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Are Currency Revaluations Contractionary in China？*

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Abstract: Chinese economy has been in a state of external imbalance and internal imbalance for some years, which certainly has something to do with the undervaluation of renminbi (RMB). But Chinese Government hesitates to revalue RMB because of the worry that RMB revaluations are contractionary thus have negative impact on China's economic growth and employment. The purpose of this paper is to empirically assess the effects of RMB real exchange rate on China's output. The econometric work of the paper shows that even after sources of spurious correlation and reverse causation are controlled for, RMB revaluation has led to a decline in China’s output, suggesting that RMB revaluations *do* be contractionary. The paper gives some possible explanations to this finding, and points out that the finding does not consequentially imply that China should continue maintaining the undervaluation of RMB.

Key words: renminbi, exchange rate misalignment, contractionary devaluation, VAR model

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1. Introduction

In recent years, the renminbi (RMB) exchange rate and China's exchange rate policy have received the extensive concern of the international community. Has RMB been undervalued? If so, by how much it is undervalued? Should RMB be revaluated? These questions have all caused the hot debate at home and abroad. Though there are no unanimous conclusion on by how much RMB is undervalued, it is more unanimous view of researchers that RMB *is* undervalued. For example, Goldstein (2004) estimates that RMB has been 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 RMB was undervalued by 35% in 2000, and judges that it is undervalued at least that much at present; Shi and Yu (2005) use a behavior equilibrium exchange rate (BEER) model to draw that RMB was undervalued by about 12% on average during 2002-2004; Coudert and Couharde (2005) use a FEER model to estimate that RMB exchange rate was undervalued by 23% in 2003.

No matter being undervalued or overvalued, exchange rate misalignment certainly results in a distortion of the economy that exerts a negative impact on economic structure and macroeconomic performance of the economy. For example, in recent years, Chinese economy has been in a state of obvious external imbalance and internal imbalance[1] which certainly has something to do with the undervaluation of RMB. According to the Swan Diagram, a classic framework for analyzing the macroeconomic policy of an open economy, RMB revaluation is a direct and effective method to resolve the imbalances of Chinese economy (Shi, 2006), but Chinese Government seems hesitate to let RMB appreciate[2], would rather adopts other measures such as adjusting the rate of tax return of export, relaxing the capital control, and adjusting the interest rate or deposit reserve ratio, etc. to deal with external and internal imbalances of the economy.

Why then, even under the situation that there is obviously an undervaluation of RMB and Chinese economy suffers from external and internal imbalances, Chinese Government still resists RMB revaluation? According to traditional macroeconomics textbook model, revaluations are contractionary: at least in the short run revaluations will raise the price of the domestic goods relative to the price of the foreign goods (namely the real exchange rate appreciation), cause the export to drop and the substitution of the home produced goods with the imported goods, and thus reduce the

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[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 the overheating of the economy and the pressure of inflation.

[2] Under the new exchange rate regime, if the monetary authority reduces the intensity of exchange market intervention, or widens the band of RMB exchange rate floating, the market will promote RMB to appreciate progressively because of the steady expectation of RMB appreciation. In this paper, we do not distinguish “appreciation” from “revaluation”.

aggregate demand[3]. So, the hesitation of Chinese Government is consistent with the view of traditional macroeconomic theory. Though Chinese Government has announced that China does not pursue too big trade surplus, indicates that Chinese policy makers would like to reduce the surplus through various kinds of means, Chinese Government certainly worries about that RMB revaluations are contractionary as what traditional macroeconomic theory says, thus have a negative impact on China's economic growth and employment, even make Chinese economy fall into a long time recession as what had happened in Japan during the 1990s. This is the main reason why Chinese Government is unwilling to allow RMB to appreciate. Under the situation that there is a high rate of unemployment caused by the economic reform and economy transition into the market economy, keeping the high rate of economic growth and maintaining employment are obviously the higher than all goals of Chinese Government.

Must revaluations be contractionary and devaluations be expansionary? For a long time, for example, at least since Hirschman (1949), the economists have realized that revaluations are not consequentially contractionary, nor are devaluations consequentially expansionary. Marked by Krugman and Taylor (1978), there appears a so-called “contractionary devaluations” literature[4]. On the demand side, the literature emphasizes the expenditure-changing effects of exchange rate change ignored by the traditional macroeconomic theory and provides a series of mechanisms and channels that devaluation can cause outputs 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, the cost of wages and firm's working capital[5]. After the 1994 Mexico currency crisis and 1997-98 East Asian financial crisis, the “contractionary devaluations” literature obtains renewed attention of economists (Kamin and Rogers , 2000), and has got new development. The new development emphasizes the importance of the balance sheet effects in explaining the economic recession caused by the devaluation in the financial crisis (Frankel, 2005).

According to the “contractionary devaluations” literature, currency revaluations are very likely to have an expansionary rather than a contractionary impact on the economy in developing countries. For instance, currency revaluation has the real cash balance effect and the real wealth effect: it lowers the domestic price level, therefore leading to real cash balance and real wealth increase, which tends to expand personal spending (Bruno, 1979, Gylfason and Radetzki, 1991). Currency revaluation also has an income reallocation effect (Diaz-Alejandro, 1963, Cooper, 1971, Krugman and

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[3] This is the expenditure-switching effect of exchange rate change.

[4] This literature is mainly about the exchange rate policy of developing countries. Devaluations are usually included in stabilization program of developing countries and balance of payment problems in developing countries generally are devaluation pressure. Therefore, the “contractionary devaluations” literature mainly investigates the situation of devaluation. However, many channels of the contractionary devaluations are equally suitable to the situation of revaluation.

[5] See Lizondo and Montiel (1989) for a survey of “contractionary devaluations” literature. Caves, Frankel and Jones (2002) provide a simple introduction of 10 kinds of “contractionary devaluations” effects.

Taylor, 1978): it tends to transfer real income from groups with high marginal propensity to saving toward groups with low marginal propensity to saving, causing total domestic expenditure to expand. This is because that revaluation raises the real wage through reducing the price level, causing the real income to shift from entrepreneur to the laborer, and laborer has higher marginal propensity to consume than that of entrepreneur. This income reallocation effect is remarkable in developing countries, because the laborers in developing countries usually have limited wealth and are subject to strong liquidity constraint, so their marginal propensities to consume are nearly equal to 1. Moreover, in developing countries, new equipment investment usually includes a large amount of imported capital goods, currency revaluation will lower domestic prices of those goods, which will help to expand investment expenditure and, therefore, total expenditure (Branson, 1986, van Wijnbergen, 1986)[6]. 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) and the lowering of marginal costs relative to the prices of final goods will lead to increased output and employment (Bruno, 1979, van Wijnbergen, 1986). 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 existed supply side effect might still makes the revaluation to be expansionary.

Regarding to the empirical literature, the majority research on the relationship between real exchange rate and output in developing countries has demonstrated that real devaluations were contractionary while revaluations were expansionary, suggesting that the channels the "contractionary devaluations" literature revealed are important in developing countries. For example, in an influential early research, Edwards (1986) uses a reduced form equation model to study a panel data set of 12 developing countries, and find that devaluations were contractionary in the short-term, but turned to be expansionary after one year, and were neutral in the long-term. Gylfason and Radetzki (1991) use 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 mid-term. Kamin and Rogers (2000) use a vector autoregression model (hereafter abbreviated as VAR model) to study the relation between real exchange rate and output in Mexico, and find that real devaluations were contractionary while revaluations were expansionary. Other recent researches, 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, all support the "contractionary devaluations" hypothesis.

