Job Market Paper

What Explains China's Foreign Reserves — An Empirical Study from a Time Series Perspective

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November 9, 2008

Abstract

This paper tries to empirically answer the question of what explains China's foreign reserve holdings. We find that some VEC models motivated by modern mercantilism perform better in predicting China's foreign reserves than selected ARIMA models and those based on precautionary demand theories, both with statistical significance. This suggests that previous econometric studies, whose emphasis has been overwhelmingly placed on precautionary motives, might have missed some more important factors in explaining China's reserve holdings. Further structural analyses of these models show that the buildup of reserve stocks by China has a negative (depreciating) effect on its real exchange rate and a positive impact on its export growth. These findings seem to corroborate the conjecture that the recent increase in China's reserve holdings is a part of its export-led development strategy, and they also suggest that such a policy is effective for China.

*I'm grateful to Professor Maurice Obstfeld for his great guidance. I also want to thank Professor Yuriy Gorodnichenko, Professor Pierre-Olivier Gourinchas, Professor Yingyi Qian, Professor Andrew Rose and Gewei Wang for helpful discussions. Email: lzeng@econ.berkeley.edu.

1. Introduction

This paper will empirically study China's foreign reserve holdings, which have increased dramatically over the past two decades[1]. The first panel of Figure 1 shows that by the end of 2007 the stock of China's foreign reserves had reached over 1.5 trillion US dollars, nearly 100 times the 16 billion US dollars held in 1982. This amount also far exceeds the second largest reserve stock in the world, 0.97 trillion US dollars held by Japan. Such increase is quite remarkable even after the rapid growth of the Chinese economy is taken into consideration. The second panel of Figure 1 shows that the reserve to GDP ratio of China has risen from 5.5% to 47.6% over the period from 1982 to 2007, an almost nine-fold increase. This not only contrasts sharply to what happened to the advanced economies, whose average reserve to GDP ratio dropped from 6.4% in 1982 to 5.3% in 2006, but also dwarfs the increase in reserve holdings by the other emerging market economies, whose average reserve to GDP ratio has increased from 5.6% to 21% over the same period[2]. The last panel of Figure 1 measures reserve holdings as months of national imports covered by them. In 1994, the reserve holdings of China, as well as the average of the other emerging market economies, covered approximately 6 months of imports. However, since then, the increase in China's reserve holdings has outpaced others and by the end of 2006 its months of imports covered by reserves is 16, much higher the average of 9 months for the other emerging market economies.

The enormous size of China's current foreign reserve stock has brought its cost efficiency into question. Bai, Hsieh and Qian (2006) find that the aggregate real rate of return to capital in China has averaged above 20% since 1978. This implies a potentially very high opportunity cost for China to hold foreign reserves, which are believed to be mostly in the form of low-yielding US Treasury and other securities. Added to the concerns of opportunity costs are the valuation effects emphasized by Gourinchas and Rey (2007). Unlike the case for the United States where depreciation of the US dollar has stabilizing effects through external adjustments, the valuation effects of dollar depreciation can lead, or probably have led, to huge losses to the value of the Chinese reserve stock and bring big

[1]Foreign reserves discussed in this paper are defined as the sum of gold, SDRs, foreign exchange reserves and reserve position with the IMF.

[2]Advanced economies are countries with IFS codes less than 199, with the exception of Turkey and South Africa. Emerging market economies are those in the Morgan Stanley emerging market index, as of April 25, 2008.

balance sheet risks to the People's Bank of China[3]. There are also other costs and risks associated with holding a huge amount of foreign reserves. For instance, the continuing rise in the level of reserve stocks can push up the costs of sterilizing interventions and make it increasingly difficult to neutralize the inflationary monetary impact of reserve accumulation. The surge in the Chinese inflation rate in 2007 and early 2008 is an example of this possibility[4].

From a broader perspective, the large stock of China's foreign reserves is often perceived as a symptom of the current global imbalances. Such a view is well summarized by a quote from the Federal Reserve Board Chairman, Ben Bernanke, during a recent speech on the current financial turmoil:

> *The Sources of the Financial Turmoil: A Longer-Term Perspective*
> *"... a substantial increase in the net supply of saving in emerging market economies contributed to both the U.S. housing boom and the broader credit boom. The sources of this increase in net saving included rapid growth in high-saving East Asian countries and, outside of China, reduced investment rates in that region; large buildups in foreign exchange reserves in a number of emerging markets; and the enormous increases in the revenues received by exporters of oil and other commodities. The pressure of these net savings flows led to lower long-term real interest rates around the world, stimulated asset prices (including house prices), and pushed current accounts toward deficit in the industrial countries–notably the United States–that received these flows."*

Important and interesting questions arise here: Why is China holding such a huge amount of foreign reserves, if the associated costs are very high and they have caused unease among its major trade partners? What are the underlying forces that have driven the growth in China's foreign reserves? Is China's current reserve holding behavior different from what we observe in its past? This paper will try to answer these questions empirically, testing a set of alternative explanations.

[3] A back-of-the-envelope calculation suggests that the loss to the value of China's reserve stock, caused by the dollar depreciation from 2005 to present, can easily exceed 3% of its annual GDP: $830 \times 0.6 \times (1 - 6.8/8.1)/2400 = 3.3\%$, where 830 billion dollars was China's reserve level at the end of 2005, 0.6 is the assumed proportion of dollar assets in the reserve stock, 8.1 was the RMB/dollar rate at the end of 2005 and 6.8 is the current RMB/dollar rate, and 2400 billion dollars was China's GDP in 2005.

[4] See Rodrik (2006) for a more general discussion on the cost of holding foreign reserves.

Recent work on international reserves indicates two possible directions for explaining a country's reserve holdings. One direction of research can be summarized as the precautionary demand theories for foreign reserves. These theories suggest that countries use foreign reserves as a preventative measure against domestic and external shocks, and the reserve stocks are built up, by and large, on the countries' own initiatives. Studies along these lines include: Flood and Marion (2001), Aizenman and Marion (2003, 2004), Aizenman and Lee (2005), Jeanne and Ranciere (2006) and Jeanne (2007), who emphasize the self-insurance role of reserve stocks against external shocks such as sudden stops in capital inflows; McKinnon and Schnab (2003), McKinnon (2006), and Obstfeld, Shambaugh and Taylor (2008), who stress the importance of domestic financial stabilities in determining countries' reserve levels.

The other direction is what has been called modern mercantilism, which is a part of the broader Revived Bretton Woods System theory, first developed by Dooley, Folkerts-Landau and Garber (2003)[5]. The modern mercantilism theory suggests that export promotion through an undervalued currency is a long-term development strategy adopted by China currently, and it has been used by other countries during certain stages of their development, e.g. Japan. It views the vast amount of foreign reserves held by China as merely a by-product of its export-led growth policy.

In this paper we construct econometric models to explore China's foreign reserve holdings following both directions. Unlike most recent empirical studies, however, we will examine the questions from a time series perspective[6]. As we will argue below, the vector error correction (VEC) model adopted by this paper has a few important advantages over the cross-country panel method, used by most previous studies, in investigating China's reserve holding behavior.

The central finding in this paper is that models motivated by modern mercantilism perform better in predicting China's foreign reserve holdings than those based on precautionary demand theories, as well as selected ARIMA models, with statistical significance. This suggests that previous econometric studies, whose emphasis has been overwhelmingly placed on precautionary motives, might have missed some more important factors

[5]Dooley, Folkerts-Landau and Garber (2004a, 2004b, 2004c, 2005a, 2005b and 2007) is a series of working papers on the Revived Bretton Woods System theory. The term *modern mercantilism* is borrowed from Aizenman and Lee (2005).

[6]A few early studies on reserves also took time-series perspectives, including Edwards (1983, 1984), Ford and Huang (1994).

in explaining China's foreign reserves. Further structural analyses of these models show that the buildup of reserve stocks by China has a negative (depreciating) effect on its real exchange rate and a positive impact on its export growth, which corroborates the conjecture that the recent increase in China's reserve holdings is a part of its export-led development strategy. When interpreted in the broader context of current global imbalances, such results seem to support the view that China should play a more active role in the adjustment process by reevaluating its currency and/or adopting a more flexible exchange rate regime.

Among considerations related to precautionary motives, imports and associated risks, such as real openness of the economy, appear to be the most important determinants for China's reserves holdings. Inflation volatility and the interest rate differential between China and the US are also helpful predictors. But our results suggest that if China wants to reduce its inflation volatility by piling up reserves, that has not been an effective policy tool. The estimated impact of the interest rate differential on China's reserve holdings is opposite to that predicted by the buffer stock model. One possible explanation for such a finding is that higher relative returns to capital in China are likely to attract more capital inflows to China, outweighing the opportunity cost consideration suggested by the buffer stock model. We find little evidence to support volatility of exports and domestic financial depth as crucial factors in explaining China's reserve holdings.

A natural question to ask is why these results obtained from the time-series VEC model are more credible than the previous ones produced by cross-country panel estimations. We answer this by carefully considering some serious limitations of using panel method to analyze China's reserve holdings and showing how the VEC model can help to overcome them.

First, cross-country panel regressions assume that the coefficients of interest are the same, or at least close to each other, across all the countries in the sample. However, on the issue of foreign reserves, there are compelling reasons to believe that China may act quite differently from other countries, especially the emerging market economies, the country group that it presumably best fits in. For instance, from a historical perspective, state economy has played a much more important role in China than in most other emerging market countries. For most of the period that we study, none of the firms and households in China were allowed to hold foreign exchanges[7]. This means that the Chinese reserve stocks that we are looking at are not only the *official* foreign reserves, but indeed *the*

[7] With the exception of remittances from abroad.

foreign reserves held by China. Since there is little hidden cushion in the private sectors and households that can help to protect China from external shocks, it should not be surprising if China has a more prudent attitude toward reserve accumulations.

Another problem of using panel methods to investigate foreign reserves is the danger of spurious regression, which seems to be largely ignored by the current empirical literature. Foreign reserve levels, as well as some explanatory variables that have been experimented with by economists, often appear to be nonstationary time series. In such cases cointegration tests should be performed before one can claim that a stable relation among these variables has been identified. In practice, however, few studies employing panel methods have actually done so. Two assumptions are therefore implicitly assumed by those studies: the variables included in the panel regressions are cointegrated, and furthermore, the cointegrating relations among these variables are identical across all the sample countries. The example shown in Figure 2 and Table 1 casts doubts on both of them. Figure 2 shows the time series of reserves and imports, both as ratios to GDP, for China and Korea, who almost always show up on the same panel in studies on foreign reserves. Although the two reserve series display a similar upward trend over time, it is obvious that the paths of imports are very different. Indeed, the Johansen cointegration test results reported in the first panel of Table 1 suggest that the reserve and import series for China are cointegrated, but they are not in the case of Korea. Nonetheless, in the second panel of the table, where we report regressions of reserves on imports, we find significant coefficients not only for China, but also for Korea and for the case where both countries are included. This illustration of spurious regression not only confirms the heterogeneity concern we pointed out earlier, but also shows that without careful consideration of the nonstationarity issue, conclusions based on panel regressions can hardly be convincing.

The endogeneity problem is widely acknowledged in the empirical literature on foreign reserves. For instance, theoretically speaking a country's need for international reserves depends on its exchange rate regime. But in the reverse direction, the abundance of a country's international reserves can affect its exchange rate arrangement as well. As we saw in the 1997 Asian Financial Crisis, many countries were forced off their *de facto* pegs to the US dollar when their international reserves were nearly depleted. However, few existing studies have provided satisfactory solutions to the problem. Part of this is probably due to the difficulty in finding good instrumental variables.

Finally, many existing empirical studies are based on theoretical models predicting the optimal reserve levels for an economy. Since panel regressions do not distinguish between the long-term equilibria and short-run fluctuations *per se*, empirical studies employing such methods are therefore hampered by the fact that the researchers do not observe the optimal levels of reserve stocks, only the actual holdings instead. As a consequence, measurement errors in the variable to be explained, the optimal reserve holdings, may interact with the constructed regressors to generate a misleading correlation between reserve holdings and its potential determinants.

The VEC model can handle all the empirical difficulties mentioned above better. First, since the VEC model studies foreign reserves from a time-series perspective, cross-country heterogeneity will not cause any concerns in the estimations. Second, all the variables involved in a VEC model are treated as endogenous, allowing us to study the dynamics among them. In addition, cointegration tests are performed when the model is estimated through the Johansen maximum likelihood method, which ensures that we are not running spurious regressions. Finally, the estimation results of the VEC model separate the long-run equilibrium relations from the short-run adjustment dynamics, which, at least to some extent, solves the measurement error problem on optimal reserve levels.

The rest of the paper is organized as the following. Section 2 introduces the VEC model, discusses the regressors that will be included in estimations, and sketches the scheme of our empirical investigation. Section 3 provides more details on the estimations and discusses all the empirical results. Section 4 concludes the paper with a summary of the main findings and a brief discussion on future work.

