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Abstract: The Chinese economy has been in a state of external and internal imbalances for some years, which has something to do with the undervaluation of renminbi (RMB). But the Chinese Government hesitates to allow RMB to appreciate because of the worry that RMB appreciations 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 results of the paper show that (1) even after source of spurious correlation is controlled for, RMB appreciation has led to a decline in China’s output, suggesting that RMB appreciations *do* be contractionary, and that (2) once the international finance linkage of Chinese economy is accounted for, the effect of RMB real exchange rate shocks on China’s output and the power of the shocks in explaining the change of China’s output are diminished. The paper gives some possible explanations to those findings, and points out that the findings do not necessarily imply that China should continue maintaining the undervaluation of RMB.

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

JEL classification: F31; F41; O53

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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 or appreciated? These questions have all caused the hot debate at home and abroad. Though there is 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, the 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, allowing RMB to appreciate is a direct and effective method to resolve the imbalances of Chinese economy (Shi, 2006), but the Chinese Government seems hesitate to allow RMB to appreciate[2], would rather

[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 China's 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".

adopts other measures such as adjusting the export tax rebates, relaxing the controls on capital outflow, 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 the Chinese economy suffers from external and internal imbalances, the Chinese Government still resists RMB appreciation? According to traditional macroeconomics textbook model, currency appreciations are contractionary: at least in the short run, appreciations will raise the price of domestic goods relative to the price of 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 aggregate demand[3]. So, the hesitation of the Chinese Government is consistent with the view of traditional macroeconomic theory. Though the Chinese Government has announced that China does not pursue too big trade surplus, indicating that the Chinese policy makers would like to reduce the surplus through various kinds of means, the Chinese Government certainly worries about that RMB appreciations are contractionary as what traditional macroeconomic theory says, thus have a negative impact on China's economic growth and employment, even make the Chinese economy fall into a long time recession as what had happened in Japan during the 1990s (as often but may not correctly being cited by those who argue against the RMB appreciation). This is the main reason why the 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 the Chinese Government.

Must appreciations be contractionary and depreciations be expansionary? For a long time, for example, at least since Hirschman (1949), the economists have realized that appreciations are not necessarily contractionary, nor are depreciations necessarily expansionary. Marked by Krugman and Taylor (1978), there appears a so-called

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

“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 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 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 may be remarkable in

[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.

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 real appreciations 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

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

contractionary while real appreciations 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 relationship between RMB real exchange rate and China’s output then? Are RMB appreciations 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 VAR models to a sample of 1991q1--2005q3. The rest of the paper is organized as follows: Section 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 decade, in order to provide a background for the issues to be discussed; Section 3 describes the models to be employed and the data to be used, and discusses the time series characteristics of the variables; Section 4 takes an econometric analysis 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.

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 (devaluating) 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 single 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, the 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, China instituted a reform of its exchange rate regime by revaluating the RMB by 2.1 percent 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 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 sixteen years.

[Figure 1 about here]

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[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 contrast with 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 10 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 10 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 some 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, so RMB also depreciated largely against those 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 about here]

By investigating the detrended real output data of China, we can find that China's real output also experienced a large fluctuation over the past more than 10 years. Concerning the correlation of the two variables, as Figure 2 shows, during the whole sample period (1991q1-2005q3), the relationship between the RMB real exchange rate and China's cyclical 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 cyclical outputs, while real depreciations have been followed by expansions of the cyclical output. The relation between RMB real exchange rate and China's 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: First, may the tight correlation 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? For example, a change in government spending will influence the real exchange rate while influencing aggregate demand. Models in Mundell-Fleming tradition predict that an increase in government spending raises real interest rate, leads to an appreciation of the real exchange rate[8]. Second, 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 preliminarily pairwise Granger causality test to examine the Granger causality between the RMB real rate and China's output. The Granger causality tests will indicate whether a set of lagged variables has explanatory power on the other variables. If the computed F-statistics are significant, we can 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 the test on the whole sample (1991q1-2005q3) shows that, with 95% level of confidence, the

[8] While the sticky-price intertemporal 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.

sample data reject the null hypothesis, indicating that China's output Granger causes the RMB real rate and the RMB real rate Granger causes the output as well. Because there seems a difference on the relationship between 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 reject 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 the number of observation in the second sub-sample is small that results in a small F-Statistic; another explanation may be that there are other variables influencing both RMB real rate and China's output at the same time that has limited the usefulness of the pairwise Granger causality test.