What is the relation between RMB real exchange rate and China's output then? Are RMB revaluations contractionary as what textbook says, or expansionary as what the "contractionary devaluations" hypothesis suggests? The purpose of this paper is to study the effects of RMB real exchange rate on China's output by using a VAR model to a sample of 1991q1--2005q3. The rest of the paper is organized as follows: Section

[6] Those are the expenditure-changing effects of exchange rate change.

2 gives a brief historical review of China's exchange rate regime, the evaluations of the RMB real exchange rate and China's output during the past two decades, in order to provide a background for the issues to be discussed; Section 3 describes the model to be employed and the data to be used, and discusses the time series characteristics of the variables; Section 4 takes an econometric analyses of the VAR models through impulse-response function graphs and variance decompositions of forecast errors; Finally, section 5 summarizes the conclusions drawn from this research, and discusses several policy implications of the research.

2. An Brief History of RMB Exchange Rate Evaluation and China's Output Fluctuation: 1991—2005

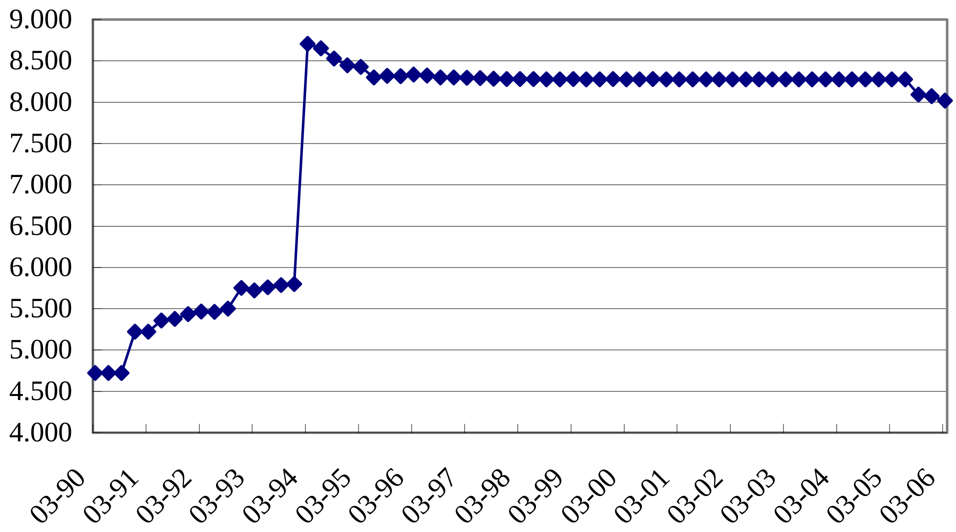
In the early stage of 1990s, what China implemented was a double exchange rate system: Official fixed exchange rate coexisted with a market exchange rate formed in the swap foreign exchange market. By 1992, up to 80% of the foreign exchange transactions were conducted at the swap foreign exchange market and the market exchange rate essentially had reflected the demand for and the supply of the foreign exchange. Because the swap market exchange rate was higher than official exchange rate implying a subsidy to exporter, the double exchange rate system caused the unfair competition and resource distortion, and was unfavorable to attract the foreign direct investments[7]. Against these negative effects, the official exchange rate of RMB was increasing (devaluing) constantly, from 4.7 yuan per U.S. dollar in 1990, devalued to 5.4 yuan per dollar in 1992, until 5.8 yuan per dollar by the end of 1993. In January 1, 1994, China reformed its double exchange rate system by unifying the two exchange rates and established a singe and managed floating exchange rate system based on market supply and demand. Afterwards, the nominal rate of RMB had gone through disconnected small pieces of appreciation, this course went on until 1997 when the financial crisis of East Asia was outburst.

Under the situation that the external demand dropped and the currencies of China's principal trade partners devalued against U.S. dollar by a wide margin (except Hong Kong), the market participators generally had anticipated that RMB would follow those currencies to devaluate. In order to stabilize the regional exchange rates and prevent the currencies from competitive devaluation, Chinese Government announced against the 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 of 2005. On July 21, 2005, however, China instituted a reform of its exchange rate regime by revaluing the RMB by 2.1 percent and terminating its peg to the U.S. dollar

[7] Under this kind of system, the foreign investment must be converted into RMB according to the official exchange rate first, when the foreign investors need foreign exchanges, however, they can only obtain them through the foreign exchange swap market, at the market exchange rate.

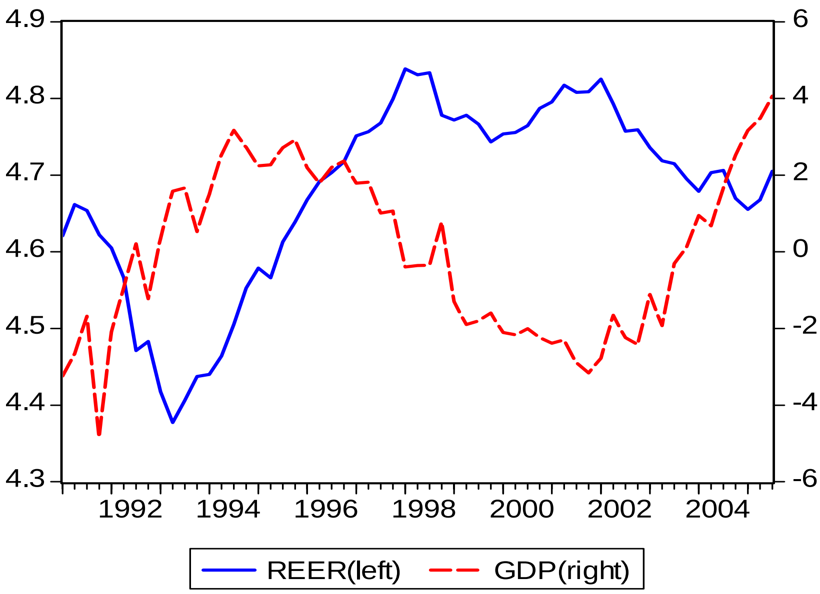
in favor of a managed float based on a basket of currencies. Under the new exchange rate regime, the daily fluctuation of RMB exchange rate is restricted within 0.3 percent on both side, and the RMB exchange rate has not moved very much because of the market intervention conducted by The People's Bank of China (PBOC). Figure 1 portrays the track of RMB nominal exchange rate against the U.S. dollar during the past two decades.

Figure 1.RMB Exchange Rate (Yuan/US Dollar)



Contrast to the relative stableness of bilateral nominal rate of RMB, the effective real exchange rate (hereafter referred to as the real exchange rate) of RMB presented a large fluctuation in the past periods in more than 20 years. As can be seen from Figure 2, the real exchange rate of RMB had gone through six different stages over the past more than 20 years. (1) 1991q1 --1993q2: The real exchange rate of RMB experienced a large amount of depreciation, this is mainly because that the nominal rate of RMB had presented a large devaluation; (2) 1993q3 --1998q1: The real exchange rate of RMB experienced a large amount of appreciation which is mainly because of higher inflation in China during the period and a small extent appreciation of RMB nominal rate. After the financial crisis of East Asia, the appreciation of RMB real exchange rate is mainly due to the sharp devaluations of the currencies of China’s trade partners; (3) 1998q2 --1999q4: The real exchange rate of RMB experienced a certain degree of depreciation, this is mainly because that there appeared a deflation in China; (4) 2000q1 --2002q1: A certain degree of appreciation of RMB real exchange rate appeared in this period, this is mainly the reflection of the mild inflation in China and a deflation in the trade partners in this period. The real exchange rate of RMB of 2002q1 rebounded to the level of 1997q4; (5) 2002q2 --2005q1: The real exchange rate of RMB turned to the course of large depreciation, this is mainly influenced by the fact that U.S. dollar depreciated largely against Euro, Japanese yen, and other key currencies; (6) 2005q2 and q3: Subject to the influence of appreciation of U.S. dollar against Euro and Japanese yen, the RMB real exchange rate turned to appreciation state again.