2. Model, Regressors, and Investigation Scheme

VEC Model

The workhorse tool in this paper is the vector error correction (VEC) model. The reduced form VEC model that we will estimate is the following:

$$\Delta y_t = \alpha(\beta' y_{t-1} + \mu) + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \gamma + \varepsilon_t, \tag{1}$$

where $y_{(n\times1)}$ is the vector of regressors, $\beta_{(n\times k)}$ with $k < n$ is the matrix of cointegrating vectors, $\alpha_{(n\times k)}$ and $\Gamma_{i(n\times n)}$ are matrices of adjustment parameters, $\mu_{(n\times1)}$ is a constant vector that allows the cointegrating equations to have nonzero means, the constant vector

$\gamma_{(n\times1)}$ allows linear trends in the levels of the data, p is the number of lags included when the model is written in levels, and ε_t is the *i.i.d.* residual vector with assumed distribution $N(0,\Omega)$[8][9]. This equation can be interpreted as saying that the current period adjustments in y are affected by their own historical values, the deviations from their long-run relations in levels in the last period, and some random shocks.

Equation (1) is called the reduced form because the coefficients for Δy_t on the left hand side is restricted to be an identity matrix. The consequence is that the elements of ε_t are not necessarily orthogonal to each other (or equivalently, Ω is not a diagonal matrix), therefore we can not simply interpret the estimation results of equation (1) as causal relations among the regressors. To determine causation, we will continue to estimate the structural coefficient matrix, A, in the structural form of the VEC model, which is equation (2) below:

$$A\Delta y_t = \overline{\alpha}(\beta' y_{t-1} + \mu) + \sum_{i=1}^{p-1} \overline{\Gamma}_i \Delta y_{t-i} + \overline{\gamma} + v_t, \tag{2}$$

where $\overline{\alpha} = A\times\alpha$, $\overline{\Gamma}_i = A\times\Gamma_i$, $\overline{\gamma} = A\times\gamma$, and most importantly, $v_t = A\times\varepsilon_t$ and it has a diagonal variance and covariance matrix, Σ. Since there are no contemporaneous correlations among the elements of v_t, they are regarded as structural (exogenous) shocks to the corresponding regressors in y.

Tests of cointegrating relations among regressors and estimations of equation (1) will both be executed using Johansen's maximum likelihood method. Identifications of the coefficients in matrix A will be based on the second moment conditions derived from the equation $v_t = A\times\varepsilon_t$:

$$\Sigma = A\Omega A'. \tag{3}$$

Since the number of elements in A exceeds the number of moment conditions implied by equation (3), identification restrictions will have to be imposed. In this paper we

[8] γ and $\alpha\mu$ are orthogonal to each other.

[9] Equation (1) nests two forms of the vector autoregression (VAR) model. If $k=n$, then $(a\beta')$ is an unrestricted $n\times n$ matrix and equation (1) is in fact a VAR model in levels. The VAR model in levels fits the data better than the VEC model and therefore would be preferable if all the variables in y are stationary series. But since the variable of our primary interests, China's foreign reserves, is an $I(1)$ process, the VEC model is more appropriate and efficient. If $k=0$, then equation (1) becomes a VAR model in first order difference. Such a model is appropriate if all the variables in y are nonstationary $I(1)$ processes and no cointegrating relation exists among them. We will, however, just ignore these situations, because they imply that no other variables in the model have a stable long-run relation in levels with the variable that we are trying to explain.

will follow the just-identification strategy proposed by Bernanke (1986). Details of the restrictions imposed will be discussed in the related parts of section 3.

Regressors

The variable of our primary interests in this paper is China's foreign reserve holdings scaled by GDP ($\underline{res}$). The other regressors included in the VEC models are motivated by previous theoretical and empirical work on foreign reserves. The construction details and summary statistics for all the variables are provided in the data appendix. The reasons for the inclusion of each regressor are briefly discussed below.

We start with variables related to precautionary motives of holding reserves. Import ($\underline{imp}$) is the most robust regressor for reserves found by the empirical literature. Reserves are the "financing option of last resort" in covering a country's import demand, providing a natural link between these two variables. In a broader sense, imports can also be interpreted as a measure for real openness and therefore the vulnerability to external shocks of an economy. The buffer stock model introduced by Frenkel and Jovanovic (1981) suggests that the optimal level of reserve holdings by a country is affected by the opportunity cost of holding them. This is proxied by the interest rate differential between China and the US ($\underline{idif}$) in the paper. Another factor that we consider is external debt ($\underline{debt}$). The importance of external debts in determining a country's reserve levels has regained much attention since the 1997 Asian Financial Crisis, which can be seen from the now-famous Guidotti-Greenspan rule[10]. Due to data availability, we will only study the impact of total external debts in this paper. We also check whether volatility of exports ($\underline{vexp}$) can help to explain China's reserve holdings. It can be regarded as a measure for volatility in international transactions. If a country holds reserves to smooth its international transactions, then higher volatility in exports would justify the holding of more reserves. Two variables associated with domestic financial stabilities, volatility of inflation ($\underline{vcpid}$) and M2 to GDP ratio ($\underline{m2gdp}$), are also examined. The inclusion of inflation volatility is based on the view, shared by McKinnon and Schnab (2003) and McKinnon (2006), that China should peg its currency to the US dollar so as to provide a nominal anchor to its domestic price level and for most of the time reserves are helpful to maintaining such a peg. M2 to GDP ratio is a predictor for reserve holdings proposed

[10]The emphasis on the role of external debts in determining a country's reserve levels can in fact be traced back to at least a century ago. Please see Obstfeld, Shambaugh and Taylor (2008) for a quote from *Treatise on Money* (1930) by John Maynard Keynes.

by Obstfeld, Shambaugh and Taylor (2008), who emphasize the cushion effect of reserves against potential capital flight caused by domestic financial instabilities.

The modern mercantilism theory provides an alternative thought on explaining China's foreign reserves, claiming that China has been piling up reserves to keep an undervalued currency and promote exports. We take two different approaches to assess this story. One is to first estimate the deviation of the Chinese exchange rate from some benchmark value and then include such deviation in the VEC model to see whether it helps to explain China's foreign reserves. The deviation measure ($\underline{penn}$) used in this paper is based on the empirical regularity called the Balassa-Samuelson relation, which predicts an association between higher (appreciated) real exchange rate and higher level of real per capita income[11]. The other way is to directly include exchange rate ($\underline{exrt}$) in the VEC model and inspect how it interacts with reserves over time. When we proceed in this second way, we will also control for some other factors that may affect the exchange rate, including the real GDP growth rate of China relative to the rest of the world ($\underline{rgg}$) and China's external debt level ($\underline{debt}$). One last regressor studied in the paper is the real export growth rate ($\underline{expg}$). It is at the heart of the modern mercantilism theory and affects both reserves and exchange rates. We want to know whether buildup of reserve stocks has helped China to promote exports.

Investigation Scheme

The VEC model usually performs better with parsimonious specifications. It would be inefficient, and practically infeasible, to include all the regressors that we study in a single VEC model. Therefore an investigation scheme is designed, to help us identify the best predictors for China's reserve holdings while keeping the estimation results tractable.

We divide the regressors other than res into three groups. The first one consists of the "usual suspects" that have been tested extensively in the empirical literature on reserves, including imp, $idif$, $debt$ and $vexp$. There are two goals that we want to realize through the study of this group of regressors. One is to check how well these variables can explain China's reserve holdings and the other is to search for some benchmark specifications, to

[11]One may want to turn to more sophisticated "fundamentals-based" models to search for the equilibrium values of exchange rates. However, as Dunaway, Leigh and Li (2006) showed specifically for China, small changes in model specifications, explanatory variable definitions, and time periods used in estimation can lead to very substantial differences in equilibrium real exchange rate estimates.

which we can augment other regressors later on. We need such benchmark specifications because, as we will see in section 3, some regressors do not appear to be cointegrated with *res* by themselves. However, this does not necessarily imply that they cannot contribute to the explanations of reserves at all. We will do further examinations by adding them to the benchmark specifications before reaching the conclusions. The second group includes the two regressors associated with domestic financial stabilities, *vcpid* and *m2gdp*, and variables motivated by the modern mercantilism theory are in the third group. For these two groups, we will first check how well they can explain reserves by themselves. If the results are not satisfactory, we will then add them to the benchmark specifications and see whether they can bring some improvements.

Time-series models such as VEC and VAR are best known for their predictive capability. This is the key for our cross-specification comparisons. We will compare predictions by different models using the Diebold-Mariano test, taking both in-sample and out-of-sample forecasts into consideration. Furthermore, for models with good predictive power, we will check and see whether their implications are consistent with theories and previous empirical findings that motivate them. One possible way to do this is to look at the long-run relations among the regressors implied by the models, but a more informative method is to study the impulse response functions (IRF). When causal relations among the regressors are of particular interests, we will continue and estimate the structural form of the VEC model, and then implement post-estimation analysis with tools such as structural impulse response functions and forecast error variance decompositions (FEVD)[12].

All planned investigations will be carried out for both the full sample (1983Q1-2005Q4) and a subsample (1996Q1-2005Q4).

[12]There are several reasons why we want to study the nonstructural IRF, even for those models whose structural forms are estimated. First, for prediction purposes, we should look at the nonstructural IRF. Second, since previous panel regressions had no satisfactory solutions to the endogeneity problem, it is possible that they were merely estimating the correlations between reserves and the explanatory variables. If it is indeed so, we should look at the nonstructural IRF to see whether our results match previous findings. Finally, it is interesting to compare the structural and nonstructural results. The difference between them shows how crucial it is to take the endogeneity among the variables into consideration in order to find out the true causal relations among them.

3. Estimations and Empirical Findings

Data available for estimations in this study cover 1983Q1-2007Q4. The last two years (2006 and 2007) are saved for out-of-sample predictions, therefore the full sample used to estimate the VEC models ranges from 1983Q1 to 2005Q4. The Chinese economy has been in fast transitions since the start of its economic reform and opening in the late 1970s. Particularly, in the mid 1990s there were several important policy shifts regarding to China's exchange rate regime and foreign exchange management. To check whether our results are sensitive to the time frame, we will also estimate the models using the subsample from 1996Q1 to 2005Q4.

3.1 Full Sample (1983Q1-2005Q4)

Following the investigation scheme discussed in section 2, estimations using the full sample are summarized in Tables 2.1-3. The Diebold-Mariano test results for prediction comparisons are reported in Table 3[13].

Precautionary demand (1)

The VEC models in Table 2.1 involve four regressors other than res. They are imp, $idif$, $debt$ and $vexp$. An exhaustive search strategy is taken here, that is, models with all possible combinations of the four variables are estimated.

The first result to notice is that imp is the only variable that is cointegrated with res by itself, which is why the numbering of the models is inconsecutive in the first column of the table[14]. As we will see later, such a result stays true even if we take into consideration the other two variables motivated by precautionary demand, $vcpid$ and $m2gdp$. It suggests that if there is only one long-term determinant for China's foreign reserve holdings among these variables, it is most likely to be imp.

A more surprising result is that the simple VEC specification with only res and imp (F1_01) produces the best predictions for res among all the models in Table 2.1. From the table we can see that this specification has the smallest root mean squared error (RMSE)

[13]Predictions by different models were also compared using the Davidson-MacKinnon test. Since the results are largely consistent with those given by the Diebold-Mariano test, they are not reported.

[14]Here is an example of how we name the models. "Model F1_05" means that is the fifth model that we estimate for the first group of regressors using the full sample.

and root mean squared forecast error (RMSFE) for the *res* equation[15]. We can also see this result from the first part of Table 3, where model F1_01 is used as the benchmark for the Diebold-Mariano test. The test results show that the predictions for *res* by all the other specifications in Table 2.1 are worse than those by model F1_01. Although the differences are not statistically significant, such results at least show that the three variables, *idif*, *debt* and *vexp*, are not very essential to the explanation of China's reserve holdings.

As mentioned earlier, one purpose of studying this group of regressors is to look for benchmark specifications for later estimations. An ideal benchmark would be a simple model that produces a good fit for the variable to be explained. Model F1_01 meets both conditions. In addition, we will also use the model with *res*, *imp* and *idif* (F1_05) as a benchmark, which is a clear "second best" in terms of predictions among the models in Table 2.1.