[Table 1 about here]

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

3. Model and Data

3.1. The Models

We use VAR model to study the relationship 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. Owing to the relatively small sample size, 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. Following Kamin and Rogers (2000), the basic model includes China's gross domestic product (GDP), RMB real effective exchange rate (REER), China's inflation rate (INFL) and foreign gross domestic product (GDPF). Following the tradition of business cycle literature, we detrend the data of gross domestic product so as to focus upon the growth cycle. Therefore, GDP and GDPF represent the cyclical components of gross domestic product (or GDP gap) of China and foreign countries respectively. The reasons for selecting these four variables are as follows: GDPF is taken as a proxy of external shocks. This variable let us examine the effect on Chinese economy of external shocks. GDP and REER are the variables we want to study. INFL is the "intermediate" variable in between the real exchange rate and output, proxying all possible channels link the real exchange rate to output. Being different from Kamin and Rogers (2000), we choose GDPF instead of US interest rate as the proxy of external factors. This is based on the following consideration: China still implements the capital controls, therefore, the relation between US interest rate and China's interest rate should not be 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,

[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, thus, affect the statistic dependability of the results.

the ratio of foreign trade to GDP in China has reached a high level of 70% at present. In that situation, the business cycles of the trading partners have important influence on that of China through the channel of import and export.

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 problem of spurious correlation. For example, it provides us with little sense of which channels link the real exchange rate to output. Therefore, we enter one endogenous variable each time into the basic model, and estimate more other 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. We enter government spending (GOV) and money supply (M2) into the basic model respectively to examine fiscal and monetary channels in the relationship between real exchange rate and output. In addition, we enter US interest rate (RUS) so as to investigate the international financial linkage of Chinese economy and examine the efficiency of capital controls in China. Therefore, besides the basic model which is indicated as model 1, we further estimate three more VAR models. The models can be expressed in the form of unrestricted VAR model as follows:

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

Where,

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

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

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

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

k_l indicates the lags of l-th VAR model， A_i^l is parameter matrix of 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 AIC criterion and SC criterion, the different numbers of lags are tried for each VAR model, and the optimum lags turn out to be 4 for all four models.

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 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. We select the variable orders of our four models as above, the rationale for the orderings are as follows.

GDPF is ordered first because GDPF captures the external shocks that may have significant contemporaneous effects on Chinese economic variables like INFL, REER and GDP due to the openness of Chinese economy. 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, we adopt an ordering a little bit different from that of Kamin and Rogers (2000)[10], we order INFL prior to REER and GDP by assuming that inflation shocks have a contemporaneous effect on RMB real exchange rate since RMB nominal exchange rate is stable due to high official intervention, and on aggregate demand. In contrast, we assume that price is sticky in the short run, so it responds to real exchange rate and aggregate demand shocks only with lags. REER is ordered prior to GDP as we assume that real exchange rate shocks have a contemporaneous effect on aggregate demand through traditional channel or those indicated by the "contractionary devaluations" literature, while

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

aggregate demand shocks do not affect contemporaneously 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, money supply reacts not to realized inflation but to expected inflation. In model 4, RUS is ordered prior to GDPF because US interest rate shocks affect contemporaneously the world aggregate demand, but due to the relative closeness of US economy, US interest rate is unlikely affected contemporaneously by world aggregate demand and any Chinese economic variables.

3.2. The Data

The data are quarterly one; the sample interval is 1991q1--2005q3. 1991q1 is the earliest time for which the quarterly gross domestic product data are available in China, The gross domestic product data of 2005q4 are collected according to a new statistical method and without comparability with the data in the past, and 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 foreign gross domestic product index, GDPF, is calculated according to the trade-weighted average of gross domestic product indices of 14 principal trade partners of China. GDP and GDPF are detrended gross domestic products. In 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, i.e. at the end of the sample the estimates are particular 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. Those problems become serious when sample size is small. Because of the relatively small sample we have, we do not use the H-P filter in this study; instead, we use quadratic detrending to construct GDP and GDPF data, which is implemented by regressing the logarithm of quarterly real gross domestic product on a trend and its quadrate. The regression with a quadratic time trend has higher degree of goodness of fit than one with a linear time trend in our case.

REER (RMB real effective exchange rate index) is taken from the International Financial Statistics database of International Monetary Fund (IMF), a rise in it indicating an appreciation. China's inflation rate INFL is obtained by differencing the logarithm of consumer's price index. GOV expresses the Chinese Government spending. M2 is China's broad money supply. 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 GDPF have been seasonally adjusted. Data of other countries or regions come from the International Financial Statistics database of IMF. 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 come from IMF World Economic Outlook Database 2006, which have 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 relations 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 all are 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 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 about here]

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). Table 3 reports the results of Johansen cointegration tests which indicate that there is at least one cointegration vector for each VAR model. Therefore, nonstationary of data needs less concern in this study. In fact, as elaborated in Sims, Stock, and Watson (1990), when variables are cointegrated, using a VAR in levels model is not misspecified, and the estimates are consistent. Some economists suggest that when one really don’t know whether there is cointegration or what the cointegration vector is, the VAR in levels approach is probably better than the approach that tests for cointegration, estimates of cointegrating relations and then estimates a vector error correction (VEC) model (Cochrane, 2005). We follow the suggestion and conduct our study on the relationship between RMB real exchange rate and China’s output by using VAR in levels model in next section.

