja, Dante Canlas, Michael Dooley, Peter Garber, Takatoshi Ito, and Andrew Rose for insightful comments, and Guoqing Song for help in obtaining data used in this research. The views expressed herein are those of the author and do not necessarily reflect the views of the National Bureau of Economic Research.

[1] Specifically, external imbalance is evidenced by the large current account surplus and a big growth in foreign exchange reserves; the internal imbalance manifests itself in overheating of the economy and inflationary pressures.

government seems hesitant to allow it to appreciate (Shi, 2006).[23] Instead, it would rather adopt other measures such as adjusting export tax rebates, relaxing controls on capital outflows, and adjusting the interest rate or deposit reserve ratio, etc., to deal with external and internal imbalances of the economy.

Why then, when the RMB is obviously undervalued, and the Chinese economy suffers from external and internal imbalances, does the Chinese government still resist RMB appreciation? According to the traditional textbook macroeconomic model, currency appreciations are contractionary: in the short run, currency appreciation will raise the price of domestic goods relative to the price of foreign goods (namely, real exchange rate appreciation), causing exports to drop and the substitution of home-produced goods with imported goods, thereby reducing aggregate demand.[4] So, hesitation by the Chinese government is consistent with traditional macroeconomic theory. Although the Chinese government has announced that China does not pursue too large a trade surplus (indicating that Chinese policymakers would like to reduce the surplus through various means), the Chinese government certainly worries that an RMB appreciation would be contractionary. This would have a negative impact on China's economic growth and employment, even pushing the Chinese economy into a long-term recession, as happened to Japan during the 1990s. In a situation where there is a high rate of unemployment caused by economic reforms and transition to a market economy, keeping a high rate of economic growth and maintaining employment are obviously central goals of the Chinese Government.

Must currency appreciations be contractionary and depreciations expansionary? At least since Hirschman (1949), economists have realized that appreciations are not necessarily contractionary, nor are depreciations necessarily expansionary. Following Krugman and Taylor (1978), a so-called "contractionary devaluations" literature has evolved.[5] On the demand side, the emphasis is on the expenditure-changing effects of exchange rate changes ignored by

---

[2] Under China's new exchange rate regime, if the monetary authorities either, reduce the intensity of exchange market intervention, or widen the band within which the RMB exchange rate can float, the market will promote the RMB to appreciate progressively because of the steady expectation of RMB appreciation.
[3] In this chapter, the terms "appreciation" and "revaluation" are used interchangeably.
[4] This is the expenditure-switching effect of an exchange rate change.
[5] This literature is mainly about the exchange rate policy of developing countries. Devaluations are usually included in the stabilization programs of developing countries and balance of payment problems in developing countries generally are due to devaluation pressures. Therefore, the "contractionary devaluations" literature mainly investigates the situation of devaluation. However, many of the channels through which contractionary devaluations work are equally applicable to revaluations.

traditional macroeconomic theory, providing a series of mechanisms and channels through which devaluation can cause output to drop. On the supply side, the literature demonstrates the "contractionary devaluations" effect mainly through the influence of devaluation on the cost of imported intermediate goods, wage costs, and firm's working capital.[6] After the 1994 Mexico currency crisis and the 1997-98 East Asian financial crisis the "contractionary devaluations" literature gained the renewed attention of economists (Kamin and Rogers, 2000). Recent research emphasizes the importance of balance sheet effects in explaining the economic recession caused by devaluation during financial crises (Frankel, 2005).

According to the "contractionary devaluations" literature, currency revaluations are likely to have an expansionary rather than a contractionary impact on the economy in developing countries. For instance, currency revaluation has a real cash balance effect and a real wealth effect: it lowers the domestic price level, therefore leading to real cash balance and real wealth increases, which tend to expand personal spending (Bruno, 1979; Gylfason and Radetzki, 1991). Currency revaluation also has an income reallocation effect: it tends to transfer real income from groups with a high marginal propensity to save towards groups with a low marginal propensity to save, causing total domestic expenditure to expand (Diaz-Alejandro, 1963; Cooper, 1971; Krugman and Taylor, 1978). This is because revaluation raises real wages through a reduction in the price level, causing real income to shift from entrepreneurs to labor, with the latter having a higher marginal propensity to consume. This income reallocation effect may be quite strong in developing countries, because labor in developing countries usually has limited wealth and is subject to tight liquidity constraints, so marginal propensities to consume are nearly equal to one. Moreover, in developing countries new equipment investment usually includes a large amount of imported capital goods. Consequently, currency revaluation will lower the domestic prices of those goods, helping to expand investment expenditure and, therefore, total expenditure (Branson, 1986; van Wijnbergen, 1986).[7] Finally, currency revaluation will lower the domestic prices of imported intermediate goods and raw materials, such as petroleum and minerals, which, in turn, will lower the production costs of all final goods (including non-tradable goods). The reduction in marginal costs relative to the price of final goods will lead to increased output and employment (Bruno, 1979; van Wijnbergen, 1986).

---

[6] See Lizondo and Montiel (1989) for a survey of the "contractionary devaluations" literature. Caves, Frankel and Jones (2002) provide a simple introduction to 10 kinds of "contractionary devaluations" effects.
[7] These are the expenditure-changing effects of an exchange rate change.

Therefore, even if the net effect of revaluation on aggregate demand is contractionary (the expenditure-switching effect is large enough to dominate the expenditure-changing effect), the supply-side effect might still result in the revaluation being expansionary.

Regarding the empirical literature, most of the research on the relationship between real exchange rates and output in developing countries demonstrates that real devaluations have been contractionary while real appreciations have been expansionary, suggesting that the channels of the “contractionary devaluations” literature are important in developing countries. For example, in some early influential research, Edwards (1986) used a reduced form equation model to study a panel data set of 12 developing countries, finding that devaluations were contractionary in the short-term, but were expansionary after one year, and were neutral in the long-term. Gylfason and Radetzki (1991) used a macroeconomic simulation method to find that for the 12 developing countries studied, devaluations were all contractionary in the short-term as well as in the medium-term. Kamin and Rogers (2000) used a vector auto-regression (VAR) model to study the relationship, between the real exchange rate and output in Mexico. They found that real devaluations were contractionary, while real appreciations were expansionary. Other recent research, such as Hoffmaister and Vegh (1996) on Uruguay; Moreno (1999) on six East Asian countries; Akinlo and Odusola (2003) on Nicaragua; and Berument and Pasaogullari (2003) on Turkey, supports the “contractionary devaluations” hypothesis.

What then is the relationship between the real RMB exchange rate and China’s output? Are RMB appreciations contractionary as per the textbook model or expansionary, as suggested by the “contractionary devaluations” hypothesis? The purpose of this chapter is to study the effects of the real RMB exchange rate on China's output by applying VAR models to a sample over the period 1991q1--2005q3. In order to provide a background for the issues to be discussed, the next section contains a brief historical review of China’s exchange rate regime, covering valuation of the RMB real exchange rate, and China’s output during the past decade; then the models employed and the data used are described, along with a discussion of the time-series characteristics of the variables; the following section presents the results of econometric analysis of the VAR models through impulse-response function graphs and variance decompositions of forecast errors; and finally the conclusions drawn from this research are summarized.

A Brief History of RMB Exchange Rate Valuation and China's Output Fluctuations

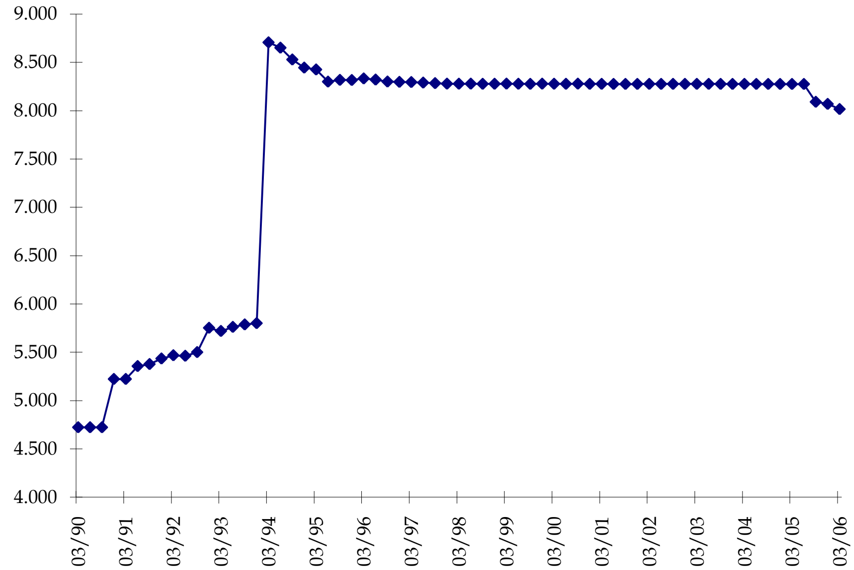
In the early-1990s, China implemented a double exchange rate system whereby an official fixed exchange rate coexisted with a market exchange rate formed in the swap foreign exchange market. By 1992, up to 80% of foreign exchange transactions were conducted in the swap foreign exchange market and the market exchange rate essentially reflected the demand for and supply of foreign exchange. The swap market exchange rate was higher than the official exchange rate, implying a subsidy to exporters. Consequently, the double exchange rate system caused unfair competition as well as resource-use distortion and was unfavorable to foreign direct investors.[8] Against these negative effects, the official exchange rate of the RMB was increasing (devaluing) constantly, from 4.7 yuan per U.S. dollar in 1990, to 5.4 yuan per U.S. dollar in 1992, and to 5.8 yuan per U.S. dollar by the end of 1993. On January 1, 1994, China reformed its double exchange rate system by unifying the two exchange rates and established a single and managed floating exchange rate system based on market supply and demand. Afterwards, the nominal rate of the RMB went through disconnected modest periods of appreciation. This continued until 1997 when the East Asian financial crisis occurred.

Under conditions where external demand dropped and the currencies of China's principal trading partners depreciated against the U.S. dollar by a wide margin (except Hong Kong), market participants generally anticipated that the RMB would follow those currencies and depreciate. In order to stabilize regional exchange rates and prevent currencies from competitive devaluation, the Chinese Government announced against market expectation that RMB would not be devalued. From then on, the RMB exchange rate was fixed at 8.28 yuan per U.S. dollar, and the so-called managed float became a de facto dollar peg. This system lasted until July, 2005. On July 21, 2005, China instituted reform of its exchange rate regime by revaluing the RMB by 2.1% and terminating its peg to the U.S. dollar in favor of a managed float based on a basket of currencies. Under the new exchange rate regime, the daily fluctuation of the RMB exchange rate was restricted within 0.3% on both sides. Due to market intervention conducted by the People's Bank of China (PBOC), the RMB exchange rate has not moved very much. Figure 1 portrays the track of the RMB nominal exchange rate against the U.S. dollar over the past 16 years.