One way to find out whether the estimation results are consistent with theories and previous empirical findings is to check the long-run relations among the regressors implied by the *res* equations. For instance, we can see from Table 2.1 that the long-run coefficients for *imp* in the *res* equations are all positive. This implies that China's reserve holdings will increase when its import to GDP ratio rises, which is in line with the theory that motivates *imp* as a regressor for *res*. It is worth noticing, however, that there are a few flaws in this method of interpreting a VEC model. First, the long-run interactions among the regressors shown by the VEC system may be different from those implied by a single equation[16]. Second, the long-run relations do not reveal the adjustment process through which the system returns to equilibrium after receiving a shock. Finally, as common to most time series models, individual coefficients for a VEC model are often statistically insignificant, making the interpretation on each one of them less meaningful. For these reasons, another tool for analyzing VEC estimation results, the impulse response functions (IRF), is more widely used.

The IRF of the two selected benchmark models are plotted in Figures 3.1 and 3.2, respectively. Both figures show that when *imp* receives a positive shock, *res* will first decrease, but then soon increase over time. It will rise for about 1.6 to 1.7 percentage point in 50 periods if the shock in *imp* is of unit size. On the other hand, *imp* will also

[15]For VEC models, RMSE is a measure for average in-sample prediction error. RMSFE is calculated based on one-period-ahead out-of-sample forecast errors.

[16]This complication can be caused by the multiple cointegrating relations among the regressors.

increase following a positive shock in res, but the response is less significant and has a much smaller size, only about 0.14 percentage point after 50 periods if the shock to res is of unit size. Although the result that res will respond positively to shocks in imp coincide with findings by previous studies, the adjustment processes depicted in these figures have different implications for the appropriate econometric tools that should be applied to analyzing reserve holdings. The IRF graphs show that it takes res very long to fully respond to the shock in imp, which implies that for most of the time the actual reserve levels might be different from the equilibrium ones. This articulates the measurement error problem associated with panel methods mentioned in the introduction.

Figure 3.2 shows that res will increase following a positive shock in $idif$. This is opposite to the prediction of the buffer stock model, which treats $idif$ as a measure for the opportunity cost of holding reserves. One possible explanation for such a finding is that higher relative returns to capital in China, reflected by higher interest rate differentials between China and the US, are likely to attract more capital inflows to China, and therefore push up its foreign reserve levels[17].

Another question raised earlier is whether China's current reserve holding behavior is different from what we observed in the past. Some clues to answering this can be found in the prediction errors. In the last part of Table 2.1 we see that for all the models, the mean prediction errors on res are slightly negative for the subsample period from 1983 to 1995, slightly positive for 1996-2005, and positive but of much bigger sizes for the out-of-sample period 2006-2007. This pattern seems to suggest that there is a systematic bias among the out-of-sample predictions made by the VEC models in Table 2.1 and China is holding more and more reserves over time. However, further examinations show that such statements are not quite accurate. Plotted in Figure 4 are the prediction errors on res by the benchmark model F1_01. Four big outliers can be seen in the graph, two in the early period, one for 1992Q3 and the other 1994Q1, two toward the end of the time line, one in 2004Q4 and the other 2007Q1[18]. When these outliers are excluded, there is no obvious shift of patterns among the prediction errors. In the last few columns of Table 2.1 we see

[17]We also estimate the structural forms of models F1_01 and F1_05, using the Cholesky decomposition and assuming res to be the "most endogenous" variable. For these models, the structural dynamics are qualitatively the same as what we see in the nonstructural results. They are not reported because later we will see similar analysis for more complicated models with better fits.

[18]The causes for the early outliers are relatively clear. The negative spike in 1992Q3 is most likely the result of China's large trade deficit in that period. The positive shock in 1994Q1 can be explained by the upsoaring of China's trade surplus following the RMB devaluation from 5.7 to 8.7 yuan/dollar.

that after excluding 2004Q4, model F1_01's mean prediction error on *res* for 1996-2005 is almost zero, and the mean for 2006-2007 without 2007Q1 actually turns slightly negative. Similar results are found for most other models as well, including those we will see later in Tables 2.2 and 2.3. This suggests that other than the two big positive shocks received in 2004Q4 and 2007Q1, China's reserve holding behavior in recent years is not very much different from before.

Precautionary demand (2)

We next study the two variables related to China's domestic financial stability, *vcpid* and *m2gdp*. Since no cointegrating relations are identified between these two variables and *res*, whether individually or combined together, we proceed by adding them to the two benchmark specifications and checking whether any improvement can be achieved. The estimation results are summarized in Table 2.2[19].

When *vcpid* is added to the benchmark specifications, the in-sample predictions for *res* by both models get better. The RMSEs of the *res* equations in models F2_04 (*res*, *imp*, *vcpid*) and F2_07 (*res*, *imp*, *idif*, *vcpid*) are 0.743 and 0.744, respectively, both smaller than the 0.768 of model F1_01 and 0.776 of model F1_05. This comes with the cost of slightly worse out-of-sample forecasts. The RMSFE for *res* of model F2_04 is 1.52, very close to the 1.517 of model F1_01, and model F2_07's 1.551 is slightly larger than the 1.535 of model F1_05. Taking both the in-sample and out-of-sample predictions into consideration, the Diebold-Mariano test results in Table 3 show that both new models, F2_04 and F_07, predict *res* better than the more fitting benchmark F1_01 does, and the improvement in model F2_07 is significant. Indeed F2_07 is the only model in Tables 2.1 and 2.2 whose predictions on *res* beat model F1_01 significantly. These results suggest that *vcpid* is a useful predictor for China's reserve holdings.

The addition of *vcpid* does not change the long-run coefficients of *imp* in the *res* equations by much, which still imply that *res* will rise following a positive shock in *imp*. The long-run coefficient of *idif* for *res* stays positive in model F2_07 and has become more significant. The long-run coefficients of *vcpid* in models F2_04 and F2_07 are both positive, though insignificant. They imply that when inflation becomes more volatile, China tends to hold more foreign reserves. These inferences based on the long-run coefficients have

[19]No cointegrating relation is found when the model includes *imp*, *idif*, *vcpid* and *m2gdp*, which would otherwise be model F2_09 in the table.

supports from the IRF of the two models, which are plotted in Figures 3.3 and 3.4, respectively. Both figures show that res will respond positively to a shock in *vcpid*, and the dynamics among res, imp and $idif$ are very similar to those seen in Figures 3.1 and 3.2.

If maintaining a nominal peg to the US dollar so as to stabilize the domestic price is part of the reason why China builds up its reserve stock, a conjecture that seems backed up the finding that rse will rise following a positive shock in *vcpid*, we would wonder how effective such a policy is. From the IRF in Figures 3.3 and 3.4, it seems that the sizes of *vcpid*'s responses to shocks in res are extremely small.

Yet we have to caution ourselves before drawing any conclusion, because the analyses based on Figures 3.3 and 3.4 are nonstructural. To figure out the exact causal relations among the regressors, we need to obtain the structural IRF by estimating the coefficient matrix A in equation (2). We only report the structural analysis for model F2_07 here. With similar identification assumptions, what we learn from model F2_04 are qualitatively the same as the findings for model F2_07.

The identification restrictions we impose to estimate the structural form of model F2_07 can be described by the following matrix equation:

$$A\varepsilon = \begin{pmatrix} 1 & a_1 & a_2 & a_3 \\ a_4 & 1 & 0 & 0 \\ a_5 & 0 & 1 & 0 \\ a_6 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \varepsilon_{res} \\ \varepsilon_{imp} \\ \varepsilon_{idif} \\ \varepsilon_{vcpid} \end{pmatrix} = \begin{pmatrix} v_{res} \\ v_{imp} \\ v_{idif} \\ v_{vcpid} \end{pmatrix} = v. \qquad (4)$$

With four variables in the model, the moment conditions implied by equation (3) allow ten coefficients to be estimated freely. Six of them are parameters a_1-a_6 shown in equation (4), and the other four will be the standard deviations for the elements of vector v. The first line of equation (4) is saying that in any period res is affected not only by its own structural shock, but also directly by contemporaneous structural shocks to all the other variables in the system. The rest of equation (4) says that structural shocks in res have direct impacts on the other variables as well, but variables other than res do not have direct interactions among them within the period when the structural shocks occur. Notice that this is weaker than assuming imp, $idif$ and *vcpid* are exogenous to each other, because, for instance, v_{imp} can still affect ε_{vcpid} through its impact on ε_{res}. In fact the structure laid out in equation (4) implies that no variable in the system is exogenous.

The structural IRF for model F2_07 based on the estimation of equation (4) are plotted in Figure 5.1.1[20]. The graphs in the third column are the responses of *res* to different structural shocks. They show that exogenous shocks to *idif*, *imp* and *vcpid* will all cause *res* to increase. Checking the impact of *res* on *vcpid* (the third graph in the last column), we still see that the responses of *vcpid* to shocks in *res* are very close to zero, with a perceivable size only in the period when the shock occurs. The ineffectiveness for *res* to affect *vcpid* can also be seen from the forecast error variance decompositions (FEVD) for model F2_07, which are plotted in Figure 5.1.2. The third graph in the last column shows that the proportion of the forecast error variance in *vcpid* that can be attributed to shocks in *res* is near zero. These results imply that China tends to hold more reserves when its domestic inflation gets more volatile, but if it wants to reduce the inflation volatility by piling up reserves, that has not been an effective policy tool[21].

In contrast to *vcpid*, the models with *m2gdp* added, including F2_05 (*res*, *imp*, *m2gdp*), F2_06 (*res*, *imp*, *vcpid*, *m2gdp*) and F_08 (*res*, *imp*, *idif*, *m2gdp*), all have substantial deteriorations in the overall fits of the *res* equation and therefore higher RMSEs, relative to the benchmark specifications. The test results in Table 3 show that their predictions on *res* are significantly worse than those of model F1_01. Such findings lend little support to the hypothesis that increased financial depth is the main reason why China is holding increasingly more reserves. Two of the models, F2_05 and F2_06, have better out-of-sample forecasts than the benchmark model F1_01. This could be a sign of the decreased sterilization ability of the People's Bank of China, which leads to a stronger correlation between China's reserve holdings and its money stocks.

Modern mercantilism

The models estimated so far are based upon economic theories associated with various precautionary motives. But do these theories really give us any edge over "dumb" models such as ARIMA? The comparison results between our theory-based models and a selected ARIMA model are reported in the last part of Table 3. They show that among the models estimated so far, the two benchmark specifications we chose and the two models with *vcpid* added to them do perform better in predicting *res* than the ARIMA(4,1,2) model does. However, the gains are not statistically significant. In this part we will estimate models

[20]Estimation results of equation (4) and structural forms of other models are provided in Table A4.

[21]Compared to these structural results, the nonstructural dynamics for model F2_07 do not seem to be very misleading. However, as we will see later, not taking account of the endogeneity structure among the regressors will sometimes lead us to different or even wrong conclusions.

motivated by the modern mercantilism theory. As a preview of the results, some of the models beat not only the ARIMA model, but also the benchmark specifications, both with statistical significance.

We attempt two different approaches to construct the VEC models following the thought of modern mercantilism. One is to first estimate the deviation of China's exchange rate from some benchmark value and then use the deviation as a regressor to explain China's reserves[22]. The other is to directly include exchange rate as a regressor in the VEC model. Results using these approaches are reported respectively in the two panels of Table 2.3.

In the first panel of the table, although the deviation measure *penn* and its combination with *expg* both appear to be cointegrated with *res* (models F3_01 and F3_02), the fits of the *res* equations in these two models are much lower than the benchmark specifications. The Diebold-Mariano test results in Table 3 suggest that their predictions on *res* are significantly worse than those of model F1_01. The test between models F3_03 (*res*, *imp*, *penn*) and F1_01 favors model F3_03, but the very high p-value (0.947) implies that the difference between their predictions is just trivial. The prediction performances of models F3_04 (*res*, *imp*, *penn*, *expg*) and F3_05 (*res*, *imp*, *idif*, *penn*) are both worse than model F1_01.

The only specification that looks promising in the first panel of Table 2.3 is model F3_06 (*res*, *imp*, *idif*, *penn*, *expg*). Although its RMSE and RMSFE for *res* are both larger than those of the benchmark models, the overall fit of its *res* equation is so high that the Diebold-Mariano test suggests that its predictions on *res* are significantly better than those of model F1_01.

Since this model is motivated by modern mercantilism, we have to check whether its implications are consistent with the theory, before we can claim a success. Unfortunately the model fails the check. A key piece of modern mercantilism is the negative (depreciating) effect of reserve piling on the exchange rate. But the IRF graph of *penn* to *res* in Figure 3.5 (the last picture in the second to last column) suggests the opposite. We see that *penn* will rise following a positive shock in *res*, which implies a either less under-valued or more over-valued Chinese currency.