[Table 3 about here]

4. Empirical Results

This section comprises two subsections. The first subsection presents the empirical results derived from our VAR in levels models. The estimation results of the VAR models are given in the forms of impulse response functions and variance decompositions, based on those, the empirical analysis of the relationship between RMB real exchange rate and China's output is then conducted. In the second subsection, the robustness of the results obtained in the first subsection is investigated through adopting different ordering of variables, using VEC model specification, and substituting RUS for GDPF in the first three models as proxy of external shock. We want to know whether the results change significantly or not when we make those changes.

4.1. Results from the VAR in Levels Model

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

A. 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. Figure 3 and Figure 4 plot the IRFs of GDP and REER respectively calculated from four VAR models. By investigating those IRFs graphs, the following results can be drawn:

[Figure 3 and 4 about here]

First, when one standard deviation positive (appreciation) shock to REER takes place, there is an obvious decline of 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 RMB real rate shock on output turns to be positive. This effect of RMB real 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; while in Kamin and Rogers (2000), devaluations (revaluations) were contractionary (expansionary) in short-term as well as in medium-term in Mexico.

Second, in model 4, which includes RUS, the contractionary effect of positive shocks to REER on GDP is significantly less than that in other three models that do not include RUS, the former is only about half of the latter. On the other hand, shocks to RUS have a remarkable contractionary effect on GDP; the magnitude of the effect is even larger than that of REER shocks. These two findings seem to indicate that on one hand the capital control in China is less efficiency than we thought; on the other hand, 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[11]. In other words, after accounting for the effect of international finance linkage, the effect of RMB real appreciation on China's real economy may be smaller than what we have expected.

Third, one standard deviation shock to GDP has no obvious impact on REER.

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

After the 3rd quarter, the shock causes REER raise for some extent. This effect of output shock occurs in all models estimated, suggesting the robustness of the result. Because the measure of the IRFs graphs of REER 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 is much less than that of impact of RMB real rate shocks on output.

Fourth, the impact of shocks to other variables accords with virtually the economic intuition. For example, an increase in money supply has an obvious expansionary effect, and causes the real exchange rate depreciation in short-term; GDPF shocks have expansionary effect too; an increases in government spending results in RMB real appreciation in first 2 quarters; inflation shocks cause a decline of GDP in short-term. An important exception is the effect of INFL shocks on REER: an increase in inflation causes real exchange rate depreciation. We should expect that an increase in inflation causes the RMB real exchange rate to appreciate because the nominal rate of 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 the RMB real appreciation shock has contractionary effect on China's output. After controlling the influence of other variables, the RMB real appreciation shock still causes GDP to decline, which excludes the spurious correlation between RMB real exchange rate and China's output. The empirical results seem also support the guess that the direction of the causality between the RMB real rate and China's output runs from the former to the latter. Finally, the external shocks have remarkable effects on China's output; in particular, US interest rate shocks have a significant impact on China's cyclical output. When the effect of RUS is included in VAR model, the effect of REER turns to be weaker for certain degree.

B. Variance Decompositions

The IRFs provide a useful tool to assess the direction as well as the magnitude of response of a variable to various kinds of shocks; on the other hand, 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, so allow us to appraise the relative importance of contribution of different shocks to the variance of a particular variable. Table 4 provides the results of the variance decompositions of GDP and RMB real exchange rate from four VAR models. The following results emerge from the variance decompositions:

[Table 4 about here]

First, concerning the source of variation in GDP forecast error, for those models that do not include RUS, "own shocks" is the first most important source at horizons of 1 and 2 quarters, while RMB real exchange rate shock is the second most important source. Beginning from the 3rd quarter, however, the RMB real exchange rate shocks become the first most important source of variation in GDP, which accounts for 36%-70% of the GDP forecast error variance; In the medium and long-term horizon, "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 model 2 and 3 decrease greatly, only accounts for about 8% of the GDP error variance. In contrast, shocks to GDPF and M2 turn to be the second most important source of the GDP error variance in model 2 and 3 respectively in the medium and long-term horizon, which account for about 14% and 26% of the GDP error variance respectively.

Second, in model 4, which includes RUS, "own shocks" to GDP is the first most important source of the GDP error variance only at horizons of 1, 2 and 3 quarters. Beginning from the 4th quarter, however, the RUS shocks become the first most important and predominant source of variation in GDP, which accounts for 36%-69% of the GDP error variance, while "own shocks" and GDPF shocks turn to be the second and the third most important source of the GDP error variance, which account for about 13% and 11% respectively in the long-term horizon. In contrast, REER shocks become the fourth important source of variation in GDP, which only account for 7% in the long-term horizon. When RUS is included in VAR model, the power of REER shocks in explaining the error variance of GDP has significantly declined. This result is consistent with that we obtained in IRFs analysis.

Third, in the source of variation in RMB real exchange rate forecast error, “own shocks” is the first most important and predominant source, which accounts for 63%-98% of the forecast error variance at horizons of 1 to 4 quarters, and 40%-70% after 8 quarters. On the other hand, the contribution of GDP shocks to the error variance of REER is negligible at horizons of 1 to 4 quarters. 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 other three models to under 7% in model 2 and model 3 and about 12% in model 4. On the contrary, shocks to M2, GDPF and RUS in other three models all have relatively large contribution to the error variance of REER. What merits attention is that GOV has very little contribution to the error variance of REER.