---

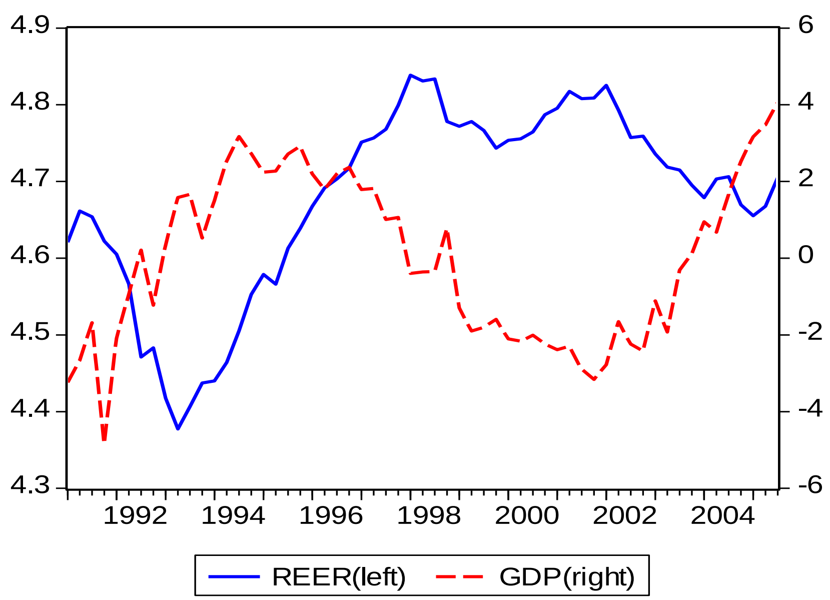
[8] Under this kind of system, foreign investment had to be converted into RMB according to the official exchange rate first, when foreign investors needed foreign exchange, however, they could only obtain it through the foreign exchange swap market, at the market exchange rate.

Figure 1: RMB Nominal Exchange Rate (Yuan/US Dollar)



Source: IMF, International Financial Statistics

Figure 2: RMB Real Exchange Rate and Real GDP



Notes: REER stands for an index of the RMB real exchange rate, an increase indicating an appreciation; GDP stands for de-trended real gross domestic product. See the third section for a definition and explanation of the variables

In contrast to the relative stability of the bilateral nominal rate of the RMB, the real effective exchange rate (hereafter referred to as the real exchange rate) of the RMB has fluctuated significantly. As can be seen from Figure 2, the real exchange rate of the RMB has gone through six stages over the past 10 years:

(1) 1991q1-1993q2: the RMB real exchange rate experienced a large amount of depreciation, mainly because the nominal rate of RMB exhibited a large devaluation;

(2) 1993q3-1998q1: the RMB real exchange rate experienced a large amount of appreciation, mainly because of higher inflation in China during the period and also a small amount of appreciation of the RMB nominal rate. After the East Asian financial crisis, appreciation of the RMB real exchange rate was due mainly to sharp devaluations in the currencies of some of China's trade partners;

(3) 1998q2-1999q4: the RMB real exchange rate experienced a certain degree of depreciation, mainly because there appeared to be deflation in China;

(4) 2000q1-2002q1: a certain degree of appreciation of the RMB real exchange rate occurred in this period. This was due to mild inflation in China and deflation in its trade partners during this period. In 2002q1, the real exchange rate of the RMB rebounded to the previous level of 1997q4;

(5) 2002q2-2005q1: the RMB real exchange rate experienced a large depreciation. This was influenced mainly by the fact that the U.S. dollar depreciated against the Euro, the Japanese yen, and other key currencies, so the RMB also depreciated against those currencies; and

(6) 2005q2 and q3: as a result of appreciation of the U.S. dollar against the Euro and Japanese yen, the RMB real exchange rate returned to a state of appreciation.

An investigation of the de-trended real output data of China reveals that China's real output also experienced large fluctuations over the same period. As illustrated in Figure 2, the correlation between the RMB real exchange rate and China's cyclical output over the entire sample period (1991q1-2005q3) is actually not that clear. However, since 2000q1, there has been an obvious negative correlation: appreciations of the real exchange rate have been associated with falls in cyclical output, while real depreciations have been followed by expansions in cyclical output. The relationship between the RMB real exchange rate and China's output is in accord with the forecast of traditional open economy macroeconomics where RMB appreciations are contractionary, while RMB depreciations are expansionary.

However, for the observed correlation between the RMB real exchange rate and China's output in Figure 2, two issues still need to be clarified:

(1) Whether the tight correlation between the RMB real exchange rate and China's output is spurious (i.e., whether it is simply reflecting the response of both variables to a third external variable when the two variables actually have nothing to do with each other). For example, a change in government spending will influence the real exchange rate while influencing aggregate demand. Models in the Mundell-Fleming tradition predict that an increase in government spending raises the real interest rate, leading to an appreciation of the real exchange rate.[9]

(2) The nature of the causality between real exchange rates and output, assuming they are truly relevant. In other words, does a change in the RMB real exchange rate cause the change in output or, conversely, does a change in output cause the change in the RMB real exchange rate? In order to answer these questions, a preliminary pair-wise Granger causality test was conducted in order to examine the Granger causality between the RMB real exchange rate and China's output. The Granger causality tests indicate whether a set of lagged variables has explanatory power with respect to the other variables. If the computed F-statistics are significant, we can claim in Granger's sense that one variable causes the other variable.

Table 1 reports the results of the Granger causality test. The result of the test for the whole sample (1991q1-2005q3) shows that, with a 95% level of confidence, the sample data reject the null hypothesis. This indicates that China's output Granger causes the RMB real exchange rate and the RMB real exchange rate Granger causes output as well.

Because there seems to be a difference in the relationship between the RMB real exchange rate and China's output before and after 2000q1, the whole sample was divided into two sub-samples (1991q1-1999q4 and 2000q1-2005q3), and two separate Granger causality tests were conducted. The results were surprising. For the first sub-sample (1991q1-1999q4), the data reject the null hypothesis with a 99% or higher level of confidence, suggesting that output Granger causes the real exchange rate and the real exchange rate Granger causes output as well. However, the second sub-sample (2000q1-2005q3) in which there seems to be a strong correlation between output and the real exchange rate cannot reject the null hypothesis. This

---

[9] In contrast, the sticky-price inter-temporal models of the New Open Economy Macroeconomics predict a fall in the real interest rate in response to an increase in government spending (Obstfeld and Rogoff, 1995), hence a depreciation of the real exchange rate.

shows a strange result that output does not Granger cause the real exchange rate; nor does the real exchange rate Granger cause output. This means that neither variable is helpful in explaining the movement of the other. One explanation of this unexpected result may be the small number of observations in the second sub-sample, resulting in a small F-Statistic. Another explanation may be that there were other variables simultaneously influencing both the RMB real exchange rate as well as China's output, thus limiting the usefulness of the pair-wise Granger causality test.

Table 1: Pairwise Granger Causality Tests

Sample: 1991Q1--2005Q3			
Null Hypothesis:	Obs	F-Statistic	Probability
GDP does not Granger Cause REER	55	2.65	0.04
REER does not Granger Cause GDP		2.85	0.03
Subsample: 1991Q1--1999Q4			
Null Hypothesis:	Obs	F-Statistic	Probability
GDP does not Granger Cause REER	32	3.69	0.02
REER does not Granger Cause GDP		9.38	0.00
Subsample: 2000Q1--2005Q3			
Null Hypothesis:	Obs	F-Statistic	Probability
GDP does not Granger Cause REER	23	0.86	0.51
REER does not Granger Cause GDP		0.52	0.72

In order to investigate the relationship between the RMB real exchange rate and China's output more precisely, we employ VAR models to control for the influence of variables that may impact both the RMB real exchange rate and China's output, thereby answering the earlier questions. The estimated VAR models also let us study other interesting issues.

Model and Data

The Models: VAR models are used to study the relationship between the RMB real exchange rate and China's output. The goal is to study whether the correlation indicated in Figure 2 is spurious and to determine the direction of causality between the real exchange rate and output. Due to the relatively small sample size, not all variables of interest could be included within one VAR model, so the modeling strategy of Kamin and Rogers (2000) is adopted.[10]

[10] Because a VAR model involves estimating quite a lot of parameters, introducing too many endogenous variables will cause serious loss of degrees of freedom, thereby affecting the statistical dependability of the results.

A basic model is estimated first and then expanded by entering another external variable to the basic model each time. Following Kamin and Rogers (2000), the basic model includes China's gross domestic product (GDP), the RMB real effective exchange rate (REER), China's inflation rate (INFL), and foreign gross domestic product (GDPF). Following the tradition of the business cycle literature, the gross domestic product data are de-trended so as to focus upon the growth cycle. Therefore, GDP and GDPF represent the cyclical components of the gross domestic product (or GDP gap) of China and foreign countries respectively. There are several considerations when selecting these four variables. GDPF is treated as a proxy for external shocks to the Chinese economy. GDP and REER are the variables of interest. INFL is the "intermediate" variable in-between the real exchange rate and output, proxying all possible channels for linking the real exchange rate to output. In contrast to Kamin and Rogers (2000), GDPF was used instead of the U.S. interest rate as the proxy for external factors. This is because China still implements capital controls. Therefore, the relationship between the U.S. interest rate and China's interest rate should not be that close. On the other hand, after allowing convertibility of the RMB for current account transactions and formally joining the World Trade Organization (WTO), the openness of China's real economy is constantly increasing. The ratio of foreign trade to GDP in China has now reached a high level of 70%. In this situation, the business cycles of its trading partners have an important influence on China's business cycles through import and export channels.