Are these positive responses of *penn* to *res* merely a correlation or they actually reflect the structural relation between them? We estimate the structural form of model F3_06

[22]Please refer to section 2 and the data appendix for details on the deviation measure used here.

with restrictions in equation (5)[23]:

$$A\varepsilon = \begin{pmatrix} 1 & a_1 & a_2 & a_3 & a_4 \\ a_5 & 1 & 0 & a_6 & a_7 \\ a_8 & 0 & 1 & 0 & 0 \\ a_9 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & a_{10} & 1 \end{pmatrix} \begin{pmatrix} \varepsilon_{res} \\ \varepsilon_{imp} \\ \varepsilon_{idif} \\ \varepsilon_{penn} \\ \varepsilon_{expg} \end{pmatrix} = \begin{pmatrix} \upsilon_{res} \\ \upsilon_{imp} \\ \upsilon_{idif} \\ \upsilon_{penn} \\ \upsilon_{expg} \end{pmatrix} = \upsilon, \tag{5}$$

where *res* is again assumed to be directly affected by all the structural shocks, and it has direct influences on all the other variables as well, except *expg*. The only variable that affects *expg* directly is *penn*. Also assumed in equation (5) is that *imp* will be directly affected by the deviation of exchange rate from its benchmark and the growth rate of real exports[24]. The structural IRF in Figure 5.2.1 show that although a positive shock in *res* causes *penn* to drop (the Chinese currency depreciates) immediately, such a negative effect lasts only very briefly, for about 4 periods, and then turns positive with even larger magnitude. More importantly, the stimulus that a *res* shock gives to *expg* is also temporary (the last graph in the first column), whose size is much smaller than the subsequent decrease of *expg*. For most of the time the effect of *res* on *expg* stays negative. These can hardly be interpreted as strong evidence supporting the modern mercantilism theory.

However, the fail of models F3_01-06 is not the end of the road. Rather, a careful look at the deviation variable *penn* suggests that the problem probably lies in the imperfect benchmark measure for the exchange rate. In the data appendix we can see that the correlation between *penn* and *exrt* is almost one, and the reason is that the benchmark exchange rates based on the Balassa-Samuelson relation are not nearly as volatile as the actual exchange rate series[25]. Since *penn* is essentially the same series as *exrt*, it leads us to our second approach of constructing the VEC model, that is, to directly include *exrt* as a regressor.

Thus far we have centered the VEC models around *res*, because it is this variable that we want to explain. But if the immediate target of China's reserve policy is the exchange

[23]We tried alternative sets of restrictions with slight modifications to equation (5). The conclusion remained the same.

[24]We assume that *imp* is directly affected by *expg* because processing trade accounts for a large proportion in China's exports.

[25]It could be related to "the exchange rate disconnect puzzle", as termed by Obstfeld and Rogoff (2000).

rate, as suggested by the modern mercantilism theory, logically we should also control other factors that influence the exchange rate in the VEC model. This is the thinking that underlies models F3_07-10, which are reported in the second panel of Table 2.3.

The main control variable added to these models is *rgg*, China's real GDP growth rate relative to the rest of the world. We use it as a proxy for relative productivity, which has been proposed by the literature as a determinant for real exchange rate. If reserves affect exchange rate as a demand factor for foreign exchanges, then external debt can be thought of as a component on the supply side. It is controlled in two of the models and turns out be a helpful regressor.

We now check the details of these models and first verify that both *expg* and *debt* are helpful to the explanation of China's reserve holdings. Export growth rate, *expg*, is left out by models F3_07 (*res*, *rgg*, *exrt*) and F3_09 (*res*, *debt*, *exrt*). When it is added to model F3_07, the improvement seen in model F3_08 (*res*, *rgg*, *exrt*, *expg*) is very significant. The R^2 of the *res* equation increases from 0.29 to 0.52, and both the RMSE and RMSFE become smaller. The improvement of model F3_10 (*res*, *debt*, *exrt*, *expg*) over F3_09 is not as dramatic, but still obvious. The R^2 of the *res* equation increases from 0.53 to 0.58, although the RMSE gets higher, from 0.76 to 0.78, due to increased number of regressors. Model F3_10's RMSFE (1.373) is much smaller than that of model F3_09 (1.473), which implies better out-of-sample forecasts by model F3_10. The contribution of *debt* can be seen in a similar way, if we compare model F3_09 to model F3_07 and model F3_10 to model F3_08.

How well do these models perform relative to the other models we discussed earlier? Models F3_08-10 turn out to have the best predictive power among all the models. From Tables 2.1-3 we see that they have the highest overall fits for the *res* equation, much higher than most other models, although their RMSEs are not particularly small due to increased number of regressors. They also have the best out-of-sample forecasts, reflected by their small RMSFEs. The Diebold-Mariano test results in the last part of Table 3 show that they are the only models whose predictions beat the ARIMA(4,1,2) model significantly. They outperform the benchmark specification F1_01 as well, and the difference is significant for model F3_10. The middle part of Table 3 compares model F3_10 to all the other models, which shows that it has the best predictions for *res* and the gains over most models are significant.[26].

[26]Test results not reported in tables 3 show that models F3_08 and F3_09 also have better predictions for *res* than all the early models. But their dominances are not as significant as model F3_10.

One last task is to verify whether the implications of these models are consistent with the story of modern mercantilism. As we will see, the three models all seem supportive to the theory that motivates them.

We start with model F3_08. At a first look, its IRF graphed in Figure 3.6 do not appear to be exactly what is visioned by the modern mercantilism theory. In particular, they show that following a positive shock to *res*, *exrt* will appreciate (the third graph in the second column), and *expg* will first have a temporary rise, but then the impact will fluctuate around zero until it dies out over time (the third graph in the first column).

For this model, however, the structural IRF in Figure 5.3.1 and FEVD in Figure 5.3.2 suggest a different story. Their underlying structural form is estimated by imposing the following restrictions[27]:

$$A\varepsilon = \begin{pmatrix} 1 & a_1 & a_2 & 0 \\ a_3 & 1 & a_4 & a_5 \\ 0 & a_6 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \varepsilon_{res} \\ \varepsilon_{exrt} \\ \varepsilon_{expg} \\ \varepsilon_{rgg} \end{pmatrix} = \begin{pmatrix} v_{res} \\ v_{exrt} \\ v_{expg} \\ v_{rgg} \end{pmatrix} = v. \qquad (6)$$

Equation (6) assumes *rgg* to be exogenous to contemporaneous structural shocks to the other variables, *exrt* to be directly affected by structural shocks to all the variables, *res* by all the variables but *rgg*, and *expg* only by itself and *exrt*. In Figure 5.3.1 we see that a positive shock in *res* leads *exrt* to depreciate (the third graph in the second column), and this is not a simple correlation between *res* and *exrt* because the second graph in the third column shows that a positive shock in *exrt* will cause *res* to increase. In addition, the figure shows that *res* has a sizable positive impact on *expg* right after the shock, which becomes smaller over time but stays positive throughout. Furthermore, Figure 5.3.2 indicates that shocks to *res* account for a big proportion in the forecast error variances of both *exrt* and *expg*. These results all match the story told by the modern mercantilism theory, and the importance of taking account of the endogeneity structure is manifested by the difference between the structural and nonstructural dynamics.

Figures 3.7 and 3.8 are the IRF of models F3_09 and F_10, respectively. Since the dynamics in Figure 3.7 are similar to those seen in Figure 3.8, and because model F3_09 misses the variable *expg*, we will focus our discussions on model F3_10. Figure 3.8 shows that following a positive shock in *res*, *exrt* will first appreciate (the second to last graph

[27]We also tried other sets of restrictions with slight modifications to equation (6). The results are qualitatively the same.

in the third column). Such a positive effect lasts for about 15 periods and then turns negative, with an increased size over time until becoming constant after about 35 periods of the initial shock. In the mean time, except for a very short period, the influence of res on $expg$ stays positive and remains sizable even after 50 periods of the shock. These findings seem to support the modern mercantilism theory, because we see both of its key components, the negative effect of res on $exrt$ and its positive effect on $expg$. But their supports are much weakened by the result that the the exchange rate will first appreciate for a substantial period of time following a positive shock in reserves.

Nonetheless, further examinations show that such appreciation is not the structural response of the exchange rate to an exogenous shock in reserves. The estimation of the structural form of model F3_10 is based on the following identification assumptions:

$$A\varepsilon = \begin{pmatrix} 1 & a_1 & a_2 & a_3 & 0 \\ a_4 & 1 & a_5 & a_6 & a_7 \\ 0 & a_8 & 1 & 0 & 0 \\ a_9 & a_{10} & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \varepsilon_{res} \\ \varepsilon_{exrt} \\ \varepsilon_{expg} \\ \varepsilon_{debt} \\ \varepsilon_{rgg} \end{pmatrix} = \begin{pmatrix} v_{res} \\ v_{exrt} \\ v_{expg} \\ v_{debt} \\ v_{rgg} \end{pmatrix} = v. \tag{7}$$

Equation (7) is similar to equation (6). With *debt* in the system, it assumes that this newly added variable will directly interact with res and $exrt$, but not $expg$ and rgg. The structural IRF are graphed in Figure 5.4.1, which shows a clearer negative effect of res on $exrt$ than Figure 3.8 does. In the second last graph of the third column, we see that a positive structural shock in res will cause $exrt$ to depreciate immediately, and the impact will decrease over time but always be negative. The influence of res on $expg$ stays mostly positive and has a notable size for the about 10 periods (the second to last graph in the second column). The FEVD graphs in Figure 5.4.2 show that res is the most important variable in explaining the short-term forecast errors in $exrt$, but such importance fades away as the forecast horizon increases. For $expg$, res accounts for about 10% of the variance in its short-term forecast errors, and as the forecast horizon increases, the proportion gradually reduces to around 5%. These results all look confirmative to the mercantilism explanation for China's reserve holdings and they also suggest that such a policy is effective for China..

3.2 Subsample (1996Q1-2005Q4)

Factors such as exchange rate regime and financial openness are often considered in the empirical literature on reserves. We control these aspects and test the robustness of our previous findings by studying a subsample period, 1996Q1-2005Q4, during which the exchange rate arrangements and foreign reserve management policies for China remained relatively stable[28]. We follow the same investigation scheme as before. The estimations are summarized in Tables 4.1-3, and the Diebold-Mariano test information between predictions is reported in Table 5. As we will see, the results are largely consistent with those for the full sample.

Precautionary demand (1)

In Table 4.1 the model that produces the best predictions for *res* is again the simplest specification with only *res* and *imp* (S1_01). Although some other models have better overall fits for *res* and therefore smaller RMSEs, the test results in Table 5 show that if both the in-sample and out-of-sample forecasts are taken into consideration, predictions by model S1_01 are still the most accurate ones. The only regressor other than *imp* that is cointegrated with *res* by itself is *idif* (S1_02). But due to a larger number of regressors coupled with a poorer fit for the *res* equation, model S1_02 has a much larger RMSE than model S1_01. Another difference between Table 4.1 and Table 2.1 is that model S1_05 (*res*, *imp*, *idif*) is no longer the "second best" in Table 4.1. But for comparison purposes, we will keep it as a benchmark specification for later estimations.

The IRF of model S1_01 are plotted in Figure 6.1. The interactions between *res* and *imp* look qualitatively very similar to those seen in Figure 3.1, that is, *res* will rise following a positive shock in *imp*, and vice versa. Quantitatively, the long-run responses of *res* to shocks in *imp* seem to have larger sizes than the previous results for the full sample,

[28]Because of the 1997 Asian Financial Crisis, many previous panel studies take that year as the cutting points for their subsamples. However, China is a special case in at least two senses. First, thanks to an almost closed domestic financial market, the impact of the 1997 Asian Financial Crisis on China was much smaller than those on many other countries. Second, there were no significant changes in China's foreign reserve and exchange rate policies around the time of the financial crisis. In our sample period, other than some new measures adopted in late 2005, China's most significant reform steps regarding to foreign reserves and exchange rates were all taken between 1994 and early 1996. 1994 and 1995 are excluded from our subsample to avoid some transitional fluctuations, especially those caused by the RMB devaluation in 1994.

which probably reflects a more cautious standpoint taken by the Chinese policymakers when the economy becomes more open.

As before, model S1_01's prediction errors on *res* graphed in Figure 7.1 suggest 2004Q4 and 2007Q1 as the two largest outliers. It should be noted, however, that unlike for the full sample, such a pattern in the prediction errors is not robust across all the subsample models. For instance, model S3_10, which will be discussed later, shows in Figure 7.2 that China also received a big positive shock in 2007Q2. One possible reason why the results become weaker could be the fewer degrees of freedom in the subsample estimations.

Comparing model S1_01 to model F1_01, we see that the full sample estimation has a smaller RMSFE for the *res* equation, which implies better out-of-sample forecasts. The same is also true for most other specifications, suggesting that the early years in the sample period, 1983-1995, probably contain useful information for the predictions of China's reserve holdings.

Precautionary demand (2)

The Diebold-Mariano test results in Table 5 indicate that four models in Table 4.2 have better predictions on *res* than model S1_01. But since no improvements brought about by these models are actually significant, we will keep our focus on model S2_07 and compare its results to model F2_07, which was found earlier to have one of the best predictive performances on *res* for the full sample[29].