In sum, the analyses based on the variance decompositions suggest that (1) the shocks to RMB real exchange rate have a large contribution to the variation in China’s output in models that do not include the US interest rate, and some contribution to the variation in China’s output in model that includes the US interest rate, suggesting the possibility of the spurious correlation between RMB real exchange rate and China’s output can be excluded; (2) except for the basic model (Model 1), the shocks to GDP have small contribution to the variation in RMB real exchange rate, and the contribution is negligible at horizons of 1 to 4 quarters, suggesting the possibilities of reverse causation running from the GDP to the RMB real exchange rate can be excluded; and (3) when US interest rate is included in VAR model, the power of REER shocks in explaining the error variance of GDP has significantly declined.

4.2. 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 our VAR models with different and plausible ordering. In addition, because all variables in our models are variables of I (1) and there are cointegration vectors for each model, it is worth trying to check the results obtained from the VAR in level models with those obtained from the cointegration restricted VAR models, i.e. the VEC models[12]. Furthermore, the results of previous subsection suggest that the magnitude of the effect of RMB exchange rate shocks on China's output is diminished remarkably by including US interest rate in the VAR model, therefore it is also interesting to substitute RUS for GDPF as proxy of external shock in our first three VAR models. In this subsection we therefore investigate the robustness of the results as regards these three points.

A. Different Ordering

Kamin and Rogers (2000) adopt orderings a little bit different from those of ours in their VAR models. Except for GDPF, variables in our 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 we relax the assumption of price sticky in short run, the above orderings seem plausible. For example, in model 1, an appreciation of real exchange rate shifts demand away from non-traded goods and decreases the price of non-traded goods and general price level for a given level of nominal exchange rate. The adjustment of the price level then causes the change of output.

We re-estimate our four VAR models by adopting the above orderings and find that the results are quite similar to those of previous subsection. Owing to the space

[12] Some economists argue that it is appropriate to estimate VEC model when variables are I (1) and there are cointegrating relations between them (Engle and Granger, 1987).

limitation, we only present the impulse response functions of GDP from the four VAR models using orderings adopted by Kamin and Rogers (2000) (Figure 5).

[Figure 5 about here]

B. Results from VEC Model

The VEC models to be estimated have following forms:

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

where : $ECM_{t-1}^l = \beta^{l\prime} Y_{t-1}^l$ is the error correction terms, reflecting the long-run equilibrium relationship between the variables. $\beta^{l\prime}$ is the matrix of cointegration vectors. 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 is parameter matrix of variables in differences, the elements of them reflect the short-term effect of the variables on a dependent variable.

We estimate four VEC models adopting the same orderings of previous subsection. By investigating the estimation results of four VEC models, we find that the IRFs of VEC models are very similar with those of VAR models in direction and dynamic path of the responses. The results of variance decompositions are basically similar too. But one difference is: the effect of various shocks in VEC models case seems more lasting than that in VAR models. Taking the response of GDP to the REER shocks as an example, the contractionary effect of an appreciation of REER sustains longer before the expansionary effect appears. Because restricted by space, we only provide the results of variance decompositions of GDP and REER and impulse response functions of GDP from the VEC models (Table 5 and Figure 6).

[Table 5 and Figure 6 about here]

C. Substitution RUS for GDPF in VAR Model

When we Substitute RUS for GDPF in VAR Models and re-estimate the first three VAR models of previous subsection we find that comparing to the situations of original models using GDPF as proxy variable for external shocks, (1) the IRFs of three new VAR models are similar with those of model 4 of previous subsection: the magnitude of the effect of RMB exchange rate shocks on China's output is diminished, especially in medium and long-term; (2) the expansionary effect of REER shocks appears earlier; (3) concerning the source of variation in GDP forecast error, in all three new VAR models, the RUS shocks become the first most important and predominant source of variation in GDP, while in contrast REER shocks turn to be the second, the third and the fourth important source of the GDP error variance respectively. The contributions of "own shocks" and M2 to variation in GDP have exceeded the contribution of REER in the second and third new models; (4) the effects of other shocks on GDP are similar between new models and 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 agent variable of external shocks.

[Figure 7 and table 6 about here]

In sum, the robustness analysis confirms that our basic result, namely the shocks to RMB real exchange rate have a contractionary effect on China's output, essentially does not change even if we adopt the orderings of Kamin and Rogers (2000) or use VEC model in our model specification. But after including the international finance linkage of the Chinese economy, the effect of REER shock on China's output and the power of REER shocks in explaining the changes of China's output turn to be relative small, while US interest rate shock has relatively large effect on China's output, the magnitude of it is exceed that of RMB exchange rate shocks.