The basic model is too parsimonious to allow us to investigate more comprehensively the influence of variables that affect both the real exchange rate and output; and so it may not be a particularly efficient means to study the problem of spurious correlation. For example, it provides little sense of which channels link the real exchange rate to output. Therefore, one endogenous variable is added to the basic model each time. Additionally, other VAR models are estimated. This determines whether the final results are robust, while allowing for control of the size of the VAR model within the appropriate level according to the sample. Government spending (GOV) and money supply (M2) are entered, respectively, into the basic model to examine fiscal and monetary channels in the relationship between real exchange rates and output. In addition, the U.S. interest rate (RUS) is included to allow investigation of the international financial linkages of the Chinese economy, and examination of the efficiency of capital controls in China. Therefore, besides the basic model (Model 1), three more VAR models are estimated. The models can be expressed in the form of an unrestricted VAR model as follows:

$$(1) \qquad Y_t^l = \sum_{i=1}^{k_l} A_i^l Y_{t-i}^l + \varepsilon_t^l, \quad \varepsilon_t^l : \text{IID}\left[o^l, \Omega^l\right] \quad l = \overline{1,4},$$

where,

$$Y_t^1 = (\text{GDPF}_t, \text{INFL}_t, \text{REER}_t, \text{GDP}_t)'$$
$$Y_t^2 = (\text{GDPF}_t, \text{INFL}_t, \text{GOV}_t, \text{REER}_t, \text{GDP}_t)'$$
$$Y_t^3 = (\text{GDPF}_t, \text{M2}_t, \text{INFL}_t, \text{REER}_t, \text{GDP}_t)'$$
$$Y_t^4 = (\text{RUS}_t, \text{GDPF}_t, \text{INFL}_t, \text{REER}_t, \text{GDP}_t)'.$$

k_1 indicates the lags of l^{th} VAR model, A_i^l is the parameter matrix of the l^{th} VAR model for $i = 1, 2, ..., k_l$, ε_t^l is a random residual vector of l^{th} VAR model, o^l is the zero mean vector of ε_t^l, and Ω^l is a covariance matrix of ε_t^l. According to the AIC criterion and the SC criterion different numbers of lags are tried for each VAR model, and the optimum number of lags turns out to be 4 for all four models.

The familiar two-stage approach is used to estimate the VAR models. At the first stage, the variables are regressed on lags of all the variables in the system. At the second stage, the Cholesky decomposition technique used by Sims (1980) is employed to orthogonalize the residuals so as to identify the primitive structural system. The Cholesky decomposition imposes a recursive contemporaneous causal structure on the VAR models. The model variables are ordered in a particular sequence, and variables higher in the ordering are assumed to cause contemporaneous changes in variables lower in the ordering. Variables lower in the ordering are assumed to affect variables higher in the ordering only with a lag. Because of that, determining a reasonable order for endogenous variables is an important issue in employing a VAR model. The variable orders of our four models are selected as above. The rationale for the orderings is discussed below.

Due to openness of the Chinese economy, GDPF is ordered first because GDPF captures the external shocks that may have significant contemporaneous effects on Chinese economic variables such as INFL, REER, and GDP. On the other hand, the outputs of China's trade partners as a whole are unlikely affected contemporaneously by any Chinese economic variables. For REER, INFL, and GDP, a somewhat different ordering to that of Kamin and

Rogers (2000) is used.[11] Since the RMB nominal exchange rate is stable due to high official intervention, INFL is ordered prior to REER and GDP by assuming that inflation shocks have a contemporaneous effect on the RMB real exchange rate and on aggregate demand. In contrast, it is assumed that prices are sticky in the short run, so that they respond to the real exchange rate and aggregate demand shocks only with lags. REER is ordered prior to GDP because it is assumed that real exchange rate shocks have a contemporaneous effect on aggregate demand through either traditional channels or those indicated by the "contractionary devaluations" literature, while aggregate demand shocks do not contemporaneously affect the real exchange rate.

In Model 2, GOV is ordered after INFL by assuming that government spending shocks affect inflation only with a lag. In Model 3, M2 is ordered prior to INFL under the assumption that as the monetary policy instrument in China, the money supply reacts, not to realized inflation but to expected inflation. In Model 4, RUS is ordered prior to GDPF because U.S. interest rate shocks contemporaneously affect world aggregate demand, but due to the relative independence of the U.S. economy, the U.S. interest rate is unlikely to be contemporaneously affected by world aggregate demand or any Chinese economic variables.

Data: The data are quarterly and the sample interval is 1991q1--2005q3. 1991q1 is the earliest time for which quarterly gross domestic product data are available for China. The gross domestic product data for 2005q4 were collected according to a new statistical method and without comparability with the data in the past. Therefore, it is excluded from the sample. Except for the inflation rate, the variables are in real terms: the U.S. real interest rate is obtained by subtracting the U.S. inflation rate from the nominal interest rate, and other real variables are drawn from the nominal ones divided by the consumer price index. The base period is 1992.

GDPF is calculated according to the trade-weighted average of the gross domestic product indices of 14 principal trade partners of China. GDP and GDPF are de-trended gross domestic products. In the business cycle literature, the Hodrick-Prescott (H-P) filter is widely used to generate the cyclical components. It is well known, however, that the H-P filter has an end-of-sample problem, such that at the end of the sample the estimates are particularly unreliable. In addition, the filter depends on the choice of the "smoothness parameter," which makes the resulting cyclical component and its statistical properties highly sensitive to this choice. These

[11] Kamin and Rogers (2000) adopt the following ordering: REER→ INFL→ GDP.

problems become serious when the sample size is small. Because of the relatively small sample, the H-P filter is not used in this study. Instead, quadratic de-trending was used to construct the GDP and GDPF data, which is implemented by regressing the logarithm of quarterly real gross domestic product on a trend and its quadrate. In this study, the regression with a quadratic time trend is a better fit than one with a linear time trend.

REER is taken from the International Financial Statistics Database of the International Monetary Fund (IMF), with an increase indicating an appreciation. China's inflation rate INFL is obtained by differencing the logarithm of the consumer price index. GOV measures Chinese government spending. M2 is China's broad money supply. RUS indicates the U.S. real interest rate based on three month Treasury bills. Except for INFL and RUS, the variables are in logarithms.

GDP, GOV, INFL and GDPF are seasonally adjusted. Data from other countries or regions are taken from the International Financial Statistics Database of IMF. The data for China's variables, except REER, comes from the State Statistics Bureau, the People's Bank of China, the China Ministry of Finance, and General Customs of China. Taiwan's annual GDP data comes from the IMF World Economic Outlook Database translated into quarterly data.

The Time Series Characteristics of the Data: Because many macroeconomic variables are not stationary, to avoid spurious regressions, the time-series of relevant variables in the models need to be tested for stationarity. If the variables turn out to be non-stationary, it then has to be determined whether long-run steady relations among those endogenous variables exist. The unit root tests and cointegration tests are chosen for these purposes below.

Table 2: Unit Root Tests

	Level		*First Difference*	
	ADF Test	Phillips-Perron Test	ADF Test	Phillips-Perron Test
GDP	-1.53*	-1.45*	-1.88*	-9.26**
REER	-1.27*	-1.37*	-5.56**	-5.69**
INFL	-1.24*	-1.89*	-12.00**	-11.38**
GDPF	-2.26*	-2.64***	-7.00**	-7.02**
GOV	1.12*	1.21*	-6.10**	-10.10**
M2	0.20*	-0.44*	-3.91**	-6.01**
RUS	-1.61*	-1.87*	-6.42**	-6.44**

* denotes hypothesis that the variable contains a unit root cannot be rejected at the 10% level of significance
*** denotes hypothesis that the variable contains a unit root ca not be rejected at the 5% level of significance
** denotes rejection of hypothesis that the variable contains a unit root at the 1% level of significance

(i) Unit root tests: Both the augmented Dickey-Fuller (ADF) test and the Phillips-Perron test are used for unit root tests. Table 2 reports the results of the unit root tests of all relevant variables in the models. For the level variables, both tests reveal that the presence of a unit root cannot be rejected, which shows that all of these variables are non-stationary. On the other hand, the Phillips-Perron test rejects the null hypothesis of presence of a unit root at the 1% level of significance for the first difference of all variables, while the ADF test rejects the null hypothesis at the 1% level of significance for the first difference of all variables except GDP. The ADF test cannot reject the presence of a unit root for the first differenced time series of GDP. Here, the result of the Phillips-Perron is adopted to test for GDP. Therefore, it can be asserted that all variables in our models are first order integrated variables, namely variables of I (1).

Table 3: Cointegration Tests for Alternative Specifications

Hypothesized No. of CE(s)	*Eigenvalue*	*λ-Trace Statistics*	*λ-Max Statistics*
Model 1: Series: GDPF INFL REER GDP			
None	0.68	94.67*	62.30*
At most 1	0.26	32.38*	16.73
At most 2	0.19	15.65*	11.54
At most 3	0.07	4.11*	4.11*
Model 2: Series: GDPF INFL GOV REER GDP			
None	0.70	149.45*	65.79*
At most 1	0.56	83.66*	45.72*
At most 2	0.35	37.95*	23.93*
At most 3	0.17	14.01	10.02
At most 4	0.07	4.00*	4.00*
Model 3: Series: GDPF M2 INFL REER GDP			
None	0.69	137.91*	63.97*
At most 1	0.62	73.94*	52.53*
At most 2	0.25	21.42	15.68
At most 3	0.10	5.73	5.70
At most 4	0.00	0.03	0.03
Model 4: Series: RUS GDPF INFL REER GDP			
None	0.70	154.51*	66.46*
At most 1	0.67	88.04*	60.79*
At most 2	0.27	27.25	17.00
At most 3	0.15	10.25	8.79
At most 4	0.03	1.47	1.47

* denotes rejection of the hypothesis at the 0.05% level of significance
Note: Lags interval (in first difference): 1 to 3

(ii) Cointegration tests: Because all of the variables in the models were variables of I (1), further testing is conducted to determine if there are cointegration vectors for each model. VAR-based cointegration tests are implemented using the methodology developed in Johansen (1995). Table 3 reports the results of Johansen cointegration tests, indicating that there is at least one cointegration vector for each VAR model. Therefore, non-stationary data are of less concern in this study. In fact, as elaborated in Sims, Stock, and Watson (1990), when variables are co-integrated, using a VAR in levels model is specified, and the estimates are consistent. Some economists suggest that when one really does not know whether there is co-integration or what the co-integration vector is, the VAR in levels approach is probably better than the approach that tests for co-integration, estimates co-integrating relationships, and then estimates a vector error correction (VEC) model (Cochrane, 2005). This suggestion was followed, and the study is conducted on the relationship between the RMB real exchange rate and China's output by using a VAR in levels model.

Empirical Results

This section comprise two subsections: first the empirical results derived from the VAR in levels models are presented. Estimation results of the VAR models are given in the form of impulse response functions and variance decompositions. Based on these, the empirical analysis of the relationship between the RMB real exchange rate and China's output is conducted. Second, robustness of the results obtained is investigated through adopting a different ordering of variables using a vector error correction (VEC) model specification and substituting RUS for GDPF in the first three models as a proxy for external shocks. The goal is to determine whether the results change significantly with these changes.