The IRF of model S2_07 are plotted in Figure 6.2. The dynamics between *res* and the other regressors are similar to what we saw in Figure 3.4 for model F2_07. The structural form of model S2_07 is estimated with the same assumptions as those for model F2_07, and the structural IRF and FEVD are in Figures 8.1.1 and 8.1.2, respectively. A difference between Figure 8.1.1 and Figure 5.2.1 is that Figure 8.1.1 shows a more evident negative effect of *res* on *vcpid* (the third graph in the last column). Nonetheless, Figure 8.1.2 still suggests that shocks in *res* play almost no role in accounting for the forecast error variance of *vcpid*. Together these results do not bring much change to the conclusions we reached before, that is, inflation volatility is a helpful predictor for China's reserve holdings, but piling up reserves does not appear to be an effective policy tool for China to reduce its inflation volatility.

[29]The models that beat model S1_01 are S2_05, S2_06, S2_07 and S2_09. Model S2_07 has the best predictions on *res* among them, albeit by insignificant margins.

Modern mercantilism

Previously in the full sample study, in spite of model F3_06's good predictions on *res*, we refrained from claiming it a success for the reason that the dynamics shown by the model were not consistent with its underlying theory. The judgement is easier to make in the subsample case, because model S3_06 does not have good predictions on *res* in the first place. In Table 5 we see that its predictions are worse than those by the benchmark model S1_01, and significantly worse than those of model S3_10. As for the other models in the first panel of Table 4.3, there is no substantial difference between them and their full-sample counterparts in Table 2.3, except that no cointegrating relation is identified for specification S3_03, whereas the regressors were found cointegrated in model F3_03.

On the other hand, there are a couple of interesting changes in the second panel of Table 4.3. The first one is that unlike model F3_07, whose predictions on *res* are much worse than those of model F1_01, model S3_07 beats its benchmark, model S1_01. This implies that, at least relative to *imp*, *exrt* has a closer relation with *res* in the subsample period than in the full sample. The other change is that the relative fit of model S3_09 is not as good as model F3_09. In the full sample, the addition of either *expg* or *debt* brings a big improvement to model F3_07, and the fits of models F3_08 and F3_09 are close to each other. In the subsample, adding *expg* still improves model S3_07, but adding *debt* alone actually makes it worse. This suggests that *expg* is probably playing a more crucial role in explaining *res* during the subsample period.

In the full sample, models F3_08-10 have the best predictions on *res* among all the models. The same is still true for models S3_08 and S3_10. In the first part of Table 5, we see that model S3_10 is the only one whose predictions on *res* are significantly better than model S1_01. Although the improvement of model S3_08 over model S1_01 is insignificant, it has the lowest p-value for the Diebold-Mariano test among all the models other than S3_10 which beat model S1_01. The second part of Table 5 shows that model S3_10 has the best predictions on *res* among all the models[30]. In the last part of Table 5, we see that model S3_08 is the only one which significantly outperforms the ARIMA(1,1,1) model in predicting *res*. Among the other models beating ARIMA(1,1,1), model S3_10 has the second lowest p-value, only next to model S3_07.

The structural analyses on models S3_08 and S3_10 also support the modern mercantilism theory. Before checking the structural results, we still first take a look at the

[30] Tests between model S3_08 and the other models, except model S3_10, have similar results.

nonstructural IRF of the two models, graphed in Figures 6.3 and 6.4, respectively. The effects of a positive shock to *res* are similar in these two figures, that is, it has only temporary negative effects on *exrt* and temporary positive effects on *expg*. Again, taking account of the endogeneity structure among the regressors brings us different stories. The structural forms of models S3_08 and S3_10 are estimated with the same assumptions as before, and their structural IRF are Figure 8.2.1 and Figure 8.3.1, respectively. Both figures suggest that the negative effect of *res* on *exrt* and its positive impact on *expg* are permanent. Besides, the FEVD of model S3_08, Figure 8.2.2, suggests that *res* accounts for about 20% of the forecast error variance in *exrt*, and its share in *expg*'s forecast error variance mostly falls between 7% and 20%. The same proportions shown by Figure 8.3.2, the FEVD of model S3_10, are even bigger. In summary, the evidence supporting the modern mercantilism explanation of China's reserve holdings that we found earlier is robust in the subsample period of 1996Q1-2005Q4, and the difference between the structural and nonstructural results demonstrates once again that the endogeneity among the regressors must be taken into consideration in order to identify the true causal relations among them.

4. Conclusion and Future Work

This paper tries to empirically explain the stunning increase in China's foreign reserve holdings over the past two decades. Unlike most other studies in the current literature, it investigates the question from a time series perspective, because panel regressions, the commonly-adopted methods, face several critical limitations in analyzing reserve holdings.

The difficulties encountered by panel regressions include heterogeneity across the sample countries, nonstationarity of the data series, endogeneity among the regressors and measurement errors associated with the optimal reserve levels. We show in the paper that all these problems can lead to serious bias in the estimation results of panel regressions, and the time-series VEC model, on the other hand, can handle them better. Another consideration favoring the VEC model is that its dynamic analysis allows us to evaluate the effectiveness of China's reserve policy in achieving different goals.

The VEC models estimated in the paper are motivated by two strands of early work on reserves, the precautionary demand theories and the modern mercantilism theory. For both the full sample (1983Q1-2005Q4) and the subsample (1996Q1-2005Q4), we find that models based on modern mercantilism perform better in predicting China's foreign reserves than selected ARIMA models and those constructed on precautionary grounds, both with statistical significance. This suggests that previous econometric studies, whose emphasis has been overwhelmingly placed on precautionary motives, might have missed some more important factors in explaining China's reserve holdings. Further structural analyses on these models show that the buildup of reserve stocks by China has a negative (depreciating) effect on its real exchange rate and a positive impact on its export growth, which corroborates the conjecture that the recent increase in China's reserve holdings is a part of its export-led development strategy. When interpreted in the broader context of current global imbalances, such results seem to support the view that China should play a more active role in the adjustment process by reevaluating its currency and/or adopting a more flexible exchange rate regime.

Among considerations related to precautionary motives, imports and associated risks, such as real openness of the economy, appear to be the most important determinants for China's reserves holdings. Volatility of inflation and the interest rate differential between China and the US are also helpful predictors. But our results suggest that if China wants to reduce its inflation volatility by piling up reserves, it has not been an effective policy tool. The estimated impact of interest rate differential on China's reserve holdings is opposite to that predicted by the Frenkel and Jovanovic buffer stock model, probably because higher returns to capital in China, reflected by higher interest rate differentials, attract more capital inflows to China and therefore push its reserve levels up. We find little evidence to support volatility of exports and domestic financial depth as crucial factors in explaining China's reserve holdings.

Due to a relatively short sample period, the observations available for our estimations are not particularly abundant, which is especially evident when we study the subsample. One possible way to alleviate such a scarcity of observations is to use information with higher frequency, such as monthly data. Using such data will also bring an extra benefit for the structural analysis, because the identification assumptions imposed for structural estimations often hold better with a shorter period span.

We have argued that panel regressions are not the most appropriate tools for analyzing foreign reserve holdings. But it by no means implies that cross-country information is not important for the understanding of reserve holdings. Rather, our work suggests that a better way to exploit such information is probably to first apply the method of this paper to individual countries, correctly identify the most relevant determinants for each one of them, and then do the cross-country comparison.

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Table - 1 Illustration of Spurious Regression

Panel 1. Johansen Cointegration Test

Variables: *res* , *imp* Sample period: 1983Q1-2005Q4

Country	Obs.	Lags[!]	Rank = 0			Rank = 1		
			Trace statistic	10% cv	1% cv	Trace statistic	10% cv	1% cv
China	91	1	27.53	13.43	20.04	2.67*	2.71	6.65
Korea	91	1	9.92*	13.43	20.04	1.01	2.71	6.65

[!] Selection of lag order is based on Schwarz-Bayesian information criterion

* Rank of cointegration suggested by test results

Panel 2. OLS and Panel Regressions

Country	Dep. Var.	Obs.	Coef. of *imp*	t-stat	Adj. R2
China	*res*	92	1.31	14.13	0.69
Korea	*res*	92	0.89	3.25	0.10
China & Korea	*res*	184	0.34	4.19	0.08

Table 2.1 VEC Models - Precautionary Demand (1), 1983Q1-2005Q4

Model	Regressors	# obs.	# lag	# ci.	R^{2*}	RMSE	RMSFE	Implied long-run relation, res=				Mean Prediction Error						
								imp[#] (5.43)	idif (6.04)	debt (2.08)	vexp (0.48)	83-95	96-05	06-07	04Q4	96-05 w/o 04Q4	07Q1	06-07 w/o 07Q1
F1_01[%]	imp	90	2	1	0.39	0.768	1.517	5.62 (1.48)				-0.05	0.07	0.38	2.67	0.00	4.07	-0.14
F1_05	imp idif	90	2	2	0.39	0.776	1.535	4.49 (2.79)	0.39 (0.49)			-0.05	0.06	0.45	2.66	0.00	4.14	-0.08
F1_06	imp debt	89	3	1	0.35	0.817	1.809	1.39 (0.35)		0.43 (0.82)		-0.14	0.17	0.88	3.36	0.09	4.82	0.31
F1_07	imp vexp	90	2	1	0.36	0.793	1.730	2.4 (202.1)			-3.05 (2046)	-0.16	0.20	0.90	2.81	0.13	4.64	0.37
F1_08	idif debt	89	3	1	0.32	0.833	1.685		4.23 (5.23)	1.38 (11.38)		-0.13	0.16	0.54	3.73	0.07	4.42	-0.02
F1_09	idif vexp	90	2	1	0.25	0.858	1.640		2.14 (0.9)		1.43 (8.99)	-0.15	0.19	0.61	3.58	0.11	4.47	0.06
F1_10	debt vexp	87	5	1	0.40	0.830	1.737			19.76 (14.88)	-93.38 (79.59)	-0.11	0.13	0.65	3.05	0.06	4.39	0.12
F1_11	imp idif debt	89	3	1	0.38	0.810	1.720	1.69 (1.7)	-0.57 (0.71)	0.21 (3.34)		-0.14	0.17	0.75	3.32	0.09	4.58	0.21
F1_12	imp idif vexp	90	2	2	0.36	0.799	1.731	2.4 (6.16)	0.11 (1.59)		-2.48 (27.68)	-0.15	0.19	0.90	2.79	0.12	4.64	0.37
F1_13	imp debt vexp	90	2	1	0.29	0.837	1.678	1.14 (1.24)		-0.72 (1.1)	3.36 (7.62)	-0.13	0.16	0.71	3.28	0.08	4.56	0.16
F1_14	idif debt vexp	89	3	1	0.33	0.840	1.641		2.5 (1.46)	7.29 (8.86)	-27.53 (34.18)	-0.13	0.15	0.40	3.60	0.07	4.25	-0.15
F1_15	imp idif debt vexp	89	3	1	0.39	0.814	1.658	2.02 (2.09)	-0.62 (0.93)	-2.69 (7.88)	11.93 (21.59)	-0.14	0.17	0.63	3.15	0.09	4.41	0.08

* Statistics and coefficients reported in this table are those of the *res* equations.

[#] In parentheses are standard deviations of regressors and estimated coefficients.

[%] Inconsecutive numbering of models is due to specifications for which no cointegrating relations are identified. Models missing include: F1_02 (*res* , *idif*), F1_03 (*res* , *debt*) and F1_04 (*res* , *vexp*).

Table 2.2 VEC Models - Precautionary Demand (2), 1983Q1-2005Q4

Model	Regressors	# obs.	# lag	# ci.	R^{2*}	RMSE	RMSFE	Implied long-run relation, res=				Mean Prediction Error						
								imp# (5.43)	idif (6.04)	vcpid (0.34)	m2gdp (0.38)	83-95	96-05	06-07	04Q4	96-05 w/o 04Q4	07Q1	06-07 w/o 07Q1
F2_04%	imp vcpid	90	2	1	0.44	0.743	1.520	5.72 (2.83)		11.05 (45.39)		-0.09	0.11	0.35	2.31	0.06	4.11	-0.18
F2_05	imp m2gdp	91	1	1	0.31	0.805	1.501	-9.28 (10.78)			60.5 (80.09)	-0.09	0.12	0.14	3.08	0.04	3.75	-0.38
F2_06	imp vcpid m2gdp	91	1	1	0.32	0.799	1.498	-9.51 (21.38)		-26.2 (42.88)	56.31 (248.8)	-0.10	0.13	0.12	3.06	0.06	3.73	-0.39
F2_07	imp idif vcpid	90	2	2	0.45	0.744	1.551	4.04 (4.62)	0.91 (0.54)	7.34 (46.94)		-0.07	0.08	0.45	2.28	0.03	4.22	-0.09
F2_08	imp idif m2gdp	90	2	1	0.34	0.806	1.590	0.68 (6.3)	4.55 (3.23)		-20.31 (167.7)	-0.15	0.18	0.70	2.85	0.12	4.38	0.17

* Statistics and coefficients reported in this table are those of the *res* equations.