5. Conclusion

This paper has investigated 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 source of spurious correlation is controlled for, RMB real appreciation has led to a decline in China's output, suggesting that currency appreciations are contractionary in China during past decade, as the traditional open economy macroeconomics forecasts. Second, when the international finance linkage of Chinese economy is accounted for, the effect of RMB real exchange rate shocks on China's output and the power of the shocks in explaining the change of China's output are relatively small while the effect of US interest rate shocks on China's output is relatively large. The intuition behind this finding may be that the effectiveness of China's capital controls has eroded over time and the scale of capital inflows and outflows has become large enough so that external shocks through international finance channel have significant influence on the Chinese economy, which exceeds the influence of external shocks through international trade channel. Third, besides shocks to RMB real exchange rate and US interest rate, shocks to domestic money supply and foreign demand all have important effect on China's output. However, government spending shocks have less power in explaining the change of China's output.

The conclusion that currency appreciations are contractionary in China is remarkably different from those made by the similar empirical works on developing countries. The possible explanations of this difference in 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; Second, the urban economic reform began at the early 1990s has made many people lose their jobs and traditional benefits on medicare, pension and education, etc., which has strengthened 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 may 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 (included those produced by foreign investment enterprises) to imported goods has been strengthened, therefore, the effect of RMB exchange rate on domestic investment spending 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 more than 10 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 until now, therefore, the effect of RMB exchange rate shock on China's output is mainly embodied through the expenditure-switching effect as traditional macroeconomic theory emphasized, in that situation, the appreciations of RMB are likely contractionary.

It is worth pointing out, however, that the conclusion that appreciations are contractionary in China does not necessarily mean that China should continue maintaining RMB exchange rate undervalued. Since the undervalued RMB has already caused the Chinese economy to run into internal and external imbalances in the past several years. Figure 2 tells us that 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 overheating of the Chinese economy is obvious. It is no doubt that continuing the undervaluation of RMB exchange rate will further aggravate the imbalances of the Chinese economy. On the other hand, the conclusion that appreciations 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[13]. According to the Swan Diagram of Shi (2006), allowing RMB to appreciate is helpful for the Chinese economy to realize internal and external balances.

In addition, China’s capital account surplus increases rapidly along with the rapid increases in the current account surplus in recent years. The rapid increase in the “double surplus” causes China’s foreign exchange reserve to expand in a wild manner and the money supply and the domestic credit to expand passively, which have aggravated the overheating of the Chinese economy and the difficulty of the government's macro management. In particular, as China’s capital account liberalizes gradually and the effectiveness of capital controls erodes over time, the “hot money” flows into China with great amount, which becomes one of the important reasons why the foreign exchange reserve increases so fast. The empirical work of us indicates that the effect of shocks on China’s output through international finance channel (as represented by US interest rate shocks) exceed that through international trade channel (as represented by RMB real exchange rate shocks), suggesting it is important for the Chinese authorities to handle the capital inflow problem correctly. The inflows of “hot money” in recent years mainly response to the expectations of RMB appreciation and that one of the important reasons of persisting existence of the expectations is the undervaluation of RMB. Therefore, allowing RMB to appreciate at faster speed so as to restore the equilibrium level of RMB exchange rate will lessen the expectations of RMB appreciation, thus relax the pressure of the fast increase in

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

foreign exchange reserve on the Chinese authorities.

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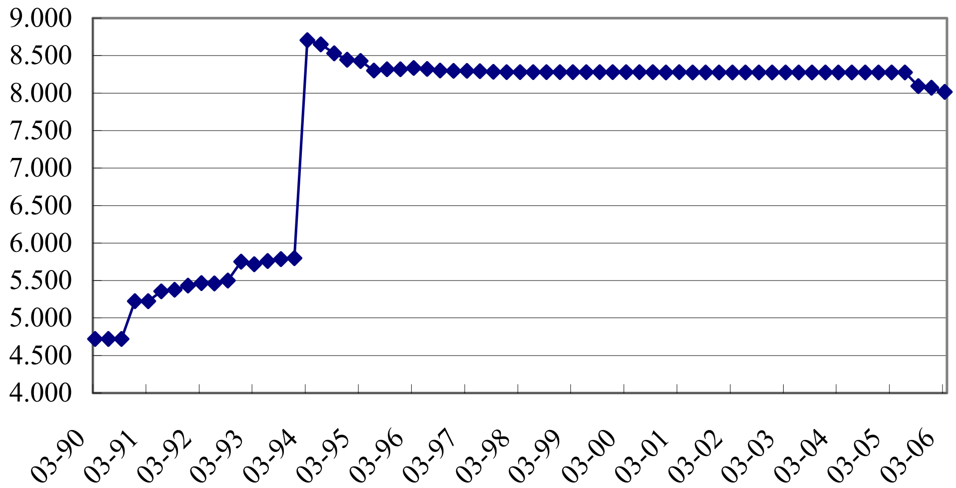
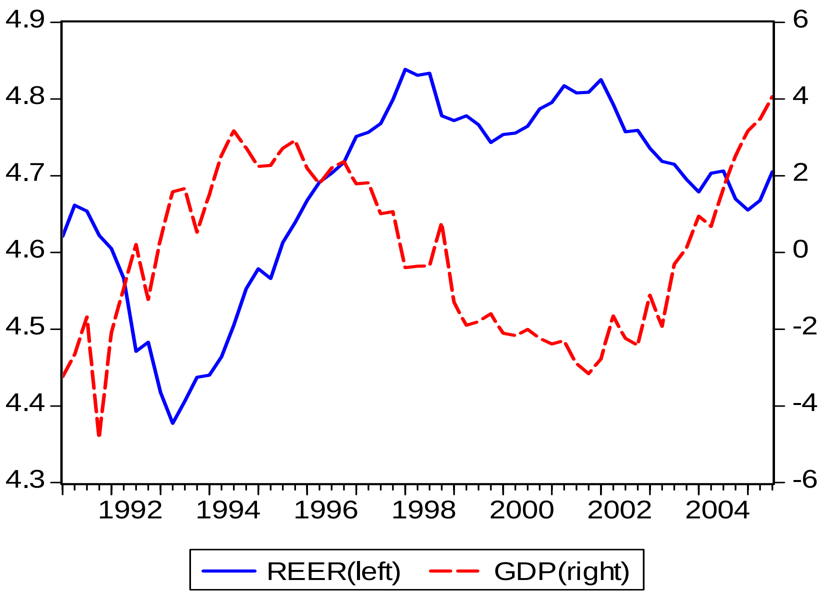
Figure 1.RMB Nominal Exchange Rate (Yuan/US Dollar)