Figure 2. RMB Real Exchange Rate and Real GDP



Similar with the fluctuation of real exchange rate of RMB, China's real output also experienced a large fluctuation over the past more than 20 years. Concerning the correlation of the two variables, as Figure 2 shows[8], during the whole sample period (1991q1-2005q3), the relationship between the RMB real exchange rate and output is not very clear, but since 2000q1, the two have presented an obvious negative correlation, namely, appreciations of the real exchange rate have been associated with falls of the outputs, while real depreciations have been followed by expansions of the output. The relation of real exchange rate and output accords with the forecast of the traditional open economy macroeconomics: RMB appreciations are contractionary, while RMB depreciations are expansionary.

However, for the shown correlation between the RMB real rate and China's output in Figure 2, two issues are still need to be clarified: (1) May the tight relevance between the RMB real rate and China's output be spurious? i.e., is that just reflecting the response of both variables to the third external variable and as a matter of fact the two variables have nothing to do with each other? (2) If real exchange rate and output are really relevant, what then is the causality between them? In other words, does the change of the real exchange rate of RMB cause the change of output, or, oppositely, does the change of the output cause the change of the real exchange rate of RMB? In order to draw the answers to above-mentioned questions, we employ pairwise Granger causality test to examine the direction of causality between the RMB real rate and China's output more precisely. The Granger causality tests will

[8] See section 3 for the definition and data explanation of the indices.

indicate whether a set of lagged variables has explanatory power on the other variables. If the computed F-statistics are significant, we can safely claim in Granger's sense that one variable does Granger cause the other variable.

Table 1 reports the results of the Granger causality test. The result of test on the whole sample (1991q1-2005q3) shows that, with 95% level of confidence, the sample data rejects the null hypothesis, indicates that China's output Granger causes the RMB real rate and the RMB real rate Granger causes the output as well. Because there is a difference on the relationship of RMB real rate and China's output before and after 2000q1, we divide the whole sample into two sub-samples (1991q1-1999q4 and 2000q1-2005q3) and conduct Granger causality test on two sub-samples separately. The results turn out to be surprise: for the first sub-sample, the data rejects the null hypothesis with 99% even higher level of confidence, suggesting the output Granger causes the real exchange rate and the real exchange rate Granger causes the outputs as well; while for the second sub-sample, upon which there seems a strong correlation between the output and real exchange rate, the date instead can not reject the null hypothesis, showing a strange result that the output does not Granger cause the real exchange rate and the real exchange rate does not Granger cause the outputs either. That means no variable is helpful in explaining the movement of the other. One explanation to this looked strange result may be that there are other variables influencing both RMB real rate and China's output at the same times that has limited the usefulness of the pairwise 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	2.65320	0.04484
REER does not Granger Cause GDP		2.85038	0.03419
Subsample: 1991Q1--1999Q4			
Null Hypothesis:	Obs	F-Statistic	Probability
GDP does not Granger Cause REER	32	3.69158	0.01833
REER does not Granger Cause GDP		9.37632	0.00012
Subsample: 2000Q1--2005Q3			
Null Hypothesis:	Obs	F-Statistic	Probability
GDP does not Granger Cause REER	23	0.85897	0.51199
REER does not Granger Cause GDP		0.51980	0.72273

So, in order to investigate the relation between RMB real exchange rate and China's output further, we employ a VAR model to control the influence of variables which may have impacts on both RMB real rate and China's output, therefore to answer above-mentioned questions. The estimated VAR models also let us carry on studies on other interested issues.

3．Model and Data

3.1. The Models

We use VAR model to study the relation between the real exchange rate of RMB and China's output. We try to find out whether the correlation indicated by Figure 2 is spurious or not, and what is the direction of causality between the real exchange rate and output in China. Restricted by the size of the sample, we can't include all interested variables within one VAR model[9], so we adopt the modeling strategy of Kamin and Rogers (2000) as follows: we estimate a basic model at first, and then, expand the basic model through entering another external variable to the basic model each time. The basic model includes China's gross domestic product (GDP), RMB real exchange rate (REER), China's inflation rate (INFL) and foreign gross domestic product (GDPW). In the basic model, we adopt the following orders similar to Kamin and Rogers (2000): GDPW, REER, INFL, and GDP[10].

Being different from Kamin and Rogers (2000), we choose GDPW instead of US interest rate as the delegate of the international factor. This is based on the following consideration: China still implements the capital controls, therefore, the relation between US interest rate and that of China is not very close; on the other hand, after fulfilled the RMB convertible for current account transactions and formally joined the World Trade Organization, the openness of China's real economy is increasing constantly, the ratio of foreign trade to GDP in China has reached a high level of 70% at present. In this situation, the business cycles of the trading partners have important influence on the business cycle of China through the channel of import and export: the change of trading partner's output exerts an influence on the current account of China through the channel of import and export, and then cause the change of the real exchange rate of RMB, which influences the adjustment of the price level, causing China's output to change.

The basic model is too frugal to allow us to investigate more comprehensive influence of the variables that influence both the real exchange rate and the output, it may not be very efficient to study the spurious relevant problem, so we enter one endogenous variable each time into the basic model, and estimate 3 more VAR models in addition. That let us see whether our final results are robust or not, at the same time let us control the size of the VAR model within the appropriate level according to the sample. The models can be expressed in the forms of unrestricted VAR model as follows:

$$\boldsymbol{Y}_t^l = \sum_{i=1}^{k_l} \boldsymbol{A}_i^l \boldsymbol{Y}_{t-i}^l + \varepsilon_t^l, \quad \varepsilon_t^l \sim \boldsymbol{IID}\left[\boldsymbol{o}^l, \Omega^l\right] \qquad \boldsymbol{l} = \overline{1,4}$$

[9] Because a VAR model involves quite a lot of parameters to be estimated, introducing too many endogenous variables will cause serious loss of the degrees of freedom, influence the statistic dependability of the results.

[10] Through trial, we find that the specific variable orders do not have remarkable influence on the result of the basic model.

Where,

$$Y_t^1 = (GDPW_t, REER_t, INFL_t, GDP_t)'$$

$$Y_t^2 = (GDPW_t, GOV_t, REER_t, INFL_t, GDP_t)'$$

$$Y_t^3 = (GDPW_t, REER_t, M2_t, INFL_t, GDP_t)'$$

$$Y_t^4 = (RUS_t, GDPW_t, REER_t, INFL_t, GDP_t)'$$

k_l indicates the lags of l-th VAR model， $\boldsymbol{A}_i^l$ are parameter matrices of l-th VAR model to be estimated， ε_t^l is a random residual vector of l-th VAR model， $\boldsymbol{o}^l$ is the zero mean vector of ε_t^l , and Ω^l is a covariance matrix of ε_t^l. The fourth model has included US interest rate so as to investigate the international interdependent between Chinese economy and the world economy and to assess the importance of external shocks on Chinese economy.

3.2. The Data

The data are quarterly one; the sample interval is 1991q1--2005q3. 1991q1 is the earliest time for which the quarterly GDP data is available in China, The GDP data of 2005q4 is collected according to a new statistical method and without comparability with the data in the past, therefore, we exclude it from our sample. Except for inflation rate, variables are the real ones, US real interest rate is obtained by subtracting US inflation rate from the nominal interest rate, and other real variables are drawn from the nominal ones divided by consumer's price index. The base period is 1992.