In parentheses are standard deviations of regressors and estimated coefficients.

% Models missing include: F2_01 (*res* , *vcpid*), F2_02 (*res* , *m2gdp*), F2_03 (*res* , *vcpid* , *m2gdp*) and F2_09 (*res, imp, idif, vcpid, m2gdp*).

Table 2.3 VEC Models - Modern Mercantilism, 1983Q1-2005Q4

Model	Regressors	# obs.	# lag	# ci.	R^{2*}	RMSE	RMSFE	Implied long-run relation, res=				Mean Prediction Error						
								imp[#] (5.43)	idif (6.04)	penn (30.0)	expg (13.1)	83-95	96-05	06-07	04Q4	96-05 w/o 04Q4	07Q1	06-07 w/o 07Q1
F3_01	penn	90	2	1	0.29	0.830	1.543			0.31 (0.66)		-0.03	0.04	0.37	3.42	-0.05	4.15	-0.17
F3_02	penn expg	91	1	2	0.29	0.820	1.500			0.16 (0.29)	-0.48 (0.62)	-0.03	0.03	0.32	3.26	-0.05	3.87	-0.19
F3_03	imp penn	90	2	1	0.40	0.766	1.544	4.08 (25.08)		0.26 (3.49)		-0.09	0.11	0.48	2.55	0.05	4.16	-0.05
F3_04	imp penn expg	88	4	2	0.41	0.820	1.655	3.47 (15.97)		0.33 (3.21)	-0.61 (2.17)	-0.09	0.11	0.46	2.83	0.04	4.27	-0.08
F3_05	imp idif penn	90	2	2	0.40	0.773	1.600	3.28 (1.46)	0.27 (0.76)	0.21 (0.1)		-0.09	0.12	0.63	2.55	0.06	4.31	0.10
F3_06	imp idif penn expg	88	4	3	0.48	0.791	1.563	3.57 (2.33)	-0.21 (1.4)	0.27 (0.15)	-0.19 (0.61)	-0.08	0.10	0.44	2.45	0.04	3.97	-0.07

Model	Regressors	# obs.	# lag	# ci.	R^2	RMSE	RMSFE	Implied long-run relation, res=				Mean Prediction Error						
								rgg (3.52)	debt (2.08)	exrt (0.31)	expg (13.1)	83-95	96-05	06-07	04Q4	96-05 w/o 04Q4	07Q1	06-07 w/o 07Q1
F3_07	rgg exrt	91	1	1	0.29	0.815	1.478	-0.67 (0.13)		14.48 (17.6)		0.01	-0.01	0.19	3.29	-0.10	3.71	-0.31
F3_08	rgg exrt expg	86	6	1	0.52	0.789	1.446	-0.84 (1.15)		113.3 (206.2)	5.67 (4.51)	-0.06	0.07	0.59	2.85	0.00	3.54	0.16
F3_09	rgg debt exrt	87	5	2	0.53	0.760	1.473	1.42 (2)	0.32 (2.64)	-19.63 (8.09)		-0.09	0.11	0.05	2.49	0.05	3.41	-0.43
F3_10	rgg debt exrt expg	86	6	3	0.58	0.780	1.373	1.51 (19.63)	2.45 (30.19)	-72.38 (59.82)	-1.49 (6.38)	-0.10	0.12	0.31	2.32	0.06	3.29	-0.12

* Statistics and coefficients reported in this table are those of the *res* equations.

[#] In parentheses are standard deviations of regressors and estimated coefficients.

Table 3 Comparison of Predictions on Reserves (Full Sample) *

Benchmark 1: F1_01			Benchmark 2: F3_10			Benchmark 3: ARIMA(4,1,2)		
Model	Predictions relative to benchmark	P-value[#]	Model	Predictions relative to benchmark	P-value	Model	Predictions relative to benchmark	P-value
						F1_01	better	0.522
F1_05	worse	0.635	F1_05	worse	0.083	F1_05	better	0.55
F1_06	worse	0.199	F1_06	worse	0.035	F1_06	worse	0.125
F1_07	worse	0.14	F1_07	worse	0.03	F1_07	worse	0.392
F1_08	worse	0.164	F1_08	worse	0.017	F1_08	worse	0.138
F1_09	worse	0.09	F1_09	worse	0.013	F1_09	worse	0.075
F1_10	worse	0.399	F1_10	worse	0.026	F1_10	worse	0.847
F1_11	worse	0.322	F1_11	worse	0.031	F1_11	worse	0.56
F1_12	worse	0.158	F1_12	worse	0.037	F1_12	worse	0.482
F1_13	worse	0.128	F1_13	worse	0.019	F1_13	worse	0.136
F1_14	worse	0.143	F1_14	worse	0.018	F1_14	worse	0.33
F1_15	worse	0.379	F1_15	worse	0.036	F1_15	better	0.881
F2_04	better	0.147	F2_04	worse	0.093	F2_04	better	0.251
F2_05	worse	0.015	F2_05	worse	0.026	F2_05	worse	0.801
F2_06	worse	0.028	F2_06	worse	0.03	F2_06	worse	0.899
F2_07	better	0.082	F2_07	worse	0.14	F2_07	better	0.226
F2_08	worse	0.099	F2_08	worse	0.038	F2_08	worse	0.849
F3_01	worse	0.088	F3_01	worse	0.023	F3_01	worse	0.476
F3_02	worse	0.046	F3_02	worse	0.027	F3_02	worse	0.702
F3_03	better	0.947	F3_03	worse	0.032	F3_03	better	0.477
F3_04	worse	0.579	F3_04	worse	0.045	F3_04	better	0.566
F3_05	worse	0.724	F3_05	worse	0.032	F3_05	better	0.549
F3_06	better	0.075	F3_06	worse	0.15	F3_06	better	0.146
F3_07	worse	0.096	F3_07	worse	0.031	F3_07	worse	0.757
F3_08	better	0.193	F3_08	worse	0.074	F3_08	better	0.049
F3_09	better	0.16	F3_09	worse	0.042	F3_09	better	0.065
F3_10	better	0.074				F3_10	better	0.033

* Results reported in this table are based on the Diebold-Mariano test. The Davidson-MacKinnon test results, not reported, are largely consistent.

[#] The null is that the difference in predictions is not significant. A large p-value implies that we cannot reject the null.

Table 4.1 VEC Models - Precautionary Demand (1), 1996Q1-2005Q4

Model	Regressors	# obs.	# lag	# ci.	R^{2*}	RMSE	RMSFE	Implied long-run relation, res=				Mean Prediction Error						
								imp[#] (5.66)	idif (1.61)	debt (1.48)	vexp (0.41)	96-00	01-05	06-07	04Q4	01-05 w/o 04Q4	07Q1	06-07 w/o 07Q1
S1_01[%]	imp	38	2	1	0.63	0.738	1.665	2.8 (1.36)				-0.08	0.07	0.74	2.25	-0.05	4.20	0.25
S1_02	idif	36	4	1	0.60	0.838	1.650		-10.46 (3.58)			-0.25	0.20	-0.09	2.35	0.08	3.07	-0.54
S1_05	imp idif	39	1	1	0.49	0.827	1.798	2.71 (1.22)	0.73 (2.34)			-0.14	0.13	0.93	3.14	-0.03	4.52	0.42
S1_06	imp debt	39	1	1	0.50	0.822	1.790	3.19 (7.56)		3.38 (14.73)		-0.25	0.24	0.93	2.96	0.10	4.53	0.42
S1_08	idif debt	36	4	1	0.61	0.875	1.669		-5.41 (2.94)	-0.71 (3.35)		-0.21	0.17	0.16	2.22	0.06	3.26	-0.28
S1_09	idif vexp	36	4	2	0.72	0.755	1.941		-24.51 (4.74)		-157 (44.03)	-0.15	0.12	0.06	1.78	0.04	3.08	-0.37
S1_11	imp idif debt	39	1	1	0.44	0.873	2.167	2.62 (4.62)	1.66 (2.96)	3.12 (13.35)		-0.30	0.28	1.45	3.42	0.12	5.10	0.93
S1_12	imp idif vexp	36	4	1	0.79	0.690	2.404	1.38 (0.79)	2.97 (4.7)		35.38 (108.2)	-0.15	0.12	0.01	1.80	0.03	3.06	-0.42
S1_14	idif debt vexp	36	4	1	0.73	0.774	1.970		2.91 (6.14)	-2.38 (17.43)	54.41 (16.45)	-0.11	0.09	0.04	1.70	0.01	2.88	-0.37
S1_15	imp idif debt vexp	36	4	1	0.84	0.649	2.501	0.7 (2.62)	2.29 (5.53)	-1.32 (32.26)	26.24 (97.07)	-0.10	0.08	0.13	1.19	0.02	2.98	-0.28

* Statistics and coefficients reported in this table are those of the *res* equations.

[#] In parentheses are standard deviations of regressors and estimated coefficients.

[%] Models missing include: S1_03 (*res, debt*) and S1_04 (*res, vexp*), S1_07 (*res, imp, vexp*), S1_10 (*res, debt, vexp*) and S1_13 (*res, imp, debt, vexp*).

Table 4.2 VEC Models - Precautionary Demand (2), 1996Q1-2005Q4

Model	Regressors	# obs.	# lag	# ci.	R^{2*}	RMSE	RMSFE	Implied long-run relation, res=				Mean Prediction Error						
								imp[#] (5.66)	idif (1.61)	vcpid (0.34)	m2gdp (0.20)	96-00	01-05	06-07	04Q4	01-05 w/o 04Q4	07Q1	06-07 w/o 07Q1
S2_03[%]	vcpid m2gdp	39	1	1	0.48	0.838	1.514			-317.5 (101.9)	-956.3 (411.4)	-0.19	0.18	0.02	2.94	0.04	3.70	-0.51
S2_04	imp vcpid	38	2	1	0.68	0.698	1.902	2.05 (4.59)		5.43 (26.49)		-0.13	0.12	1.14	1.82	0.03	4.61	0.65
S2_05	imp m2gdp	38	2	1	0.66	0.716	1.670	2.68 (2.17)			-16.68 (28.23)	-0.13	0.12	0.84	2.02	0.02	4.20	0.36
S2_06	imp vcpid m2gdp	38	2	1	0.72	0.662	1.803	1.62 (3.18)		6.95 (14.75)	9.03 (8.39)	-0.09	0.08	1.06	1.55	0.00	4.46	0.57
S2_07	imp idif vcpid	36	4	1	0.82	0.639	1.764	2.17 (1.33)	1.84 (5.27)	7.24 (33.52)		-0.10	0.08	0.52	1.14	0.02	3.55	0.09
S2_08	imp idif m2gdp	36	4	2	0.80	0.676	2.093	3.08 (1.39)	0.61 (2.02)		-19.99 (21.88)	-0.05	0.04	0.88	1.25	-0.02	3.50	0.51
S2_09	imp idif vcpid m2gdp	39	1	2	0.58	0.767	1.513	1.1 (2.94)	-2.27 (4.26)	21.16 (23.81)	59.04 (117.6)	-0.14	0.14	0.36	2.24	0.03	3.91	-0.14

* Statistics and coefficients reported in this table are those of the *res* equations.

[#] In parentheses are standard deviations of regressors and estimated coefficients.

[%] Models missing include: S2_01 (*res* , *vcpid*) and S2_02 (*res* , *m2gdp*).