Source: IMF, International Financial Statistics.

Figure 2. RMB Real Exchange Rate and Real GDP



Note: 1. REER stands for RMB real exchange rate index with a rise indicating an appreciation; 2. GDP stands for detrended real gross domestic product. See section 3 for the definition and explanation of the variables.

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

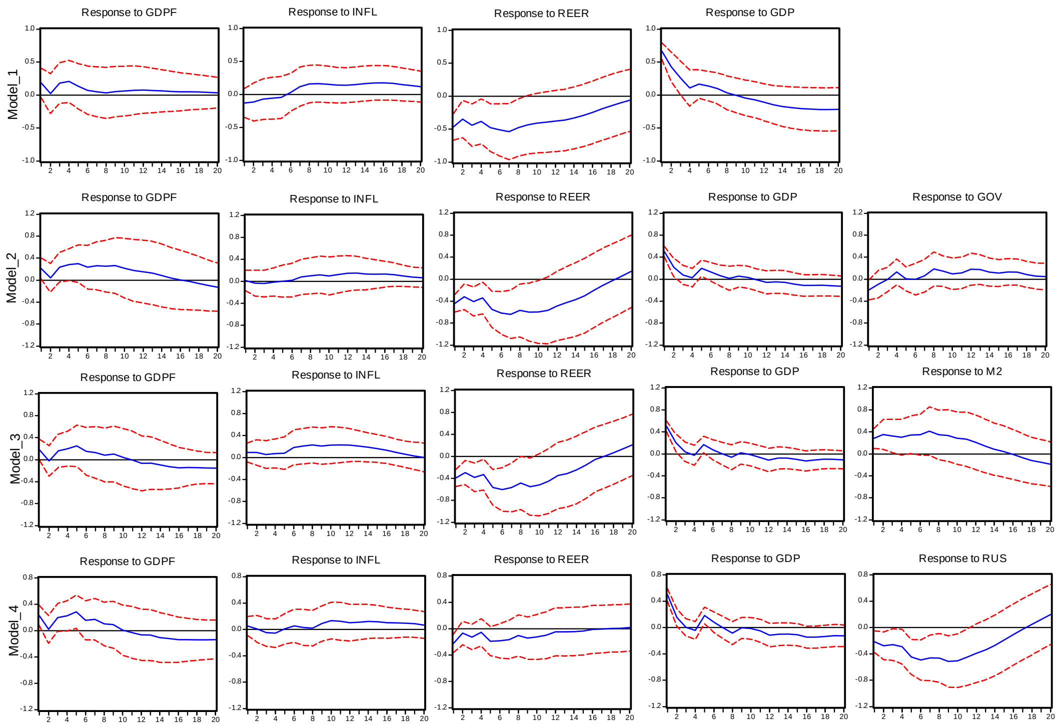


Figure 4: Impulse Responses of REER to Cholesky One S.D. shocks ± 2 S.E.