The GDP data is detrended one, which is calculated as the residuals from a regression of the logarithm of quarterly real GDP on a constant and a quadratic time trend because the regression with a quadratic time trend has higher degree of goodness of fit than one with a linear time trend. REER stands for RMB real exchange rate index with a rise indicating an appreciation. China’s inflation rate, INFL, is obtained by differencing the logarithm of consumer's price index. GOV expresses the expenditure of Chinese Government. M2 is China's broad money supply. The foreign gross domestic product, GDPW, is calculated according to the trade-weighted average of gross domestic product index of 14 principal trade partners of China. RUS indicates US real interest rate of 3 months Treasury bill. Except for INFL and RUS, variables are in the logarithm. GDP, GOV, INFL and GDPW have been seasonally adjusted. REER data and data of other countries or regions come from IMF international finance statistics database. The data of China’s variables except REER come from State Statistics Bureau, the People's Bank of China, China

Ministry of Finance and General customs of China. Taiwan GDP annual data comes from IMF World Economic Outlook Database 2006, which has been translated into quarterly data.

3.3. The Time Series Characteristics of the Data

Because many macroeconomic variables are not stationary, to avoid spurious regressions, we need to test if the time series of relevant variables in our models are stationary or not. If the variables turn out to be nonstationary, we need to know further whether there exist long ran steady relationships among those endogenous variables or not. We take the unit root tests and cointegration tests for those purposes below.

A. Unit Root Tests

We use both the augmented Dickey-Fuller (ADF) test and the Phillips-Perron test for unit root tests. Table 2 reports the results of the unit root tests of all relevant variables in our models. For the level variables, both tests reveal that we cannot reject the presence of unit root, which shows these variables are all non-stationary; on the other hand, Phillips-Perron test rejects the null hypothesis of presence of unit root at the 1 per cent level of significance for the first differences of all variables, while ADF test rejects the null hypothesis of presence of unit root at the 1 per cent level of significance for the first difference of all variables except GDP. ADF test cannot reject the presence of unit root for the first difference time series of GDP. Here, we adopt the result of Phillips-Perron test for GDP, and therefore assert that all variables in our models are the first order integrated variables, namely variables of I (1).

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**
GDPW	-1.01*	-1.00*	-6.98**	-7.00**
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 that the hypothesis that the variable contain unit root can not be rejected at the 10 per cent level of significance.

** denotes the rejection of the hypothesis that the variable contain unit root at the 1 per cent level of significance.

B. Cointegration Tests

Because all variables in our models are variables of I (1), we need to further test if there are cointegration vectors for each model. We implement VAR-based cointegration tests using the methodology developed in Johansen (1995). For that purpose, we need to estimate the unrestricted VAR models first. We take the familiar two-stage approach 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 used to orthogonalize the residuals. According to AIC criterion and SC criterion, the different numbers of lags are tried for each VAR model, and the optimum lags are 4 for all four models. Table 3 reports the results of Johansen cointegration tests based on the estimated unrestricted VAR models. The results indicate that there is at least one cointegration vector for each VAR model.

Table 3 Cointegration Tests for Alternative Specifications

Hypothesized No. of CE(s)	*Eigenvalue*	*λ-Trace Statistics*	*λ-Max Statistics*
	Model 1: Series: GDPW REER INFL GDP		
None	0.552047	78.58229 *	44.16865 *
At most 1	0.408896	34.41363 *	28.91697 *
At most 2	0.079248	5.496661	4.541031
At most 3	0.017225	0.955630	0.955630
	Model 2: Series: GDPW GOV REER INFL GDP		
None	0.691449	131.8465 *	64.67274 *
At most 1	0.435870	67.17373 *	31.48586 *
At most 2	0.363049	35.68787 *	24.80847 *
At most 3	0.171236	10.87941	10.33006
At most 4	0.009938	0.549346	0.549346
	Model 3: Series: GDPW REER M2 INFL GDP		
None	0.719092	133.2365 *	69.83512 *
At most 1	0.512575	63.40134 *	39.52398 *
At most 2	0.300597	23.87735	19.66403
At most 3	0.070371	4.213322	4.013361
At most 4	0.003629	0.199961	0.199961
	Model 4: Series: RUS GDPW REER INFL GDP		
None	0.670747	112.4157 *	61.10101 *
At most 1	0.380508	51.31474 *	26.33704
At most 2	0.274396	24.97769	17.64129
At most 3	0.112526	7.336406	6.565672
At most 4	0.013916	0.770734	0.770734

* denotes rejection of the hypothesis at the 0.05 level of significance.

Note: Lags interval (in first differences): 1 to 3

4． Estimation and Econometric Analysis of the Models

Because all variables in our models are variables of I (1) and there is at least one cointegration vector for each model, it is appropriate for us to estimate the restricted VAR models that restricts the long-run behavior of the endogenous variables to converge to their cointegrating relationships，namely, the vector error correction (VEC) models. Estimation of a VEC model is carried out in two steps. In the first step, we estimate the cointegrating relations from the Johansen procedure as used in the cointegration test. We then construct the error correction terms from the estimated cointegrating relations and estimate a VAR in first differences including the error correction terms as regressors. The VEC models to be estimated have forms as follow:

$$\Delta Y_t^l = \alpha^l ECM_{t-1}^l + \sum_{i=1}^{k_l-1} \Gamma_i^l \Delta Y_{t-i}^l + \varepsilon_t^l \,, \quad \varepsilon_t^l \sim IID\left[o^l, \Omega^l\right] \qquad l = \overline{1,4}$$

where： ECM_{t-1}^l is the error correction term，reflecting the long-run equilibrium relationship between the variables. The coefficient vector α^l reflects how fast the deviation from long-run equilibrium is corrected through a series of partial short-run adjustments. Γ_i^l are parameter matrices of variables in differences, the elements of them reflect the short-term effect of the variables on a dependent variable. The estimated VEC models give variance decompositions and impulse-response functions. Then, the tables of variance decompositions and the graphs of impulse-response functions are used to analyze the relation between RMB real rate and China's output, and other relations that we are interested in.

4.1. The Analysis Based on the Variance Decompositions

Table 4-- Table 7 provide the results of the variance decompositions of GDP, RMB real rate, and inflation in four VEC models respectively. The variance decompositions give the fraction of the forecast error variance for each variable that is attributable to its own shocks and to shocks in the other variables in the system. For example, in Table 4, the figures in the first line (1-quarter forecast horizon) of top panel express that the fractions of the forecast error variance of GDP attributable to shocks in foreign GDP, RMB real rate, inflation, and GDP itself are 4.37%、46.59%、0.79% and 48.25% respectively. In other words, at the 1-quarter forecast horizon, 4.37% of the variance in GDP is attributable to shocks to foreign GDP, so are the explanations of the rest three figures. The following results can be drawn from the variance decompositions:

First, in the source of variation in GDP forecast error, “own shocks” is the first most important source at the 1-quarter forecast horizon, which accounts for about 50% of the forecast error variance in the models, while RMB real rate shock is the second most important source of variation in GDP at the 1-quarter forecast horizon, which accounts for 34%-47%. Beginning from the third quarter, however, the RMB real rate shocks become the first most important source of variation in GDP in all models except for model 2, which accounts for 37%-66% of the GDP error variance; In the medium and long-term horizon (two year after), the predominant source of variation in GDP forecast errors are the RMB real rate, while the contribution of the “own shocks” can be neglected. No matter what time horizon it is, the inflation innovations have no power in explaining the GDP forecast error variance, but the shocks of other variables such as government expenditure, money supply, foreign GDP and U.S. interest rate do have relatively large power in explaining the error variance of GDP, indicating that there can be a spurious correlation if one studies the correlation between RMB real rate and China’s output directly, without controlling the source of these variables.