Results from the VAR in Levels Model: In a VAR analysis, dynamic interactions between variables are usually investigated by impulse response functions or forecast error variance decompositions. In this subsection, empirical results concerning the relationship between the RMB real exchange rate and China's output are obtained by using these two instruments.

(i) Impulse response functions**:** The impulse response functions (IRFs) display the responses of a particular variable to a one-time shock in each of the variables in the system. Figures 3 and 4 plot the IRFs of GDP and REER, respectively, calculated from four VAR models. Investigation of the IRF graphs yield the results presented below.

First, when a one standard deviation positive (appreciation) shock to REER takes place, there is an obvious decline in GDP, indicating that RMB real rate shocks have a negative impact on China's output. From the 8th quarter, the contractionary effect is weakened to some extent but still obviously exists. After 18 quarters, the impact of an RMB real rate shock on output turns out to be positive. This effect of an RMB real exchange rate appreciation occurred in all of the models estimated, supporting the robustness of the result. This result is in contrast to that of other authors, such as Edwards (1986), as well as Kamin and Rogers (2000). In Edwards, of 12 countries studied, devaluations (revaluations) were contractionary (expansionary) in the short-term, but after one year, devaluations turned out to be expansionary. In Kamin and Rogers (2001), devaluations (revaluations) in Mexico were contractionary (expansionary) in the short-term as well as in the medium-term.

Second, in Model 4, which includes RUS, the contractionary effect of positive shocks to REER on GDP is significantly less than that in the other models that do not include RUS. The former was only about half of the latter. On the other hand, shocks to RUS have a remarkable contractionary effect on GDP, and the magnitude of the effect is even larger than that of REER shocks.

These two findings seem to indicate that on one hand capital controls in China are less efficient than originally hypothesized. However, capital flows have a significant impact on the Chinese economy, which is even larger than the impact of trade (the impact of REER) on the economy.[12] In other words, after accounting for the effect of international finance linkages, the effect of RMB real appreciation on China's real economy may be smaller than originally expected.

Third, a one standard deviation shock to GDP has no obvious impact on REER. After the 3rd quarter, the shock causes REER to rise for some time. This effect of an output shock occurs in all models estimated, suggesting robustness of the result. Because the measure of the IRF graphs of REER is only about 1/10 relative to the measure of those of GDP, it can be surmised that the magnitude of the impact of output shocks on RMB real exchange rate is much less than the impact of RMB real rate shocks on output.

[12] The impact of a rise in RUS on the Chinese economy may function through the following channel: a rise in RUS results in a decline in US demand, which in turn causes the demand for China's exports to decline. But because we have entered GDPF in Model 4, the influence of this channel has already been controlled for.

Figure 3: Impulse Responses of GDP to Cholesky One S.D. shocks ± 2 S.E.

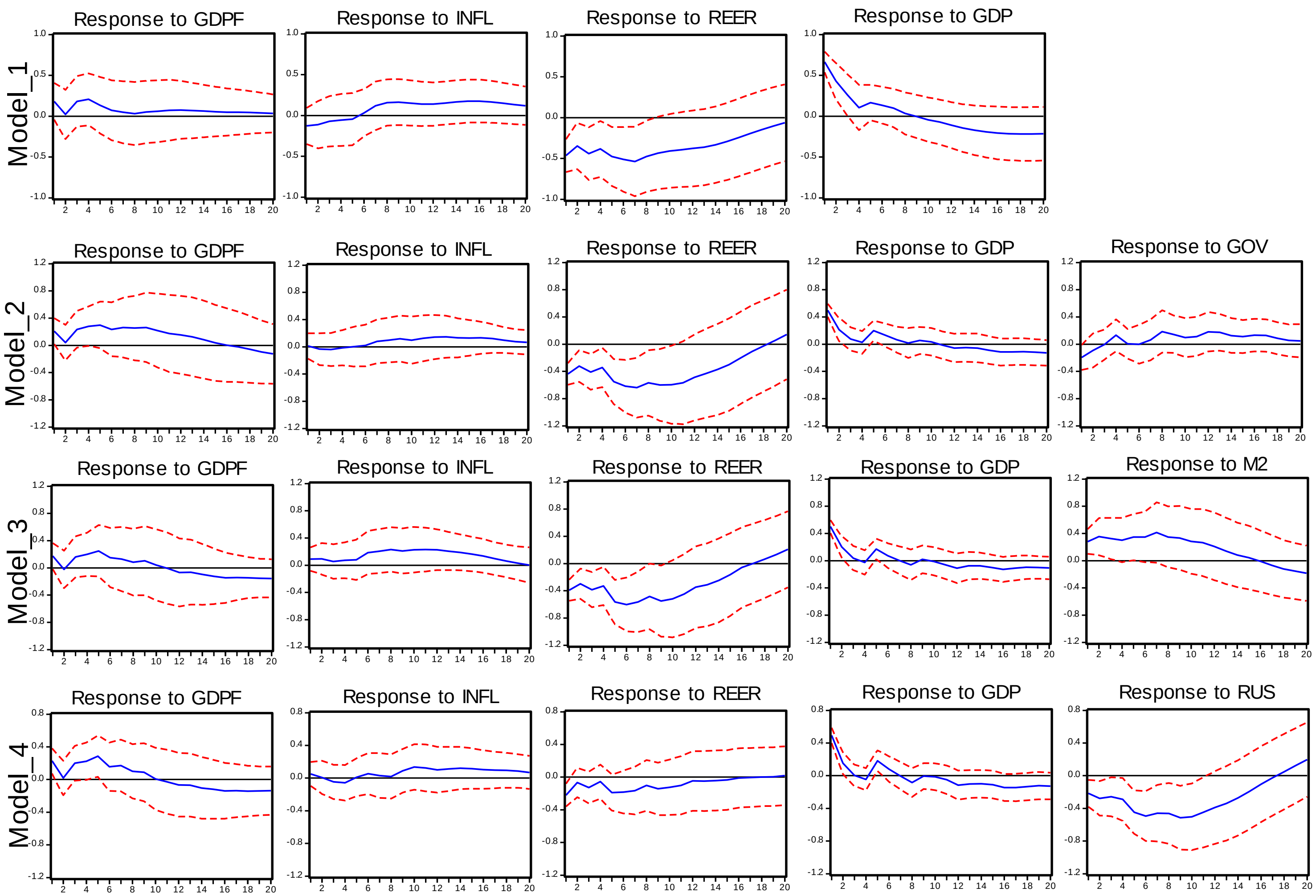
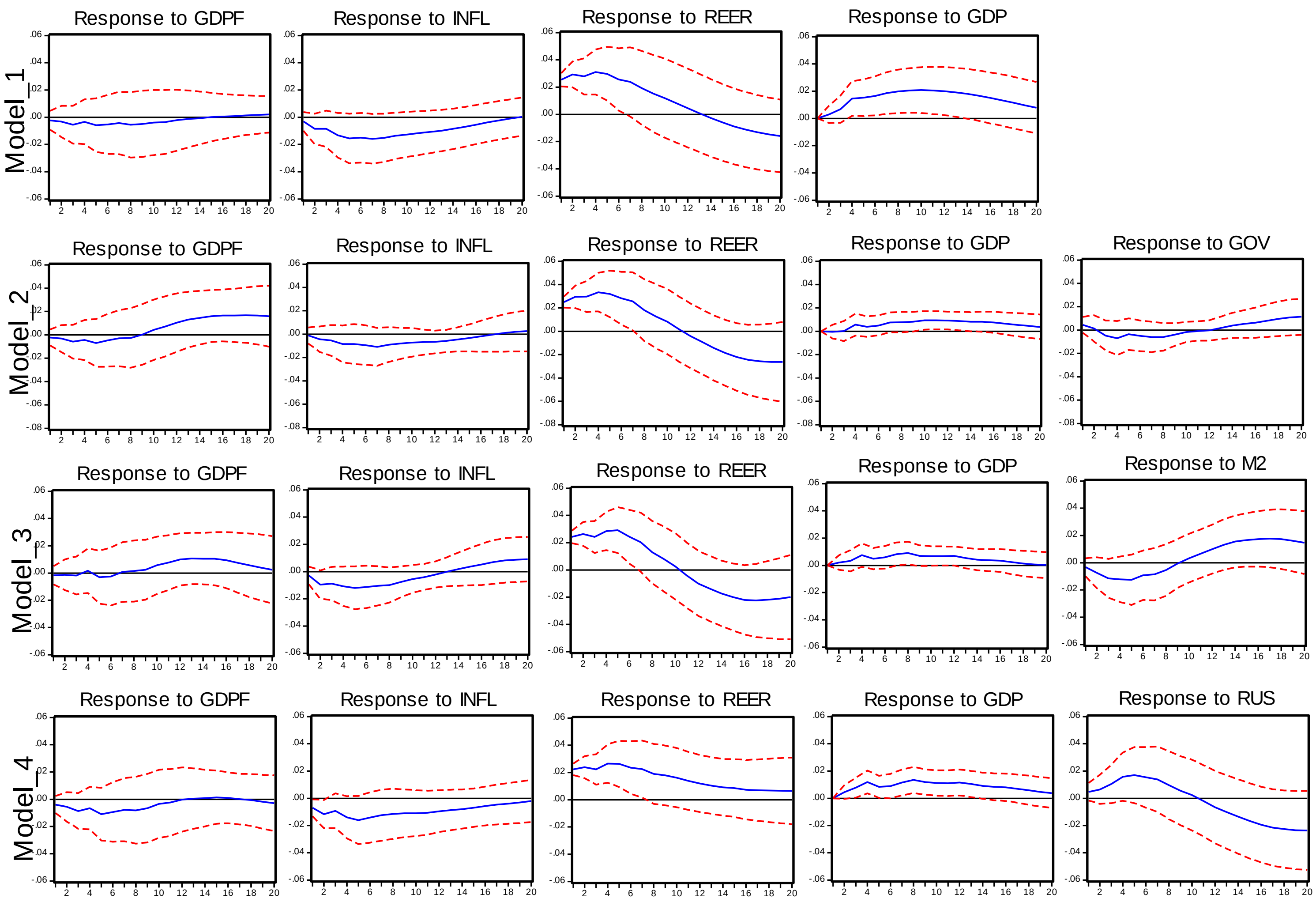


Figure 4: Impulse Responses of REER to Cholesky One S.D. shocks ± 2 S.E.