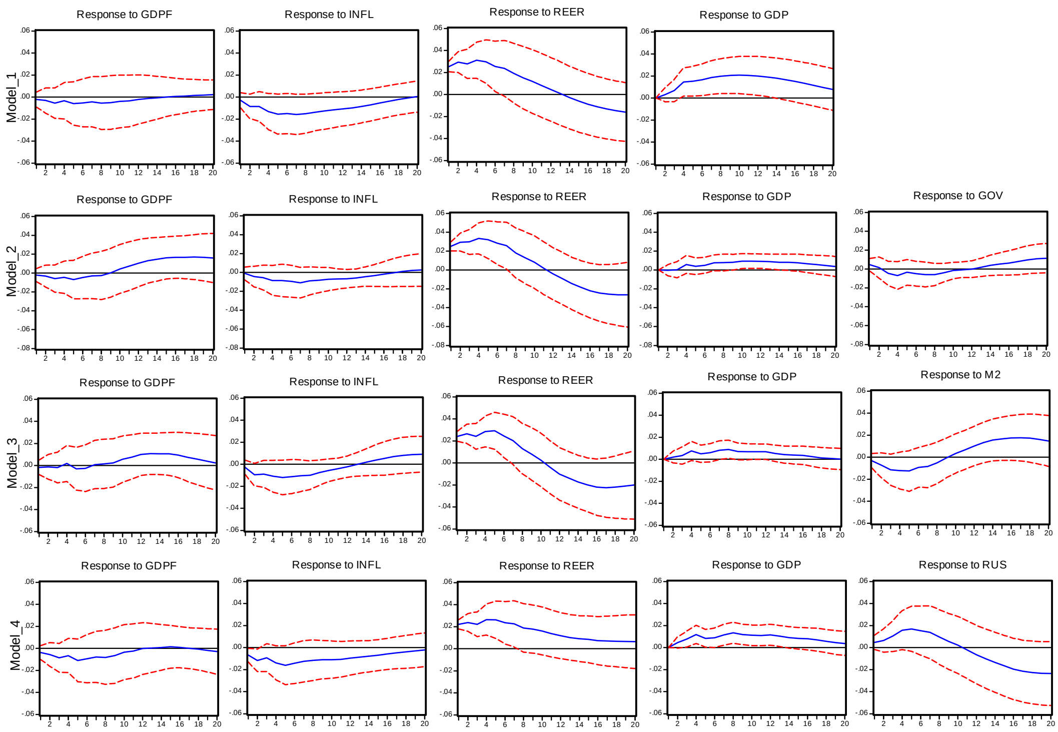


Figure 5: Impulse Responses of GDP from VARs with different ordering

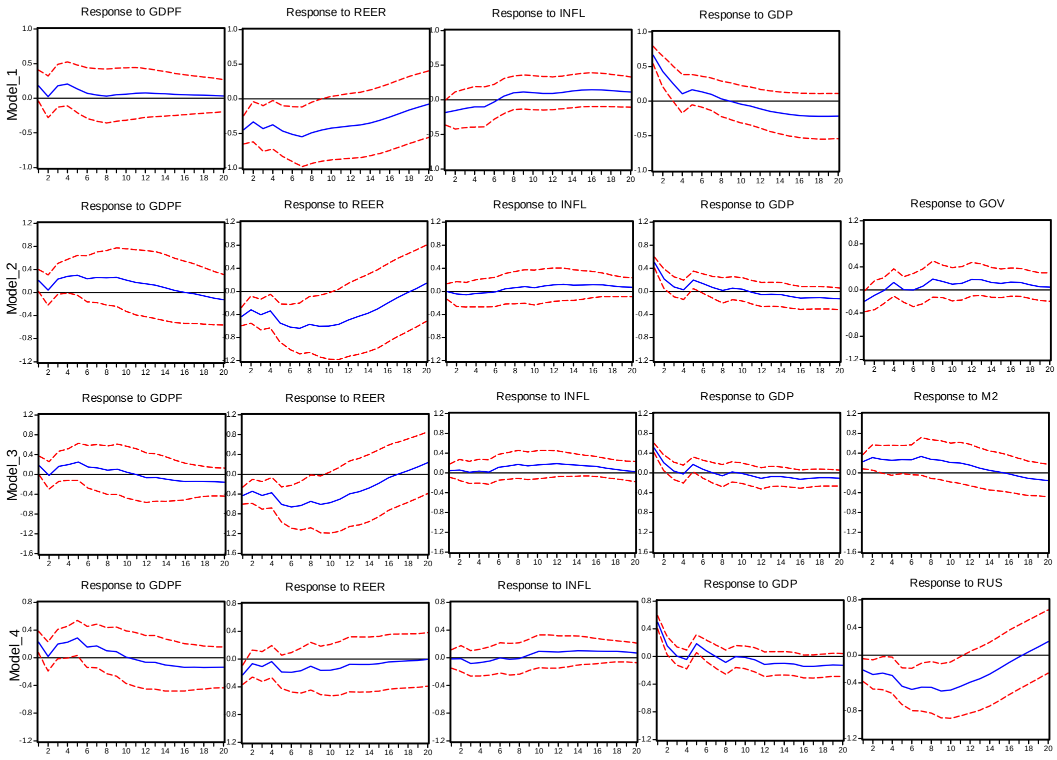
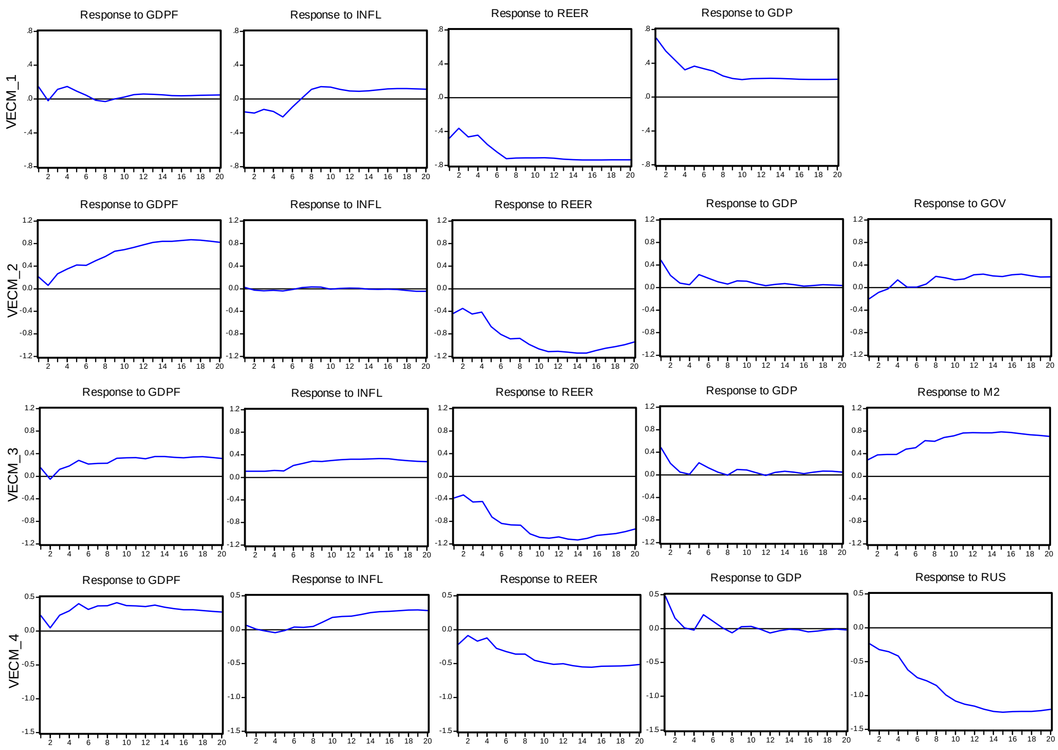