Second, in the source of variation in RMB real rate forecast error, “own shocks” account for 94%-100% of the forecast error variance at the 1-quarter forecast horizon. In the medium and long-term horizon (two year after), the “own shocks” is still the predominant source of variation in RMB real rate forecast errors in all models except for model 2. What merits attention is that, no matter what time horizon it is, the innovations of both GDP and inflation have little power in explaining the RMB real rate forecast error variance. However, the shocks of other variables such as government expenditure, money supply, foreign GDP and U.S. interest rate do make certain contribution to the error variance of RMB real exchange rate in the medium and long-term horizons.

Third, in the source of variation in inflation forecast error, “own shocks” is the predominant source of variation in forecast errors at the short-term (in one year) horizon, which accounts for 60%-80% of the forecast error variance in all models except for model 3 which includes money supply. In the medium and long-term horizon (two year after), however, the RMB real rate shocks become the first most important source of variation in inflation in model1 and model 4 and the second most important source in model2 and model 3, while the foreign GDP shocks in turn become the first most important source of variation in inflation in model2 and model 3. Besides, the shocks of government expenditure, money supply, and U.S. interest rate also have relatively large power in explaining the error variance of inflation. It is worth notice that no matter what time horizon it is, the GDP innovations hardly have power to explain the inflation forecast error variance.

In conclusion, the results drawn from the analysis of the variance decompositions suggest that (1) at all time horizons, the shocks to the real exchange rate of RMB have remarkable effect on the variation in China’s GDP, which is true for all models, suggesting the possibility of the spurious correlation between the RMB real rate and China’s output can be excluded; that (2) at all time horizons, the shocks to GDP have little effect on the variations in both RMB real rate and inflation, which is true for all models, suggesting the possibilities of reverse causation running from the GDP to the RMB real rate and running from the GDP to the inflation can be excluded; and that (3) shocks to foreign GDP and US interest rate all have remarkable effects on the variation in GDP, and the magnitudes of them are no less than those of internal shocks (to government expenditure and money supply), which reflect the structure characteristic of China's outward-looked economy.

4.2. The Analysis Based on the Impulse-Response Functions

The variance decompositions allow us to appraise the relative importance of contribution of different shocks to the variance of a particular variable; on the other hand, the impulse-response function provides a useful tool to assess the direction as well as the magnitude of response of a variable to various kinds of shocks. Because the graphs of impulse-response functions of VEC model given by the Eviews software which we use are that of level variables, and the level variables in our models are nonstationary ones, the analysis based on the impulse-response functions of VEC models is meaningless. Therefore, we estimate the unrestricted VAR models in first differences and conduct the econometric analysis based on the impulse-response graphs of those models. Figure 3-- Figure 6 provide the graphs of impulse-response functions of four VAR models respectively. Model 1 contains 4 variables, thus there should be 16 impulse-response function graphs, other three models all contain 5 variables, and thus there should be 25 impulse-response function graphs for each of the three models. In each Figure, the responses of a particular variable to a one-time shock in each of the variables in the system are displayed. As page space is limited, we have only reported part of the graphs which are interested to us. From the analysis of those impulse-response function graphs, the following results can be drawn:

First, when one standard deviation positive (appreciation) shock to RMB real rate takes place, there is an obvious decline of contemporaneous GDP. In mid term (2 to 3 years), the contractionary impact is weakened to some extent but still obviously exists. After 12 quarters, the impacts of RMB real rate shock on output turn to be neutral. This contractionary effect of RMB appreciation occurs in all models estimated, suggesting the robustness of the result. This result is in contrast with that of, say, Edwards (1986) and Kamin and Rogers (2000). In Edwards (1986), for 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 (2000), for Mexico, devaluations (revaluations) were contractionary (expansionary) in short term as well as in mid term. However, in China, as the result here indicates, devaluations (revaluations) are expansionary (contractionary) in both short term and mid term.

Second, one standard deviation shock to GDP has no impact on contemporaneous RMB real exchange rate, but in mid term, the shock causes the real rate of RMB to present certain fluctuation. This effect of output shock occurs in all models estimated, suggesting the robustness of the result. Because the measure of the impulse-response graphs of RMB real rate to other variable shock is only about 1/10 relative to the measure of those of GDP, we can think that the magnitude of impact of output shocks on RMB real rate are much less than the magnitude of impact of RMB real rate shocks on the output.

Third, one standard deviation shock to RMB real rate has no obvious impact on foreign GDP, nor does one standard deviation shock to GDP. However, one standard deviation shock to foreign GDP has a remarkable impact on China's GDP, so does one standard deviation shock to US interest rate. After one standard deviation positive shock to foreign GDP takes place, China's GDP rises remarkably, in model 4 which includes US interest rate, the impact of foreign GDP shock on China's GDP is even greater than that of real exchange rate of RMB; after one standard deviation shock to US interest rate takes place (in model 4), China's GDP drops remarkably, the magnitude of the effect of US interest rate is equal to that of real exchange rate of RMB.

Fourth, According to Figure 5, one standard deviation positive shock to money supply has little impact on GDP, but does cause the RMB real rate to depreciate in short term and mid term. According to Figure 4, one standard deviation positive shock to government expenditure has a little impact on GDP, but the magnitude of the effect is less than that of other variables, such as, RMB real rate, foreign GDP and US interest rate. One standard deviation shock to government expenditure has obvious impact on RMB real rate, causes the RMB real rate to depreciate in short and mid terms.

In conclusion, the results drawn from the analysis of impulse-response functions suggest that the RMB real appreciation shock has remarkably contractionary impact on output. After controlling the influence of other variables, the RMB real appreciation shock still causes GDP to decline remarkably, which excludes the spurious correlation between the real exchange rate and output. The results seem also support the guess that the direction of the causality between the RMB real rate and China's output run from the former to the latter. Finally, the external shocks have remarkable effects on China's output and the magnitudes of the effects are greater than those of internal shocks such as government expenditure and money supply. One possible explanation to this is as follows: China has pursued an export-oriented development strategy since 1978, which has made the export a major contributor of the growth of China's output. For example, the contribution of exports to GDP growth has reached a high level of 80% in the first three quarters of 2005. At the same time, domestic demand, especially consumption demand, has developed lags behind due to institutional and policy reasons, such as incomplete social security facility and undervalued exchange rate. As the result, Chinese economy is overly relying on the external demand.

5. Conclusion and Policy Implication

This paper has investigated the relationship between the RMB real exchange rate and China's output by using the VAR model technique. The econometric work of the paper shows that even after sources of spurious correlation and reverse causation are controlled for, RMB real revaluation has led to a decline in China's output, suggesting that currency revaluations are contractionary in China, as the traditional open economy macroeconomics forecasts. The possible explanations of this conclusion are as follows:

First, in the existing research on "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 case of currency or financial crisis till now; Secondly, the urban economic reform begun at the early 1990s makes many people lose their jobs and traditional benefits on medicare, pension and education, etc. which strengthens the motive of precautionary saving of household in urban and township areas. Under that situation, the income reallocation effect as well as the real cash balance and the real wealth effects of currency appreciation will not play a very great role.