Table 4.3 VEC Models - Modern Mercantilism, 1996Q1-2005Q4

Model	Regressors	# obs.	# lag	# ci.	R^{2*}	RMSE	RMSFE	Implied long-run relation, res=				Mean Prediction Error						
								imp# (5.66)	idif (1.61)	penn (6.41)	expg (14.36)	96-00	01-05	06-07	04Q4	01-05 w/o 04Q4	07Q1	06-07 w/o 07Q1
S3_01%	penn	39	1	1	0.50	0.825	1.503			-16.38 (12.71)		-0.30	0.29	0.39	3.10	0.14	3.80	-0.10
S3_02	penn expg	38	2	1	0.43	0.931	1.574			-1.3 (0.27)	-0.5 (0.13)	-0.31	0.28	0.40	3.40	0.12	4.24	-0.15
S3_04	imp penn expg	38	2	2	0.61	0.791	1.596	7.05 (6.83)		2.87 (3.46)	-0.18 (0.33)	-0.07	0.06	0.47	2.39	-0.06	4.25	-0.07
S3_05	imp idif penn	36	4	3	0.79	0.718	2.415	1.4 (0.28)	-0.1 (1.33)	-0.43 (0.33)		-0.04	0.03	1.48	1.75	-0.06	4.43	1.06
S3_06	imp idif penn expg	36	4	4	0.87	0.639	2.476	2.58 (35.87)	1.2 (169.3)	-0.87 (34.98)	-0.12 (8.01)	0.03	-0.03	0.61	1.14	-0.09	3.12	0.25

Model	Regressors	# obs.	# lag	# ci.	R^2	RMSE	RMSFE	Implied long-run relation, res=				Mean Prediction Error						
								rgg (2.28)	debt (1.48)	exrt (0.05)	expg (14.36)	96-00	01-05	06-07	04Q4	01-05 w/o 04Q4	07Q1	06-07 w/o 07Q1
S3_07	rgg exrt	39	1	2	0.60	0.747	1.539	-12.9 (13.99)		302.4 (405.4)		-0.26	0.24	0.65	2.96	0.10	3.46	0.25
S3_08	rgg exrt expg	38	2	2	0.66	0.737	1.543	-19.98 (29.54)		-218.3 (264.6)	-1.01 (0.94)	-0.14	0.12	0.82	3.03	-0.03	3.49	0.44
S3_09	rgg debt exrt	39	1	1	0.56	0.776	1.771	114.4 (46.8)	-21.97 (31.65)	-34.82 (87.41)		-0.28	0.27	1.09	3.19	0.11	3.76	0.71
S3_10	rgg debt exrt expg	36	4	1	0.75	0.798	1.421	-1.5 (7.06)	-2.82 (5.16)	-174.6 (181.1)	-1.21 (1.75)	-0.11	0.09	0.44	2.03	-0.01	2.87	0.09

* Statistics and coefficients reported in this table are those of the *res* equations.

In parentheses are standard deviations of regressors and estimated coefficients.

% Model missing is S3_03 (*imp, penn*).

Table 5 Comparison of Predictions on Reserves (Subsample) *

Benchmark 1: S1_01				Benchmark 2: S3_10				Benchmark 3: ARIMA(1,1,1)		
Model	Predictions relative to benchmark	P-value#		Model	Predictions relative to benchmark	P-value		Model	Predictions relative to benchmark	P-value
								S1_01	better	0.261
S1_02	worse	0.904		S1_02	worse	0.009		S1_02	better	0.557
S1_05	worse	0.047		S1_05	worse	0.031		S1_05	worse	0.403
S1_06	worse	0.041		S1_06	worse	0.026		S1_06	worse	0.41
S1_08	worse	0.906		S1_08	worse	0.013		S1_08	better	0.567
S1_09	worse	0.722		S1_09	worse	0.119		S1_09	better	0.79
S1_11	worse	0.08		S1_11	worse	0.053		S1_11	worse	0.239
S1_12	worse	0.405		S1_12	worse	0.197		S1_12	worse	0.708
S1_14	worse	0.709		S1_14	worse	0.123		S1_14	better	0.817
S1_15	worse	0.423		S1_15	worse	0.224		S1_15	worse	0.686
S2_03	worse	0.615		S2_03	worse	0.021		S2_03	better	0.576
S2_04	worse	0.524		S2_04	worse	0.144		S2_04	better	0.751
S2_05	better	0.26		S2_05	worse	0.077		S2_05	better	0.203
S2_06	better	0.894		S2_06	worse	0.198		S2_06	better	0.327
S2_07	better	0.243		S2_07	worse	0.418		S2_07	better	0.283
S2_08	worse	0.753		S2_08	worse	0.291		S2_08	better	0.877
S2_09	better	0.775		S2_09	worse	0.03		S2_09	better	0.24
S3_01	worse	0.717		S3_01	worse	0.028		S3_01	better	0.376
S3_02	worse	0.256		S3_02	worse	0.033		S3_02	worse	0.761
S3_04	better	0.7		S3_04	worse	0.035		S3_04	better	0.244
S3_05	worse	0.466		S3_05	worse	0.27		S3_05	worse	0.723
S3_06	worse	0.498		S3_06	worse	0.279		S3_06	worse	0.779
S3_07	better	0.514		S3_07	worse	0.055		S3_07	better	0.15
S3_08	better	0.233		S3_08	worse	0.198		S3_08	better	0.024
S3_09	worse	0.164		S3_09	worse	0.026		S3_09	better	0.94
S3_10	better	0.035						S3_10	better	0.156

* Results reported in this table are based on the Diebold-Mariano test.
The Davidson-MacKinnon test results, not reported, are largely consistent but often more significant.

The null is that the difference in predictions is not significant. A large p-value implies that we cannot reject the null.

Figure 1 Time Trend of China's Foreign Reserve Holdings (1982−2007)

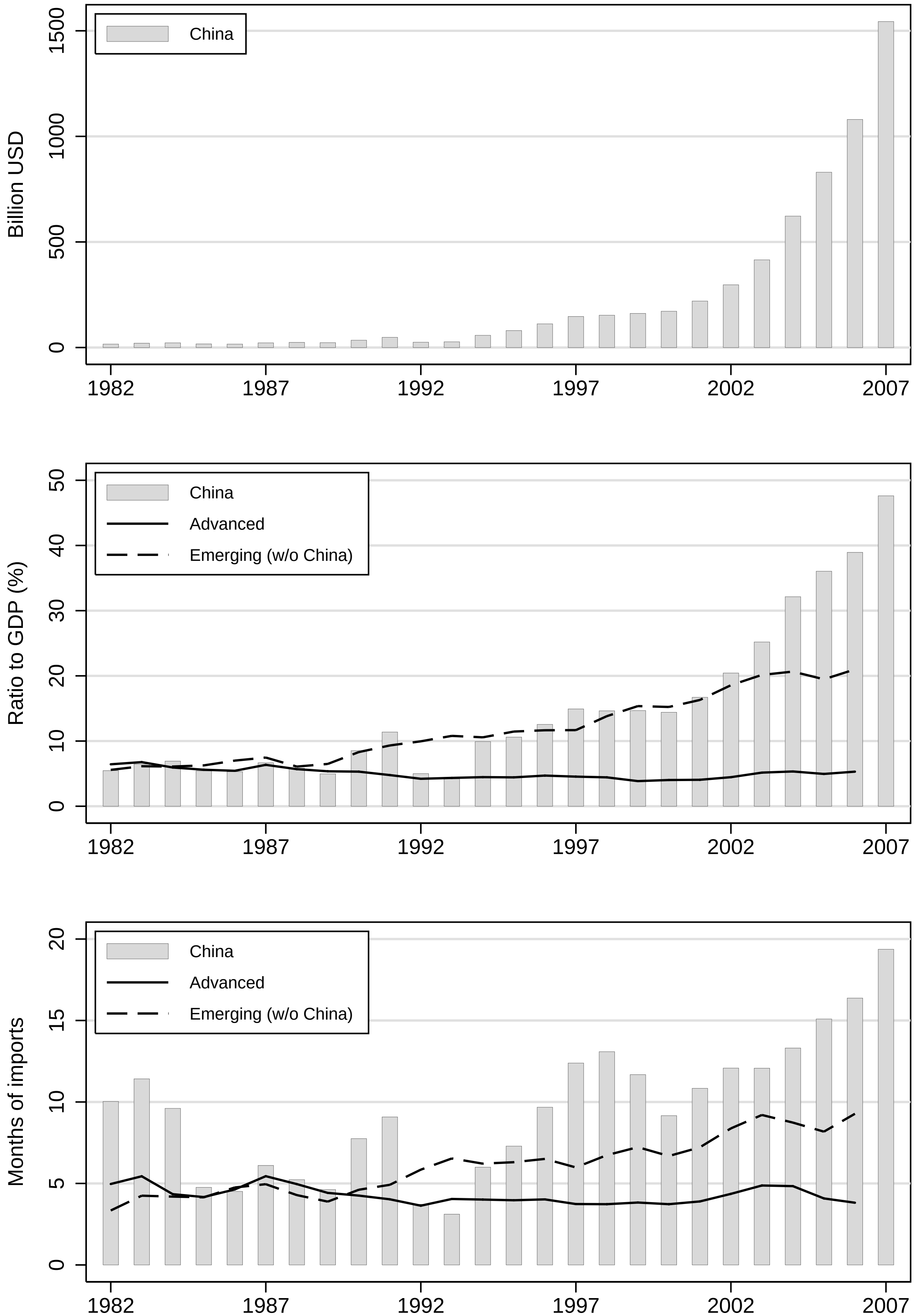
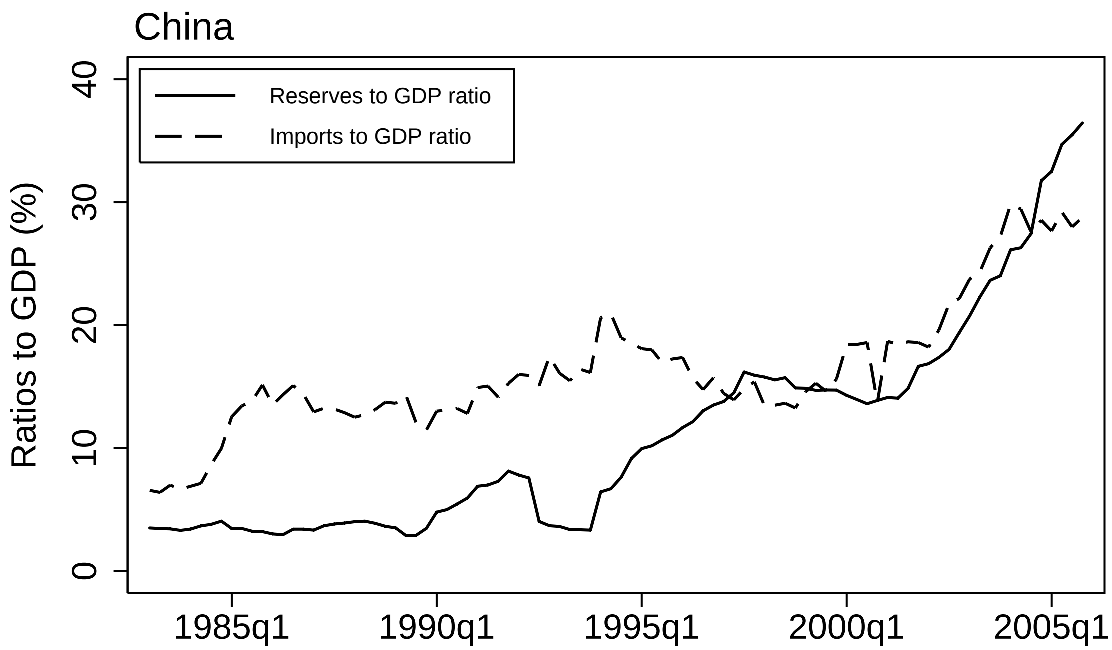


Figure 2 Reserves and Imports (China and Korea, 1983Q1−2005Q4)