Fourth, the impact of shocks on other variables is in accord with economic predictions. For example, an increase in the money supply has an obvious expansionary effect and causes real exchange rate depreciation in the short-term. GDPF shocks have an expansionary effect as well. An increase in government spending results in RMB real exchange rate appreciation in the first two quarters, and inflation shocks causes a decline of GDP in the short-term. An important exception is the effect of INFL shocks on REER, where an increase in inflation causes real exchange rate depreciation. It might be expected that an increase in inflation causes the RMB real exchange rate to appreciate because the nominal exchange rate of the RMB has been very steady since 1997. In addition, an increase in government spending causes GDP to drop in the first two quarters. One possible explanation of this may be that in the short run, government spending has a strong crowding-out effect in China.

In sum, the analyses based on IRFs suggest that an RMB real exchange rate appreciation has a contractionary effect on China's output. After controlling for the influence of other variables, RMB real appreciation still causes GDP to decline, which excludes any spurious correlation between the RMB real exchange rate and China's output. The empirical results also seem to support the hypothesis that the direction of causality between the RMB real exchange rate and China's output runs from the former to the latter. Finally, external shocks have strong effects on China's output. In particular, U.S. interest rate shocks have a significant impact on China's cyclical output. When the effect of RUS is included in the VAR model, the effect of REER turns out to be weaker.

(ii) Variance decompositions: The IRFs provide a useful tool with which to assess, the direction as well as the magnitude of response of a variable to various kinds of shocks. However, variance decompositions give the fraction of the forecast error variance for each variable that is attributable to its own shocks and to shocks from the other variables in the system, which allows one to determine the relative importance of the contribution of different shocks to the variance of a particular variable. Table 4 provides the results of the variance decompositions of GDP and the RMB real exchange rate from the four VAR models. The following results emerge from the variance decompositions.

First, concerning the source of variation in GDP forecast error, for those models that did not include RUS, "own shocks" is the most important source at horizons of the 1st and 2nd quarters, while the RMB real exchange rate shock is the second-most important source.

Beginning in the 3rd quarter, however, RMB real exchange rate shocks become the most important source of variation in GDP, accounting for 36-70% of the GDP forecast error variance. In the medium and long-term, "own shocks" is the second-most important source in Model 1, which accounts for about 24% of the GDP error variance, while the contributions of "own shocks" in Models 2 and 3 decrease greatly, and account for only about 8% of the GDP error variance. In contrast, shocks to GDPF and M2 turn out to be the second-most important source of the contribution of GDP shocks to the error variance of REER is negligible at the horizons of quarters 1 to 4. Over the medium and long-term horizon, the contribution of GDP shocks to the error variance of REER is about 30% in Model 1, but drops by a large margin in the other three models to under 7% in Models 2 and 3, and to about 12% in Model 4. In contrast, shocks to M2, GDPF and RUS in the other three models all have relatively large contributions to the error variance of REER. It is worth noting that GOV has very little contribution to the error variance of REER.

Second, in Model 4, which includes RUS, "own shocks" to GDP are the most important source of GDP error variance only at the horizons of the 1st, 2nd, and 3rd quarters. Beginning in the 4th quarter, however, the RUS shocks become the most important and predominant source of variation in GDP, which accounts for 36%-69% of the GDP error variance. "Own shocks" and GDPF shocks are the second and the third most important source of the GDP error variance, which accounts for about 13% and 11%, respectively, in the long-term. In contrast, REER shocks become the fourth most important source of variation in GDP, which accounts for only 7% in the long-term. When RUS is included in the VAR model, the power of REER shocks in explaining the error variance of GDP significantly declines. This result is consistent with the results obtained in the IRFs analysis.

Third, with respect to the source of variation in the RMB real exchange rate forecast error, "own shocks" is the most important and source, accounting for 63%-98% of the forecast error variance at the horizons of quarters 1 to 4 and 40%-70% after 8 quarters. On the other hand, the contribution of GDP shocks to the error variance of REER is negligible at the horizons of quarters 1 to 4. In the medium and long-term horizon, the contribution of GDP shocks to the error variance of REER is about 30% in Model 1, but drops by a large margin in the other three models to under 7% in Model 2 and Model 3, and to about 12% in Model 4. In contrast, shocks to M2, GDPF and RUS in the other three models all have relatively large contributions to the error variance of REER. It is worth noting that GOV has very little contribution to the error variance of REER.

Table 4: Variance Decompositions of GDP and REER from VAR Models

Model_1												
T	S.E.		GDPF		INFL		REER		GDP			
1	**0.9**	0.6	**4.6**	0.8	**2.4**	1.4	**30.7**	97.8	**62.3**	0.0		
2	**1.2**	0.7	**3.3**	1.0	**2.9**	5.1	**33.0**	93.4	**60.8**	0.5		
3	**1.5**	0.7	**4.9**	1.8	**2.6**	6.1	**40.3**	89.9	**52.2**	2.2		
4	**1.6**	0.7	**7.1**	1.5	**2.5**	8.6	**44.5**	83.1	**45.9**	6.8		
8	**1.8**	1.3	**5.0**	2.0	**3.0**	14.8	**63.4**	65.8	**28.5**	17.4		
12	**1.8**	1.6	**4.4**	2.0	**4.9**	16.5	**68.1**	53.8	**22.6**	27.7		
20	**1.9**	1.8	**3.9**	1.7	**8.2**	15.2	**63.2**	49.4	**24.8**	33.8		
Model_2												
T	S.E.		GDPF		INFL		REER		GDP		GOV	
1	**1.0**	0.6	**8.4**	0.8	**0.0**	0.2	**36.7**	96.0	**47.5**	0.0	**7.3**	3.1
2	**1.3**	0.6	**6. 7**	1.0	**0.2**	1.3	**43.2**	96.3	**43.1**	0.0	**6.9**	1.4
3	**1.5**	0.7	**11.0**	2.0	**0.3**	2.0	**50.6**	94.3	**32.9**	0.0	**5.1**	1.8
4	**1.7**	0.8	**16.0**	2.0	**0.3**	3.2	**51.4**	91.7	**26.7**	0.9	**5.7**	2.4
8	**1.8**	1.2	**16.0**	2.1	**0.7**	6.6	**68.0**	85.9	**12.3**	2.6	**3.5**	2.7
12	**1.9**	1.4	**14.0**	4.0	**1.7**	8.4	**72.4**	78.8	**8.1**	6.2	**3.9**	2.6
20	**2.1**	1.8	**13.0**	15.6	**3.5**	5.2	**70.2**	68.6	**8.4**	6.0	**5.3**	4.7
Model_3												
T	S.E.		GDPF		INFL		REER		GDP		M2	
1	**1.0**	0.0	**5.8**	0.5	**1.6**	1.4	**29.4**	96.3	**48.2**	0.0	**15.0**	1.8
2	**1.3**	0.0	**3.9**	0.3	**2.1**	6.8	**30.7**	88.0	**37.3**	0.3	**25.9**	4.5
3	**1.5**	0.0	**5.3**	0.4	**1.8**	7.9	**36.4**	82.3	**27.6**	0.7	**28.9**	8.8
4	**1.7**	0.0	**7.3**	0.3	**1.9**	8.7	**37.9**	78.6	**22.5**	2.1	**30.4**	10.2
8	**1.8**	0.0	**6.1**	0.5	**4.8**	12.0	**51.5**	72.5	**9.9**	4.3	**27.7**	10.7
12	**1.9**	0.1	**4.6**	3.1	**7.5**	12.1	**54.8**	66.8	**7.3**	6.4	**25.8**	11.6
20	**2.1**	0.1	**6.5**	5.5	**9.0**	8.9	**52.3**	59.9	**7.8**	4.0	**24.4**	21.6
Model_4												
T	S.E.		GDPF		INFL		REER		GDP		RUS	
1	**0.5**	1.0	**13.2**	2.6	**0.7**	8.2	**12.4**	85.3	**61.9**	0.0	**11.8**	3.9
2	**0.8**	1.2	**10.5**	3.4	**0.5**	13.3	**10.7**	77.1	**53.5**	1.5	**24.7**	4.7
3	**0.9**	1.5	**14.8**	5.5	**0.8**	12.2	**11.2**	70.7	**42.8**	3.7	**30.4**	7.9
4	**1.0**	1.7	**18.5**	4.7	**1.1**	13.1	**9.5**	63.9	**35.1**	6.3	**35.8**	12.0
8	**1.2**	1.8	**14.8**	6.3	**0.6**	15.1	**9.3**	54.6	**16.3**	8.6	**58.9**	15.4
12	**1.4**	1.9	**10.2**	5.6	**2.2**	16.5	**7.8**	52.6	**11.3**	12.1	**68.5**	13.1
20	**1.7**	2.0	**12.0**	4.1	**4.1**	13.5	**6.6**	40.4	**12.8**	11.6	**64.6**	30.4

Notes: 1. The two columns below a variable give the fraction of the forecast error variance for GDP and REER attributable to shocks to the variable at the given forecast horizon, with the left black column indicating the fraction for GDP. 2. The columns below "S.E." contain the forecast error of GDP and REER at the given forecast horizon

In sum, the analyses based on the variance decompositions suggest three conclusions. First, shocks to the RMB real exchange rate have a large contribution to variation in China's output in the models that do not include the U.S. interest rate and some contribution to the variation in China's output in models that include the U.S. interest rate. This suggests that the possibility of spurious correlation between the RMB real exchange rate and China's output can be excluded. Second, except for the basic model (Model 1), the shocks to GDP account for a small contribution in the variation of the RMB real exchange rate, the contribution being negligible at horizons of 1 to 4 quarters, suggesting reverse causation running from the GDP to the RMB real exchange rate can be excluded. Third, when the U.S. interest rate is included in the VAR model, the power of REER shocks in explaining the error variance of GDP significantly declines.

Robustness Analysis: The results obtained in the previous subsection may be specific to the selected ordering of endogenous variables. Therefore, it is interesting to estimate the VAR models with different and plausible orderings. In addition, because all variables in our models were variables of I (1) and there are cointegration vectors for each model, it was worth trying to check the results obtained from the VAR in the level models with those obtained from the cointegration-restricted VAR models (i.e., the VEC models). Furthermore, the results of the previous subsection suggest that the magnitude of the effect of RMB real exchange rate shocks on China's output diminishes markedly when the U.S. interest rate is included in the VAR model. Therefore, it is also interesting to substitute RUS for GDPF as a proxy for external shocks in the first three VAR models. This subsection discusses the robustness of the results after investigating these three points.