Third, China has absorbed a large amount of foreign direct investment for many years. As the result, the technological progress and production capacity of China's manufacturing industry have been promoted rapidly, the substitutability of home produced capital goods to imported goods has been strengthened, therefore, the effect of RMB exchange rate on domestic investment expenditure is not clear; Fourth, one condition that 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 the favorable surplus for over 20 years in the past except for 1993, therefore does not satisfy that condition;

Finally, Because of the characteristics of processing trade in China's manufacturing industry, and administrative controls on prices (especially on those of service sector), the supply side effect of RMB exchange rate on output is also uncertain. In a word, it seems that the expenditure-changing effect and supply side effect of RMB exchange rate are not remarkable in practice, therefore, the effects of RMB exchange rate on China's output are mainly embodied through the expenditure-switching effect as traditional macroeconomic theory emphasized, in that situation, the revaluations of RMB are likely contractionary.

What policy implications can we draw from the conclusion that currency revaluations are contractionary in China? First of all, the conclusion that revaluations are contractionary in China does not mean that China should continue maintaining RMB exchange rate undervalued. Because the undervalued RMB has already caused Chinese economy to run into internal and external imbalances in the past several years. Figure 2 tells us, China's real GDP has been running above its long-term trend since 2003, and this kind of deviation is expanding. Indeed, the situation of the overheating of Chinese economy is obvious. Trade surplus and foreign exchange reserve are increasing rapidly, which results in excess money supply and the inflation pressure, causing the operation of the monetary policy of the PBOC to be more and more difficult. It is no doubt that continuing the undervaluation of RMB exchange rate will further aggravate the imbalances of Chinese economy.

Secondly, the conclusion that revaluations are contractionary in China implies that relative to other effects of exchange rate change, the expenditure-switching effect is predominant in China; therefore it is effectual to use the orthodox Swan Diagram to analyze macroeconomic policy issues in China[11]. According to the Swan Diagram, allowing RMB to appreciate is helpful for Chinese economy to realize internal and external balances (Shi, 2006). Along with the revaluation of RMB, the public expenditure should be expanded, if necessary, to maintain the certain rate of growth and employment. However, the public expenditure should be spent on the service sector such as health and medicine, education, environment, public service facilities and social security etc. which not only have a direct impact on expanding total demand but also make it favorable for stimulating consumption by the household. The public expenditure spent on the service sector will not increase new export capacity, and thus is not in conflict with the external balance purpose.

Third, There exists a structural weakness of Chinese economy (overly dependent on external demand, and insufficient development in domestic-market oriented industries, such as service industries), which makes Chinese economy easy to be influenced by the external shocks. An undervalued RMB subsidizes export sectors but represses domestic-market oriented sector that will further aggravate the structural weakness of Chinese economy. The RMB revaluation aiming at eliminating the misalignment of RMB exchange rate will provide the domestic market oriented industry with market incentives because of the rising prices of non-tradable goods relative to tradable goods. This adjustment (plus increased public spending on the service sector) will channel more resources into the domestic-oriented industry, making it favorable for China to realize the adjustment of the industrial structure and the change toward a consumption-led economic growth model. Therefore, even if the fiscal tool in China is restricted for some reasons, thus can not stabilize fully the aggregate demand, Chinese Government still needs to balance the short-term costs and long-term benefits of the RMB revaluation.

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[11] If revaluations (devaluations) are expansionary (contractionary), the Swan Diagram is less insightful about the combination of policy instruments to fulfill simultaneously both internal and external balance. Because it is difficult in this case to decide where and how the internal and external balance schedules intercross. See, for example, Frankel (2005).

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Figure 3 Impulse Responses from Model 1