Figure 6: Impulse Responses of GDP from VEC Models



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

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

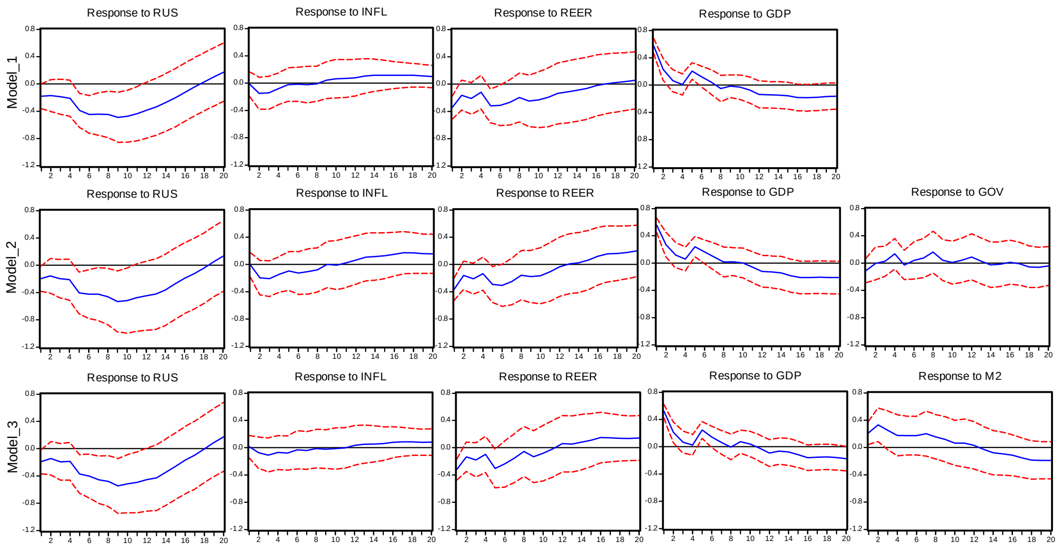


Table 1 Pairwise Granger Causality Tests

Null Hypothesis:	Obs	F-Statistic	Probability
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

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 that the hypothesis that the variable contain unit root can not be rejected at the 10 per cent level of significance.

*** denotes that the hypothesis that the variable contain unit root can not be rejected at the 5 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.

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 differences): 1 to 3

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

Note: 1. The two columns below a variable give the fraction of the forecast error variance for GDP and REER that is attributable to shocks to the variable at the given forecast horizon, with the black column in left indicating the fraction for GDP.

2. The columns below "S.E." contain the forecast error of GDP and REER at the given forecast horizon.

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

Note: 1. The two columns below a variable give the fraction of the forecast error variance for GDP and REER that is attributable to shocks to the variable at the given forecast horizon, with the black column in left indicating the fraction for GDP.

2. The columns below "S.E." contain the forecast error of GDP and REER at the given forecast horizon.

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 give 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." contain the forecast error of GDP at the given forecast horizon.