(i) Different ordering: In their VAR models, Kamin and Rogers (2000) adopted different orderings from the ones used in this analysis. Except for GDPF, variables in the four VAR models are ordered in Kamin and Rogers (2000) as follows:

Model 1: REER→INFL→GDP; Model 2: GOV→REER→INFL→GDP; Model 3: REER→M2→INFL→GDP; and Model 4: RUS→REER→INFL→GDP.

If the assumption of price stickiness in the short run is relaxed, the above orderings seem plausible. For example, in Model 1, an appreciation of the real exchange rate shifts demand away from non-traded goods, resulting in a decrease in the price of non-traded goods and the general price level for a given level of the nominal exchange rate. The adjustment of the price level then causes the change of output.

The four VAR models are re-estimated by adopting the above orderings, generating results quite similar to those of the previous subsection. Only the impulse response functions of GDP from the four VAR models using the orderings adopted by Kamin and Rogers (2000) are presented (Figure 5).

(ii) Results from VEC model: The VEC models to be estimated have the following form:

$$\Delta Y_t^l = a^l ECM_{t-1}^l + \sum_{i=1}^{k_l-1} \Gamma_i^l \Delta Y_{t-i}^l + \varepsilon_t^l, \quad \varepsilon_t^l : \mathrm{IID}\left[o^l, \Omega^l\right] \quad l = \overline{1,4}, \tag{2}$$

where $ECM_{t-1}^l = \beta^{1\prime} Y_{t-1}^l$ is the error correction term reflecting the long-run equilibrium relationship between the variables. $\beta^{1\prime}$ is the matrix of cointegration vectors. The coefficient vector a^l reflects how fast the deviation from long-run equilibrium is corrected through a series of partial short-run adjustments. Γ_i^l is a parameter matrix of variables in differences; the elements of them reflect the short-term effect of the variables on the dependent variable.

The four VEC models are estimated by adopting the same orderings as in the previous subsection. Investigation of the estimation results of the four VEC models shows that the IRFs of the VEC models are very similar to those of the VAR models in direction and dynamic path of responses. The results of variance decompositions are basically similar as well. One difference, however, is that the effect of various shocks in the VEC models seems more lasting than that in the VAR models. Taking the response of GDP to the REER shocks as an example, the contractionary effect of an appreciation of REER is sustained longer before the expansionary effect appears. Only the results of variance decompositions of GDP and REER, as well as impulse response functions of GDP from the VEC models (Table 5 and Figure 6) are presented.

(iii) Substitution of RUS for GDPF in VAR model: When RUS is substituted for GDPF in the VAR models and the first three VAR models of the previous subsection are re-estimated, it is found that when compared to the situation of the original models using GDPF as a proxy variable for external shocks:

- the IRFs of three new VAR models are similar to those of Model 4 of the previous subsection, such that the magnitude of the effect of RMB exchange rate shocks on China's output is diminished, especially in the medium and long-term;
- the expansionary effect of REER shocks appears earlier;

Figure 5: Impulse Responses of GDP from VARs with Different Ordering

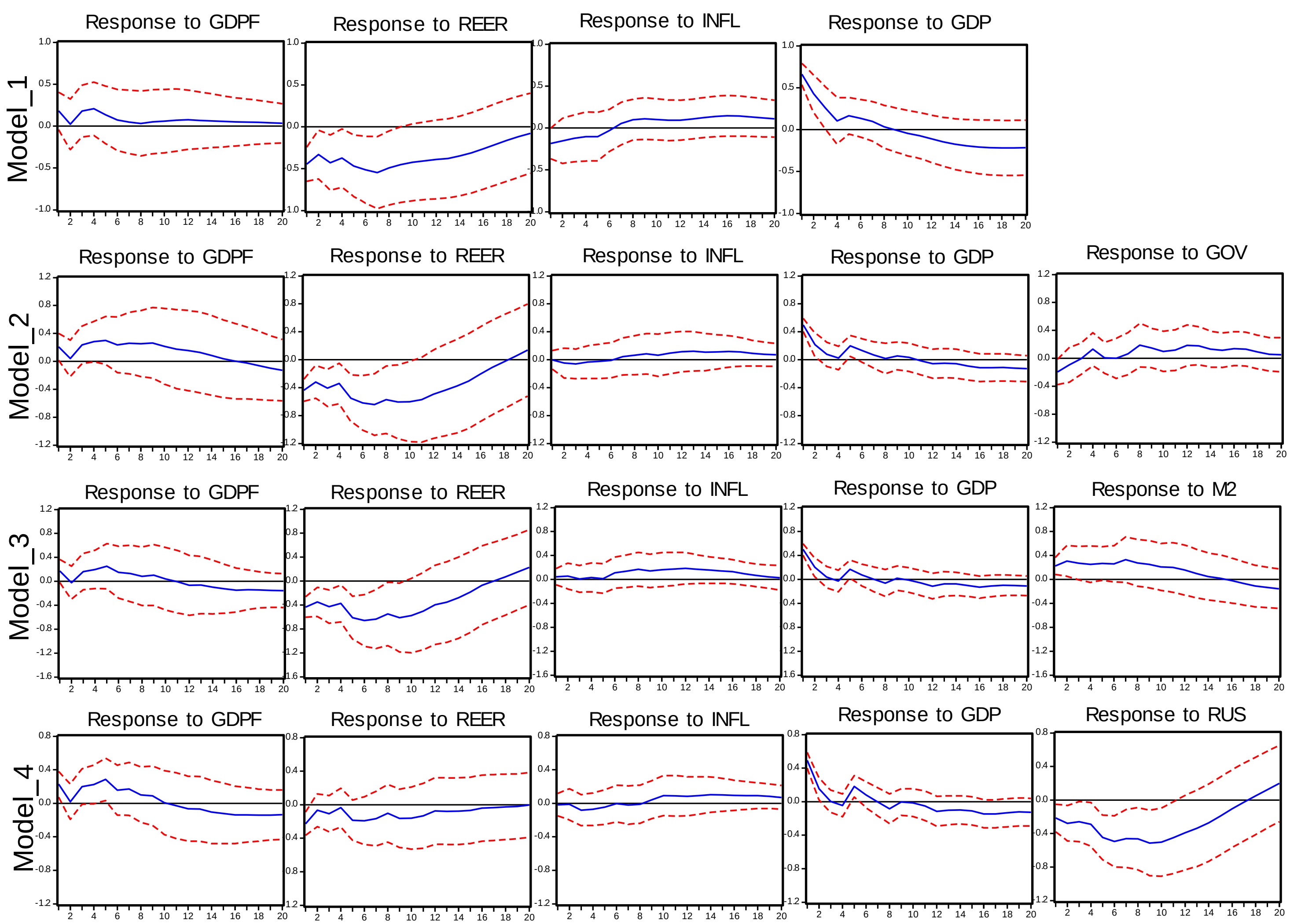
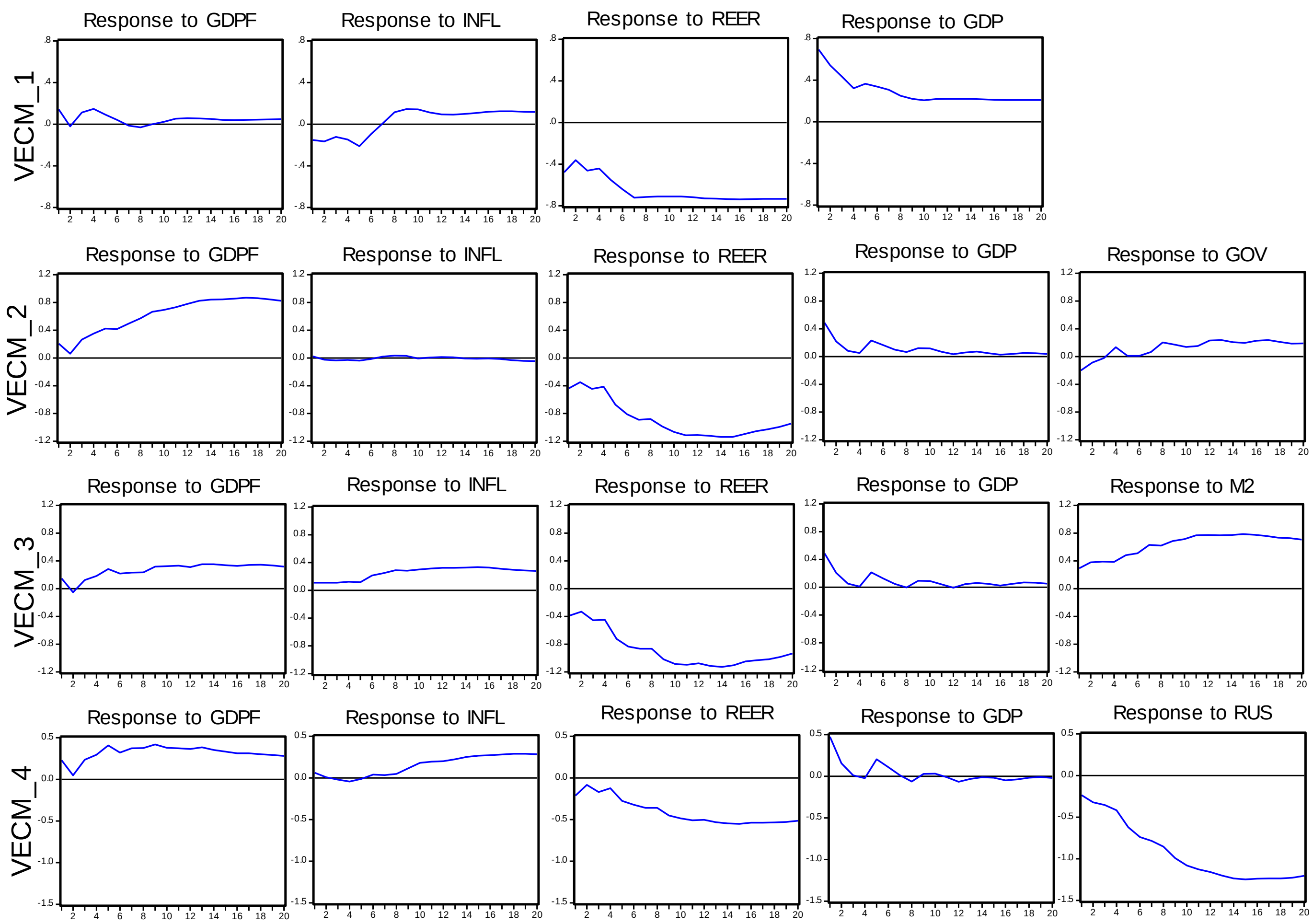