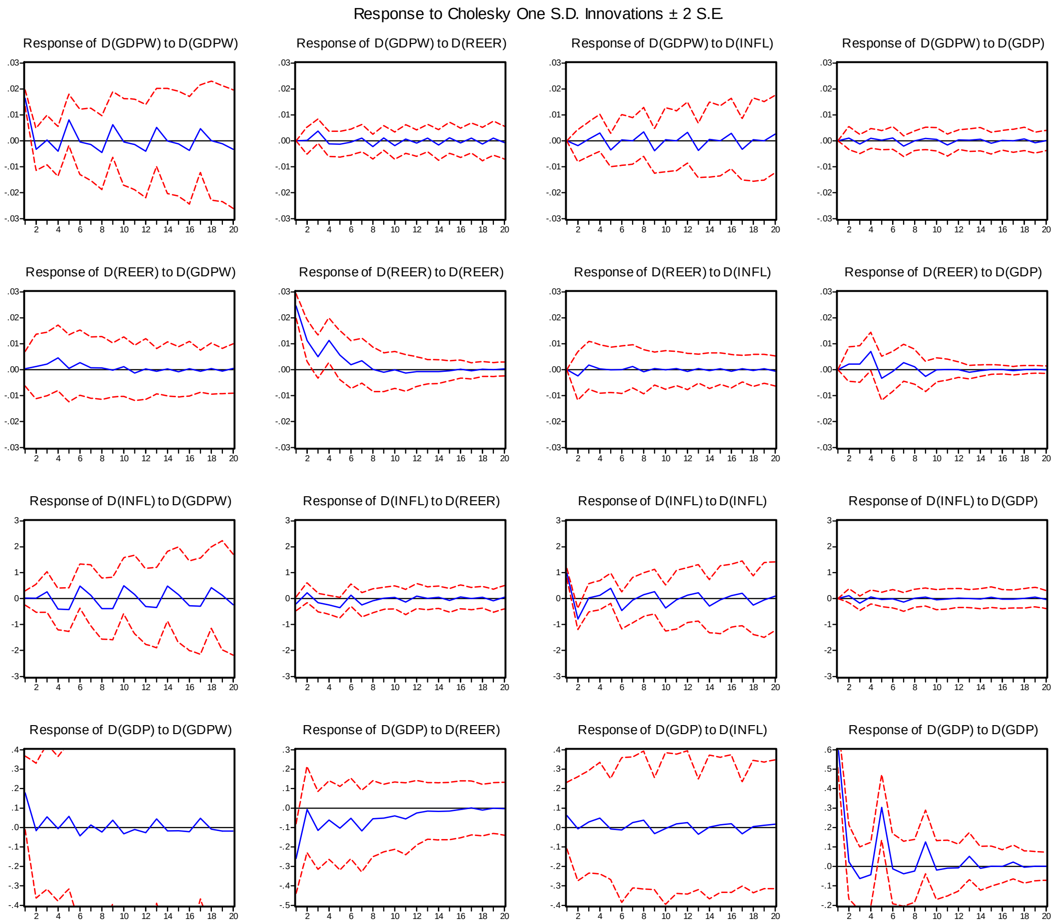

Figure 4 Impulse Responses from Model 2

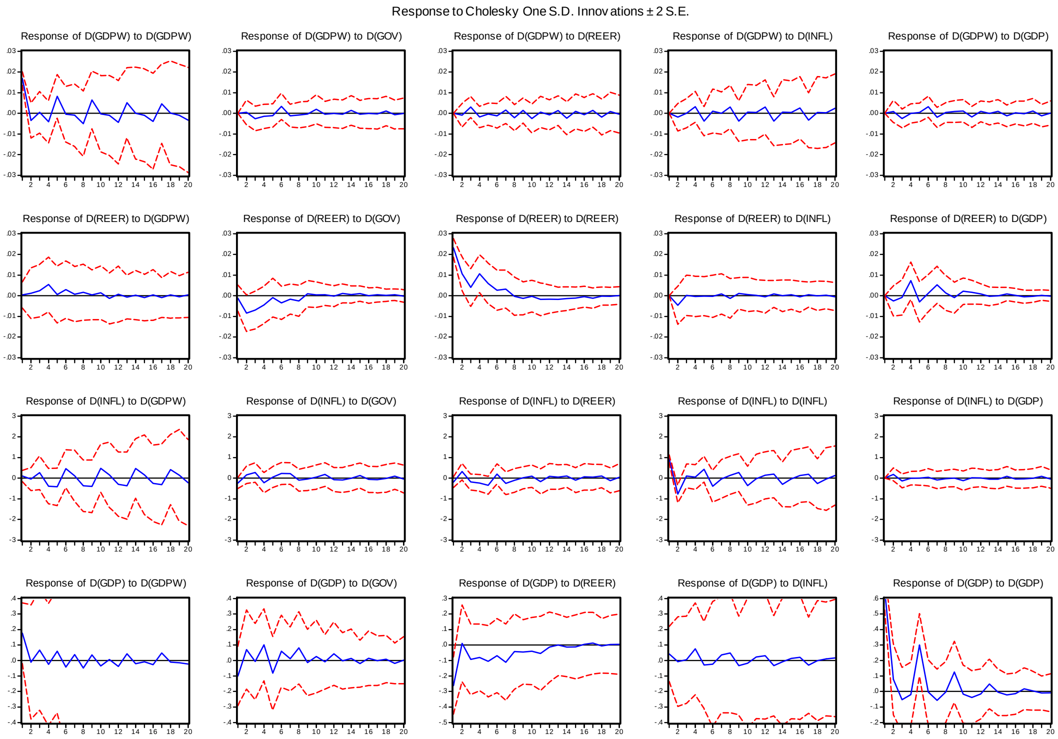

Figure 5 Impulse Responses from Model 3

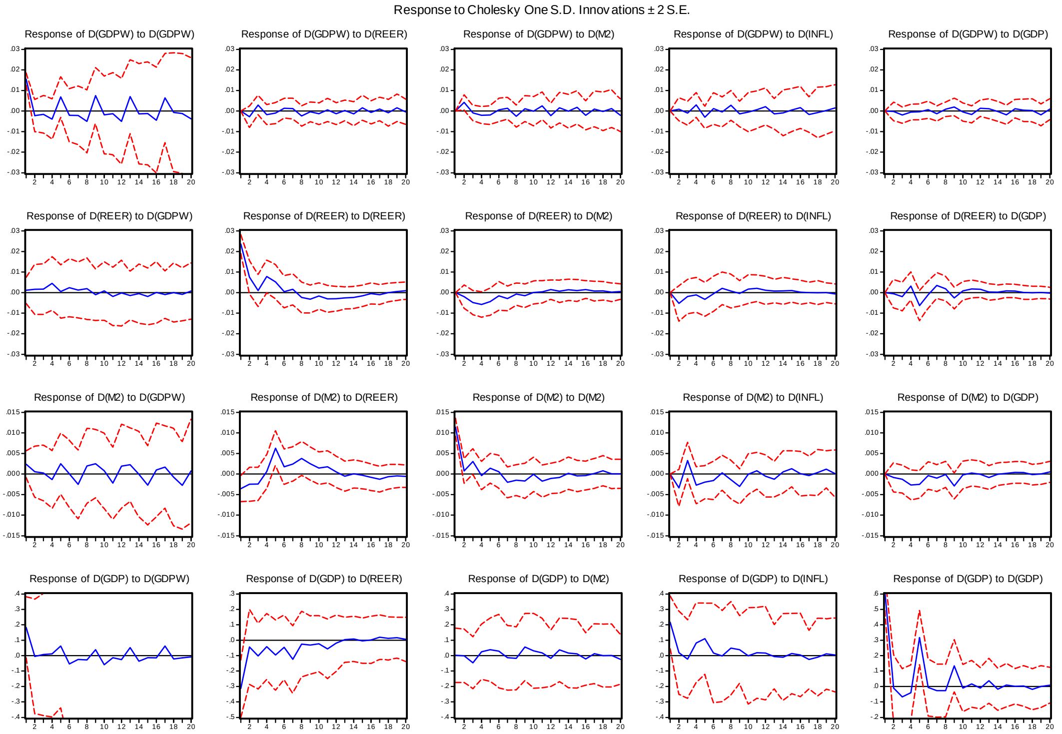

Figure 6 Impulse Responses from Model 4

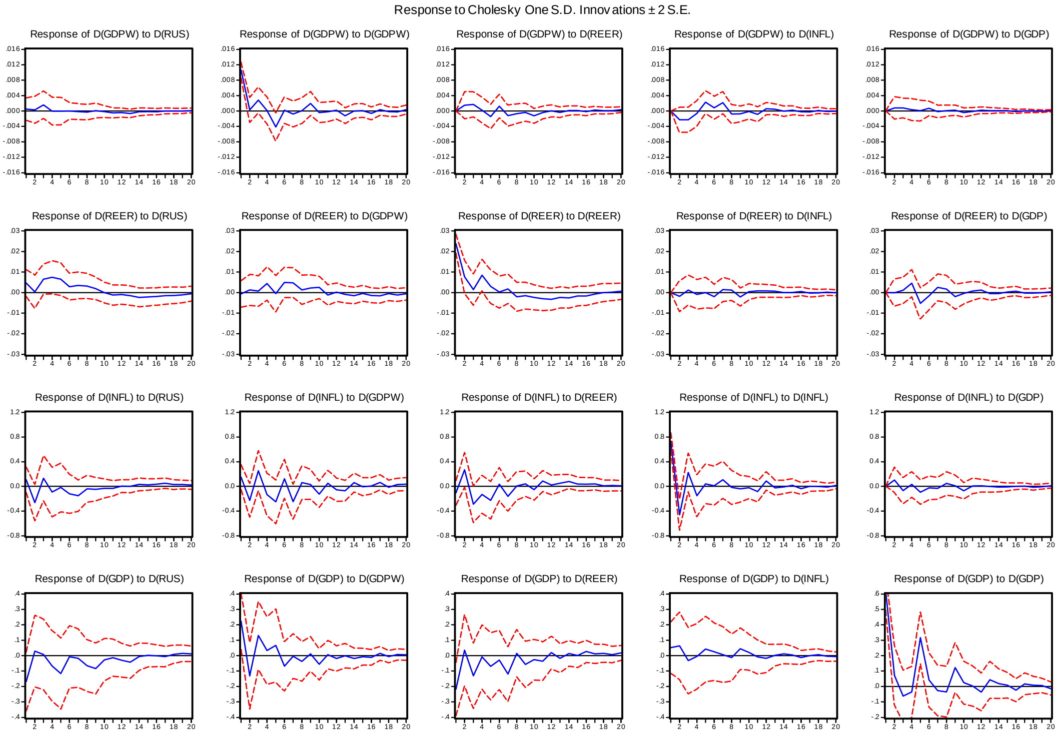

Table 4. Variance Decompositions from VEC Model 1

Period	S.E.	GDPW	REER	INFL	GDP
Variance Decomposition of GDP:					
Period	S.E.	GDPW	REER	INFL	GDP
1	0.775573	4.370216	46.58572	0.798447	48.24561
2	0.944725	2.980558	56.18312	0.968377	39.86794
3	1.124277	3.610610	66.10118	1.353943	28.93427
4	1.263125	5.471985	70.15063	1.373777	23.00361
8	2.273608	3.467035	87.22159	0.621161	8.690219
12	3.088454	2.235682	92.13450	0.337321	5.292493
20	3.915777	1.442643	93.86993	0.244929	4.442500
Variance Decomposition of REER:					
Period	S.E.	GDPW	REER	INFL	GDP
1	0.026073	0.164080	99.83592	0.000000	0.000000
2	0.040873	0.298108	98.94597	0.754256	0.001668
3	0.051703	0.203087	98.96799	0.819108	0.009812
4	0.063659	0.594874	97.88038	1.081734	0.443011
8	0.096222	4.834455	93.69062	1.239355	0.235575
12	0.108382	14.10888	84.41201	1.164210	0.314906
20	0.122145	27.39410	70.24748	0.988097	1.370323
Variance Decomposition of INFL:					
Period	S.E.	GDPW	REER	INFL	GDP
1	0.690536	18.77404	0.000634	81.22533	0.000000
2	0.699719	18.28927	1.507263	79.44101	0.762457
3	0.726061	21.57728	1.453847	76.25564	0.713232
4	0.804482	17.72315	18.80361	62.69748	0.775764
8	1.227127	9.719377	59.65465	28.57313	2.052839
12	1.437955	15.63477	60.76972	21.90944	1.686068
20	1.754259	31.11310	52.64795	14.80376	1.435201
Cholesky Ordering: GDPW REER INFL GDP					

Table 5. Variance Decompositions from VEC Model 2

Period	S.E.	GDPW	GOV	REER	INFL	GDP
Variance Decomposition of GDP:						
Period	S.E.	GDPW	GOV	REER	INFL	GDP
1	0.621295	0.102633	0.445433	35.46201	2.095631	61.89429
2	0.791767	7.594580	6.086064	28.42103	4.296199	53.60213
3	0.931901	7.895643	10.12387	32.03727	5.933878	44.00934
4	1.085273	6.766615	18.83194	31.40813	7.727984	35.26533
8	2.338872	22.25005	21.74483	32.73131	4.826227	18.44758
12	3.695959	29.16098	22.53249	31.28438	3.428024	13.59413
20	6.077442	35.77575	22.34799	28.74934	2.463364	10.66356
Variance Decomposition of REER:						
Period	S.E.	GDPW	GOV	REER	INFL	GDP
1	0.022398	3.552234	2.554186	93.89358	0.000000	0.000000
2	0.035182	7.026435	13.40865	78.10514	0.109965	1.349814
3	0.047301	9.426063	23.33817	64.45479	0.146382	2.634596
4	0.060839	12.80858	27.30470	57.94018	0.148814	1.797719
8	0.108122	34.16809	22.89513	40.05577	0.145212	2.735800
12	0.133279	45.42971	19.36748	32.09955	0.109263	2.993993
20	0.142690	50.47951	17.61867	28.90657	0.110319	2.884936
Variance Decomposition of INFL:						
Period	S.E.	GDPW	GOV	REER	INFL	GDP
1	0.701229	15.72309	1.320417	2.217637	80.73885	0.000000
2	0.722414	15.40452	1.856942	5.474855	76.08796	1.175732
3	0.753661	17.37946	1.711941	5.404093	74.40246	1.102048
4	0.795953	15.66971	1.722214	13.11879	68.31063	1.178656
8	1.233522	23.74703	15.94339	29.90568	29.21842	1.185482
12	1.608544	37.09667	17.14240	27.34072	17.38312	1.037094
20	1.782811	41.89785	16.81064	25.24525	14.61405	1.432209