Table 5: Variance Decompositions of GDP and REER from VEC Models

Model_1												
T	S.E.		GDPF		INFL		REER		GDP			
1	**1.0**	0.6	**2.7**	0.2	**3.1**	2.8	**30.4**	97.1	**63.8**	0.0		
2	**1.5**	0.7	**1.7**	0.1	**4.2**	8.4	**29.9**	91.0	**64.2**	0.6		
3	**2.0**	0.7	**2.0**	0.2	**4.0**	11.1	**35.2**	86.6	**58.8**	2.2		
4	**2.5**	0.8	**2.8**	0.1	**4.5**	14.6	**39.0**	79.4	**53.8**	5.9		
8	**3.3**	1.9	**1.6**	0.0	**3.7**	22.7	**59.9**	67.6	**34.8**	9.7		
12	**4.0**	2.8	**1.1**	0.1	**3.3**	24.9	**70.1**	63.8	**25.4**	11.2		
20	**5.1**	4.2	**0.8**	0.1	**2.8**	26.2	**78.6**	61.6	**17.8**	12.1		
Model_2												
T	S.E.		GDPF		INFL		REER		GDP		GOV	
1	**1.0**	0.6	**8.3**	0.5	**0.1**	0.4	**37.8**	95.3	**45.9**	0.0	**7.8**	3.8
2	**1.4**	0.6	**6.7**	0.8	**0.2**	1.7	**45.6**	95.7	**40.6**	0.0	**6.9**	1.8
3	**1.8**	0.7	**11.9**	2.0	**0.3**	2.3	**53.2**	94.2	**29.7**	0.0	**5.0**	1.5
4	**2.0**	0.7	**18.4**	2.1	**0.3**	3.0	**53.6**	92.7	**22.6**	0.4	**5.1**	1.8
8	**2.4**	1.3	**23.0**	6.0	**0.1**	3.1	**67.0**	88.8	**7.6**	0.6	**2.2**	1.5
12	**2.7**	1.5	**27.2**	10.0	**0.1**	2.6	**67.3**	84.9	**3.5**	1.0	**2.0**	1.6
20	**3.8**	1.6	**33.0**	11.3	**0.1**	2.4	**63.2**	82.9	**1.6**	1.2	**2.2**	2.1
Model_3												
T	S.E.		GDPF		INFL		REER		GDP		M2	
1	**1.0**	0.0	**4.4**	0.7	**2.3**	1.8	**29.9**	94.8	**46.4**	0.0	**17.0**	2.7
2	**1.5**	0.0	**3.0**	0.4	**2.9**	7.0	**32.1**	86.2	**33.9**	0.2	**28.1**	6.3
3	**2.0**	0.0	**3.3**	0.4	**2.9**	8.2	**39.1**	79.6	**23.2**	0.3	**31.5**	11.5
4	**2.5**	0.0	**4.5**	0.3	**3.1**	8.9	**42.0**	76.3	**17.4**	1.0	**32.9**	13.5
8	**3.3**	0.0	**5.0**	0.3	**4.1**	9.8	**55.8**	70.5	**5.6**	0.7	**29.5**	18.8
12	**4.1**	0.1	**5.2**	0.3	**4.6**	10.3	**58.6**	68.1	**2.6**	0.6	**29.0**	20.7
20	**5.5**	0.1	**5.6**	0.9	**4.8**	10.6	**58.6**	66.8	**1.3**	0.7	**29.6**	21.0
Model_4												
T	S.E.		GDPF		INFL		REER		GDP		RUS	
1	**0.5**	1.0	**13.6**	1.5	**1.0**	10.4	**12.0**	81.5	**58.9**	0.0	**14.6**	6.6
2	**0.7**	1.5	**10.4**	1.4	**0.7**	17.1	**10.3**	71.1	**47.8**	1.4	**30.8**	9.0
3	**1.1**	2.0	**14.9**	2.0	**0.6**	17.0	**11.3**	63.6	**34.1**	2.9	**39.2**	14.5
4	**1.3**	2.5	**19.4**	1.3	**0.6**	18.4	**9.7**	55.8	**24.7**	4.1	**45.7**	20.4
8	**2.0**	3.5	**17.1**	0.5	**0.3**	22.6	**12.4**	43.5	**7.1**	2.9	**63.2**	30.5
12	**2.4**	4.4	**12.3**	0.9	**1.2**	26.3	**13.9**	39.6	**2.9**	2.4	**69.7**	30.8
20	**2.9**	5.6	**8.1**	2.2	**2.7**	31.3	**14.3**	37.9	**1.2**	2.0	**73.7**	26.6

Notes: 1. The two columns below a variable give the fraction of the forecast error variance for GDP and REER attributable to shocks to the variable at the given forecast horizon, with the left black column indicating the fraction for GDP. 2. The columns below "S.E." contain the forecast error of GDP and REER at the given forecast horizon.

Figure 6: Impulse Responses of GDP from VEC Models



Note: impulse response standard errors are not available for VEC model in EViews soft-package that we used in this study.

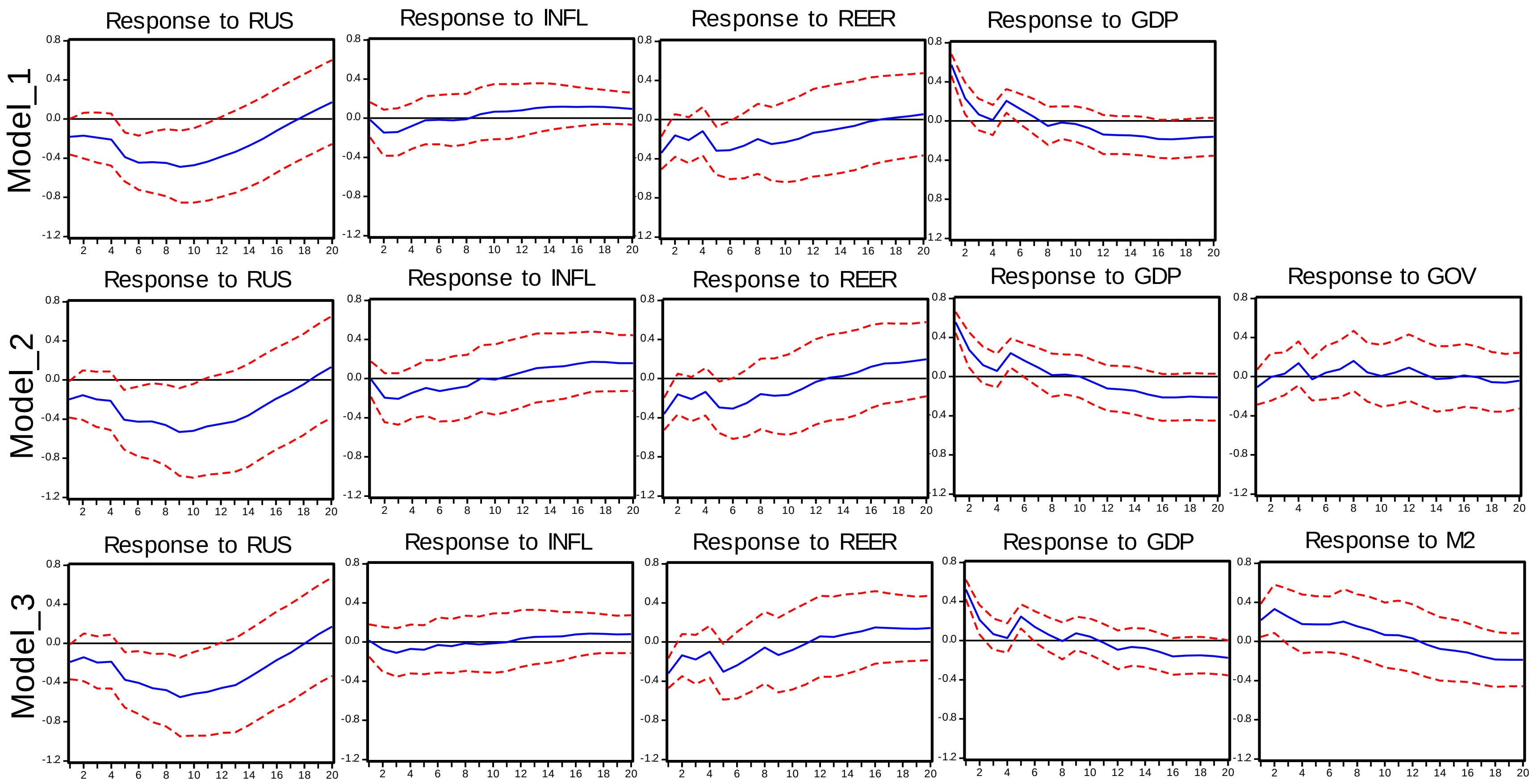
- with respect to the source of variation in GDP forecast error, in all three new VAR models, the RUS shocks become the most important and predominant source of variation in GDP, while, in contrast, REER shocks turn out to be the second, the third, and the fourth most important sources of the GDP error variance, respectively. The contributions of "own shocks" and M2 to variation in GDP exceed the contribution of REER in the second and third new models; and

Table 6: Variance Decompositions of GDP from VAR Models with RUS

Model_1						
T	S.E.	RUS	INFL	REER	GDP	
1	0.5	6.8	0.1	24.4	68.8	
2	0.8	10.1	3.7	23.4	62.8	
3	0.9	13.7	6.0	26.2	54.18	
4	1.0	18.2	6.4	25.8	49.6	
8	1.2	46.9	2.7	26.9	23.6	
12	1.4	58.0	2.3	23.4	16.2	
20	1.7	55.7	4.7	20.1	19.6	
Model_2						
T	S.E.	RUS	INFL	REER	GDP	GOV
1	0.6	8.0	0.0	26.6	63.1	2.3
2	0.8	9.8	5.9	23.9	58.7	1.7
3	0.9	13.0	10.3	25.2	49.9	1.5
4	1.0	16.5	11.4	24.3	44.4	3.4
8	1.2	42.8	7.0	23.4	23.7	3.1
12	1.3	59.1	4.7	17.6	16.2	2.4
20	1.6	54.9	7.6	16.5	19.0	2.1
Model_3						
T	S.E.	RUS	INFL	REER	GDP	M2
1	0.5	7.8	0.1	22.3	59.6	10.2
2	0.8	8.6	0.8	18.3	48.4	23.9
3	0.9	11.7	2.2	18.9	39.9	27.3
4	1.0	14.5	2.5	18.3	36.3	28.4
8	1.1	42.9	1.6	16.7	20.1	18.7
12	1.3	60.6	1.1	11.7	13.6	13.0
20	1.6	57.9	1.9	12.1	14.3	13.9

Note: 1. The column below a variable gives the fraction of the forecast error variance for GDP that is attributable to shocks to the variable at the given forecast horizon. 2. The column below "S.E." contains the forecast error of GDP at the given forecast horizon.

Figure 7: Impulse Responses of GDP from VARs with RUS Substituting for GDPF



(4) The effects of other shocks on GDP are similar between the new models and the original ones. Figure 7 and Table 6 provide IRFs and variance decompositions of GDP from the three new VAR models, with RUS replacing GDPF as a proxy variable for external shocks.

In sum, the robustness analysis confirms that the basic result - shocks to the RMB real exchange rate have a contractionary effect on China's output - does not change even if the orderings of Kamin and Rogers (2000) are adopted or a VEC model specification is used. However, after including the international finance linkage of the Chinese economy, the effect of the REER shock on China's output and the power of REER shocks in explaining changes in China's output turn out to be relatively small, while U.S. interest rate shocks have a relatively large effect on China's output, such that the magnitude of it exceeds that of RMB exchange rate shocks.

Conclusion

This chapter investigates the relationship between the RMB real exchange rate and China's output by using the VAR model technique. The empirical analysis reveals several interesting findings. First, even after the source of spurious correlation is controlled for, RMB real exchange rate appreciation leads to a decline in China's output, suggesting that currency appreciations have been contractionary in China, as suggested by traditional open economy macroeconomics.

Second, when the international finance linkages of the Chinese economy are accounted for, the effect of RMB real exchange rate shocks on China's output and the power of the shocks in explaining the change in China's output are relatively small, while the effect of U.S. interest rate shocks on China's output is relatively large. The intuition behind this finding is that the effectiveness of China's capital controls has eroded over time and the scales of capital inflows and outflows have become large enough such that external shocks through international financial channels have a significant influence on the Chinese economy, which exceeds the influence of external shocks through international trade channels.

Third, besides shocks to the RMB real exchange rate and the U.S. interest rate, shocks to domestic money supply and foreign demand have important effects on China's output. However, government spending shocks have less power in explaining changes in China's output.

The conclusion that currency appreciations are contractionary in China is remarkably different from those made by similar empirical work on developing countries. The possible explanations for this difference are outlined below:

- first, in the existing research on the “contractionary devaluations” effect in developing countries, devaluations usually take place under an abnormal environment of currency or financial crisis and thus have been associated with economic recession, but RMB devaluations did not happen in the case of currency or financial crisis until now;

- second, urban economic reform begun in the early 1990s has caused many people to lose their jobs and traditional benefits, such as healthcare, pensions, and education. In turn, this has strengthened the motive for precautionary savings in households in urban and township areas. Therefore, the income reallocation effect as well as the real cash balance and the real wealth effects of currency appreciation may not play a very great role;

- third, China has absorbed a large amount of foreign direct investment for many years. As a result, the technological progress and production capacity of China’s manufacturing industry have been promoted rapidly, the substitutability of home-produced capital goods (including those produced by foreign investment enterprises) for imported goods has been strengthened and, therefore, the effect of the RMB real exchange rate on domestic investment spending is not clear;

- fourth, one condition under which devaluation can lead to a reduction in national output is that imports initially exceed exports (Krugman and Taylor, 1978). China’s trade balance has been in surplus for more than 10 years, except for 1993, and therefore does not satisfy that condition;

- finally, because of the characteristics of processing trade in China’s manufacturing industry, as well as the administrative controls on prices (especially in the service sector), the supply-side effect of the RMB exchange rate on output is also uncertain. In short, it seems that the expenditure-changing effect and supply-side effect of RMB exchange rate changes have not been that remarkable in practice until now. Therefore, the effect of RMB real exchange rate shocks on China’s output is mainly embodied in the expenditure-switching effect as emphasized by traditional macroeconomic theory. Consequently, appreciations in the RMB are likely contractionary.

It is worth pointing out however, that concluding that appreciations have been contractionary in China does not necessarily mean that China should continue maintaining an undervalued exchange rate, since the value of the RMB has already caused the Chinese economy to run into internal and external imbalances in the past several years. Figure 2 (above) shows that China's real GDP has been running above its long-term trend since 2003, and this kind of deviation is expanding. Indeed, overheating of the Chinese economy is obvious. Undoubtedly, continuing undervaluation of the RMB will further aggravate imbalances in the Chinese economy. On the other hand, the conclusion that appreciations have been contractionary in China implies that relative to other effects of changes in the exchange rate, the expenditure-switching effect has been predominant in China until now. Hence, it is effective to use the orthodox Swan Diagram to analyze macroeconomic policy issues in China. According to the Swan Diagram, allowing the RMB to appreciate will be helpful to the Chinese economy in realizing internal and external balances (Shi, 2006).

Additionally, in recent years China's capital account surplus has increased rapidly along with increases in the current account surplus. The rapid increase in the "double surplus" has caused China's foreign exchange reserves to expand in an uncontrolled manner. In addition, the money supply and domestic credit have expanded passively, aggravating overheating of the Chinese economy and the difficulties for the Chinese government's macroeconomic management. In particular, as China's capital account is gradually liberalized and the effectiveness of capital controls erodes over time, "hot money" flows into China will expand, becoming a major reason for rapid expansion of foreign exchange reserves.

The empirical work indicates that the effect of shocks on China's output through international financial channels (as represented by U.S. interest rate shocks) exceeds that of international trade channels (as represented by RMB real exchange rate shocks), suggesting it is important for the Chinese authorities to handle the capital inflow problem correctly. The inflow of "hot money" in recent years is mainly a response to expectation of RMB appreciation, and an important reason for the persistent existence of these expectations is undervaluation of the RMB. Therefore, allowing the RMB to appreciate at a faster rate towards its equilibrium will lessen expectations of RMB appreciation, thus relaxing pressure on the Chinese authorities due to the rapid increase in foreign exchange reserves.

References

Akinlo, A.E, and A.F. Odusola. "Assessing the Impact of Nigeria's Naira Depreciation on Output and Inflation," *Applied Economics* 35 (2003): 691-703.

Berument, H. and M. Pasaogullari. "Effects of the Real Exchange Rate on Output and Inflation: Evidence from Turkey," *The Developing Economies* 41(2003): 401–35.

Branson W.H. "Stabilization, Stagflation, and Investment Incentives: The Case of Kenya, 1979-1980." In *Economic Adjustment and Exchange Rates in Developing Countries*, S. Edwards and L. Ahamed (eds.). Chicago, IL: Chicago University Press (1986).

Bruno, M. "Stabilization and Stagflation in a Semi-Industrialized Economy." In *International Economic Policy: Theory and Evidence*, R. Dornbusch and J.A. Frankel (eds.). Baltimore, MA: John Hopkins University Press (1979).

Caves, R.E., J.A. Frankel, and R.W. Jones. *World Trade and Payments: An Introduction*. Reading, MA: Addison-Wesley (2002).

Cochrane, J. H. *Time Series for Macroeconomics and Finance*, Manuscript, University of Chicago (2005).

Cooper, R. N. "Currency Devaluation in Developing Countries." In *Government and Economic Development*, G. Ranis (ed.). New Haven, CT: Yale University Press (1971).

Coudert, V. and C. Couharde. "Real Equilibrium Exchange Rate in China," CEPII Working Paper No. 2005 – 01. Paris: CEPII (2005).

Diaz-Alejandro, C. F. "A Note on the Impact of Devaluation and the Redistributive Effects," *Journal of Political Economy* 71(1963): 577–580.

Edwards, S. "Are Devaluations Contractionary?" *The Review of Economics and Statistics* 68 (1986): 501-508.

Frankel, J. A. "On the Yuan: The Choice between Adjustment under a Fixed Exchange Rate and Adjustment under a Flexible Rate," IMF Seminar Paper. Dalian, China (May 26–27, 2004).

Frankel, J. A. "Mundell-Fleming Lecture : Contractionary Currency Crashes in Developing Countries," *IMF Staff Papers* 52 (2005): 149-192.

Goldstein, M. 2004. "Adjusting China's Exchange Rate Policies," IMF Seminar Paper. Dalian, China (May 26-27, 2004).

Gylfason, T. and M. Radetzki. "Does Devaluation Make Sense in the Least Developed Countries?" *Economic Development and Cultural Change* 40 (1991): 1–25.

Hirschman, A. O. "Devaluation and the Trade Balance : A Note," *The Review of Economics and Statistics* 31 (1949): 50-53.

Hoffmaister, A. W. and C. A. Vegh. "Disinflation and the Recession-Now-Versus- Recession-Later Hypothesis: Evidence from Uruguay," *IMF Staff Papers* 43 (1996): 355-394.

Johansen, S. *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*. Oxford: Oxford University Press (1995).

Kamin, S. B. and J. H. Rogers. "Output and the Real Exchange Rate in Developing Countries: An Application to Mexico," *Journal of Development Economics* 61 (2000): 85–109.

Krugman, P. and L. Taylor. "Contractionary Effects of Devaluation", *Journal of International Economics* 8 (1978): 445–456.

Lizondo, J.S. and P. J. Montiel. "Contractionary Devaluation in Developing Countries: An Analytical Overview," *IMF Staff Papers* 36 (1989): 182–227.

Moreno, R. 1999. "Depreciations and Recessions in East Asia,"*Federal Reserve Bank of San Francisco Economic Review* 3(1999): 27–40.

Obstfeld, M. and K. Rogoff. "Exchange Rate Dynamics Redux," *Journal of Political Economy*, 103 (1995): 624-660.

Shi, J. "Adjustment of Global Imbalances and Its Impact on China's Economy," *China and World Economy* 14 (2006): 71-85.

Shi, J. and H. Yu. "Renminbi Equilibrium Exchange Rate and China's Exchange Rate Misalignment: 1991-2004," *Economic Research Journal* 40 (2005): 34-45.

Sims, C. "Macroeconomics and Reality," *Econometrica* 48 (1980): 1–48.

Sims, C., J. Stock, and M. Watson. "Inference in Linear Time Series Models with Some Unit Roots," *Econometrica* 58 (1990): 113–44.

Van Wijnbergen S. V. 1986. "Exchange Rate Management and Stabilization Policies in Developing Countries," *Journal of Development Economics* 23 (1986): 227-247.