Cholesky Ordering: GDPW GOV REER INFL GDP						

Table 6． Variance Decompositions from VEC Model 3

Variance Decomposition of GDP:						
Period	S.E.	GDPW	REER	M2	INFL	GDP
1	0.663428	0.006036	39.27720	8.965800	0.085416	51.66555
2	0.868649	8.811980	35.20407	16.29305	1.085760	38.60514
3	1.047824	7.192981	43.45374	19.64586	1.975402	27.73202
4	1.201502	5.586482	47.64405	22.88758	2.547852	21.33403
8	2.383419	6.719923	66.22886	17.72359	1.826166	7.501466
12	3.565230	6.594700	71.07709	17.06023	1.313478	3.954501
20	5.131319	6.890153	72.17116	17.42679	1.101161	2.410733
Variance Decomposition of REER:						
Period	S.E.	GDPW	REER	M2	INFL	GDP
1	0.025289	0.776685	99.22332	0.000000	0.000000	0.000000
2	0.038333	2.585024	96.32034	0.894008	0.200514	0.000117
3	0.048833	3.458183	92.15226	4.249073	0.126679	0.013806
4	0.062075	5.251369	88.37941	5.816164	0.078450	0.474609
8	0.107157	7.458667	84.24899	7.825906	0.129016	0.337424
12	0.124362	8.007897	82.89627	8.689335	0.114839	0.291654
20	0.126859	8.092359	82.58001	8.884336	0.128478	0.314819
Variance Decomposition of INFL:						
Period	S.E.	GDPW	REER	M2	INFL	GDP
1	0.602980	1.567846	5.525628	32.32454	60.58199	0.000000
2	0.716417	8.609289	11.98761	32.98774	46.06776	0.347605
3	0.766861	7.783826	12.89334	36.38863	41.73879	1.195413
4	0.812197	10.86000	17.39384	33.14341	37.22667	1.376072
8	1.368419	45.93317	24.37872	13.25529	15.77213	0.660696
12	1.750956	52.85114	24.93791	10.63072	11.07812	0.502110
20	2.096039	55.62284	25.56861	8.062854	9.865519	0.880181
Cholesky Ordering: GDPW REER M2 INFL GDP						

Table 7. Variance Decompositions from VEC Model 4

Period	S.E.	RUS	GDPW	REER	INFL	GDP
Variance Decomposition of GDP:						
1	0.691078	13.01679	0.788412	33.91864	2.125840	50.15031
2	0.852729	19.93304	4.860825	31.82228	4.417926	38.96592
3	1.013724	24.24677	3.454355	37.26792	6.903693	28.12727
4	1.146306	28.35210	3.118648	37.85113	8.621417	22.05670
8	2.247696	33.53061	3.502378	50.43183	5.140803	7.394383
12	3.267579	34.07993	5.474146	52.70012	3.818395	3.927410
20	4.499444	32.66722	8.816011	52.77875	3.215943	2.522081
Variance Decomposition of REER:						
Period	S.E.	RUS	GDPW	REER	INFL	GDP
1	0.026174	3.592297	1.037498	95.37021	0.000000	0.000000
2	0.039916	2.801331	2.035272	95.09459	0.000391	0.068418
3	0.050784	5.006026	1.732529	92.65221	0.291736	0.317503
4	0.063745	7.577874	2.087920	88.88200	0.192845	1.259362
8	0.105074	8.649480	7.773552	82.46900	0.092150	1.015818
12	0.122957	7.006146	12.66399	79.25621	0.096044	0.977604
20	0.133143	14.09602	14.05024	70.67024	0.294012	0.889489
Variance Decomposition of INFL:						
Period	S.E.	RUS	GDPW	REER	INFL	GDP
1	0.693415	5.845519	14.13106	0.405833	79.61759	0.000000
2	0.736698	8.138939	13.23032	7.960461	70.54362	0.126659
3	0.762723	7.764751	14.14128	8.743105	69.20704	0.143818
4	0.794475	8.115805	13.11823	14.34004	64.16420	0.261721
8	1.103973	10.55963	14.39306	39.21516	33.92382	1.908327
12	1.351599	9.420102	24.67075	40.48294	23.30579	2.120421
20	1.675233	20.81493	25.72479	34.87046	16.95374	1.636073
Cholesky Ordering: RUS GDPW REER INFL GDP						