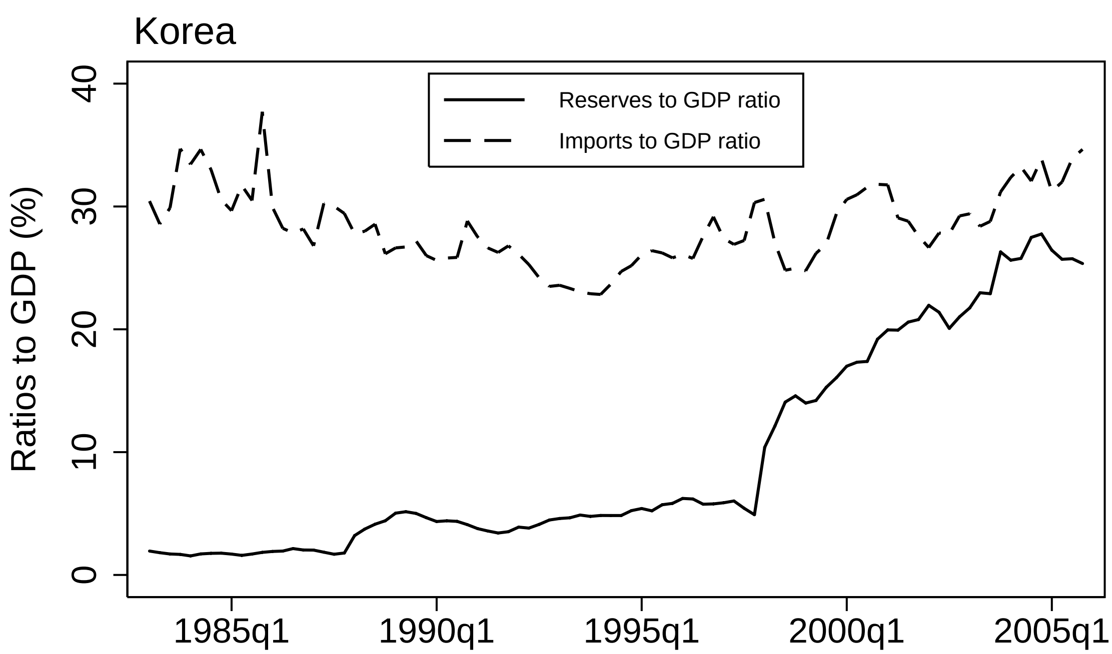
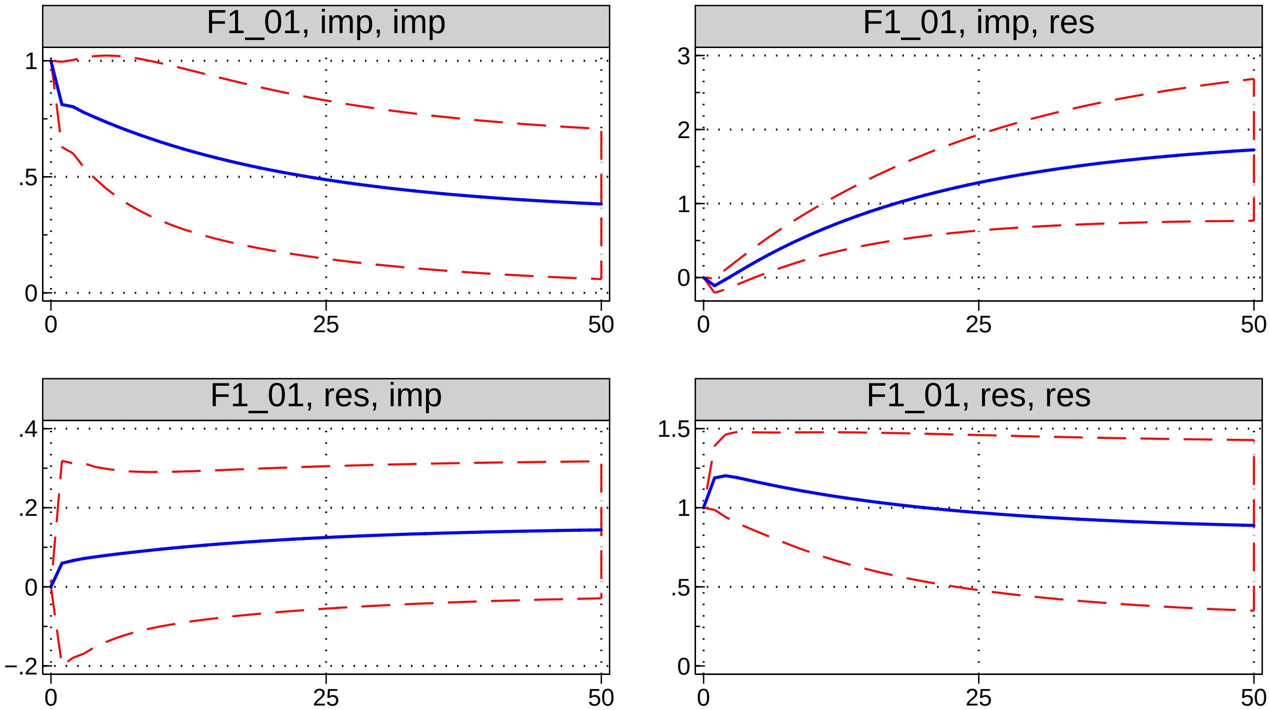
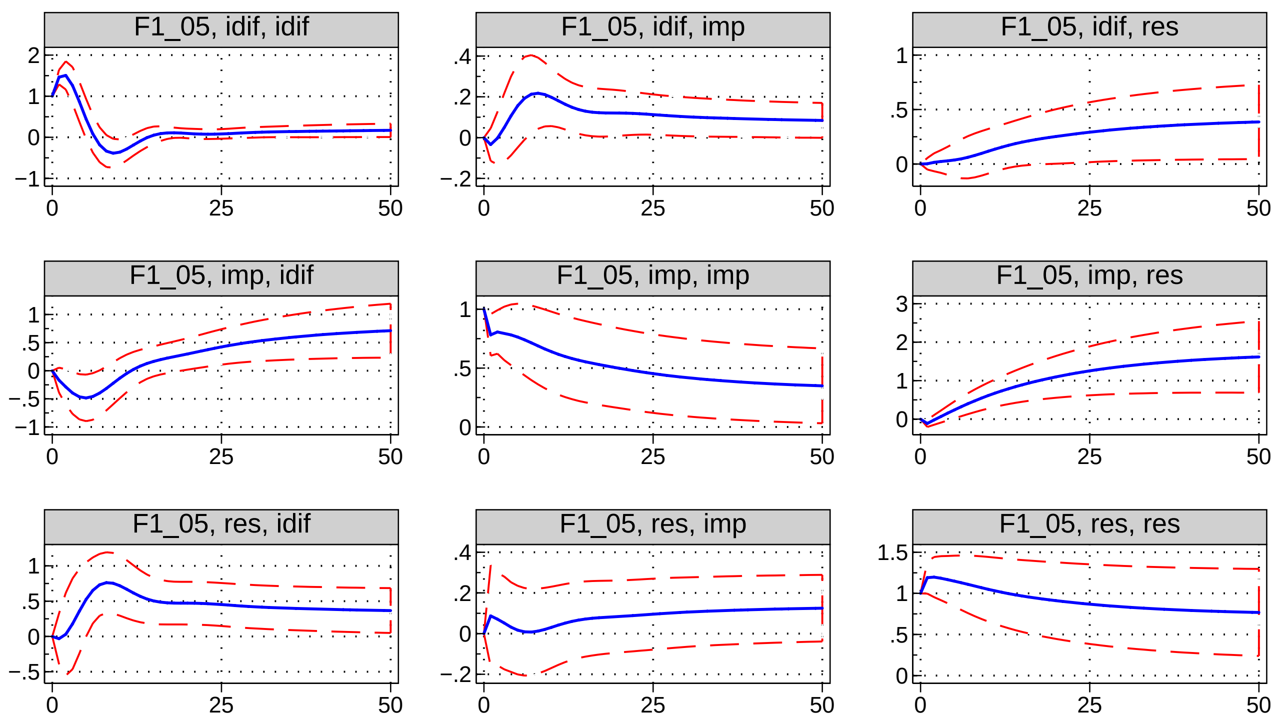


Figure 3.1 IRF of VEC Model F1_01 (Full Sample)



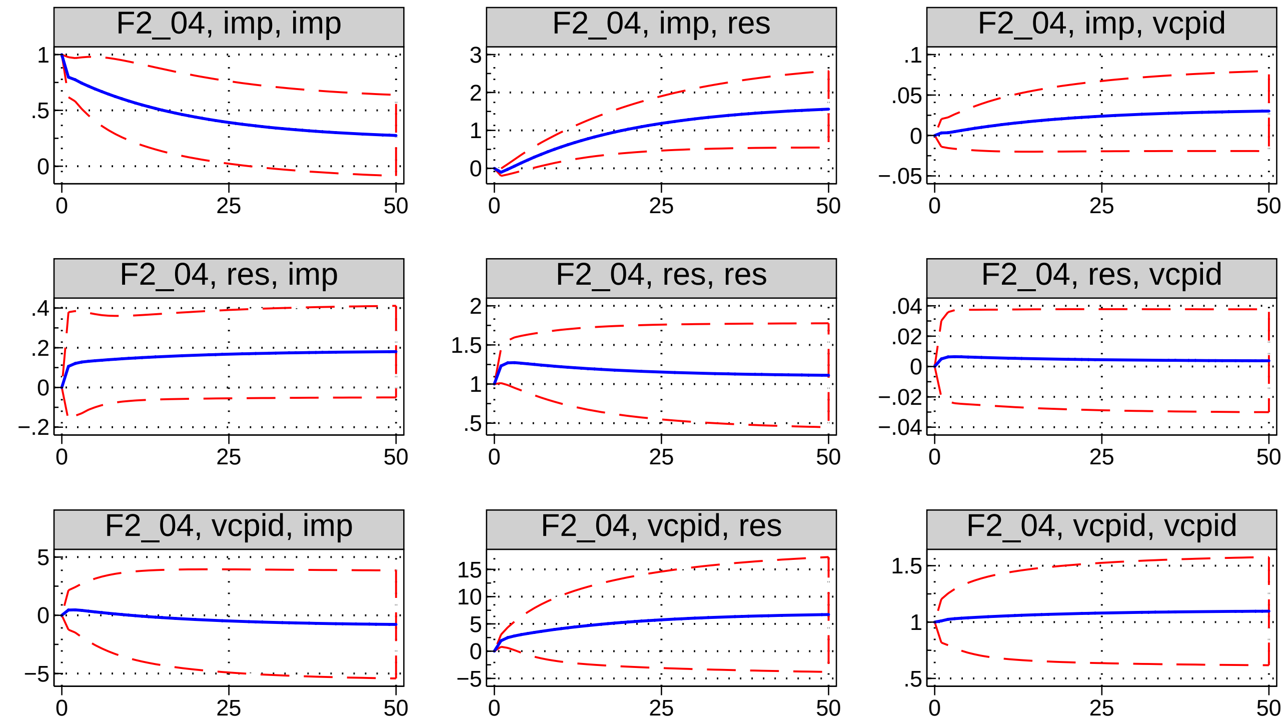
Subtitle: model, shock, response. Std(res)=8.57 Std(imp)=5.43

Figure 3.2 IRF of VEC Model F1_05 (Full Sample)



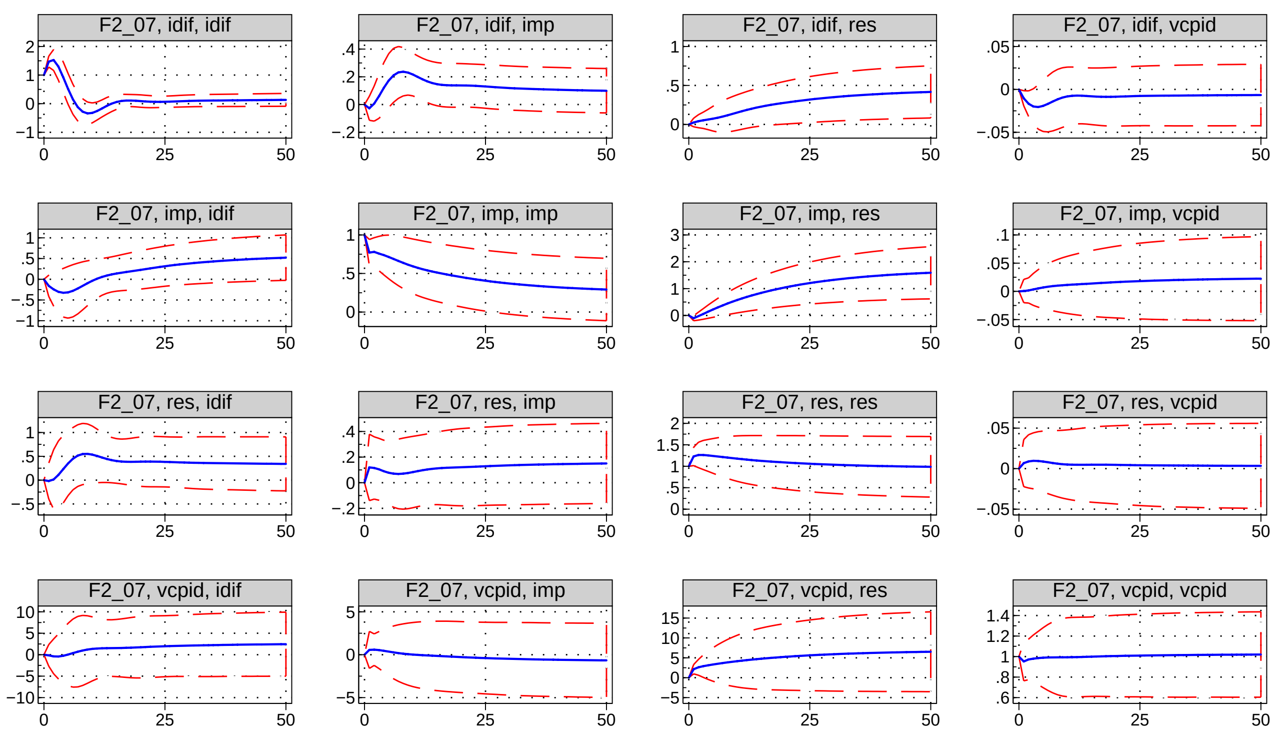
Subtitle: model, shock, response. Std(res)=8.57 Std(imp)=5.43 Std(idif)=6.05

Figure 3.3 IRF of VEC Model F2_04 (Full Sample)



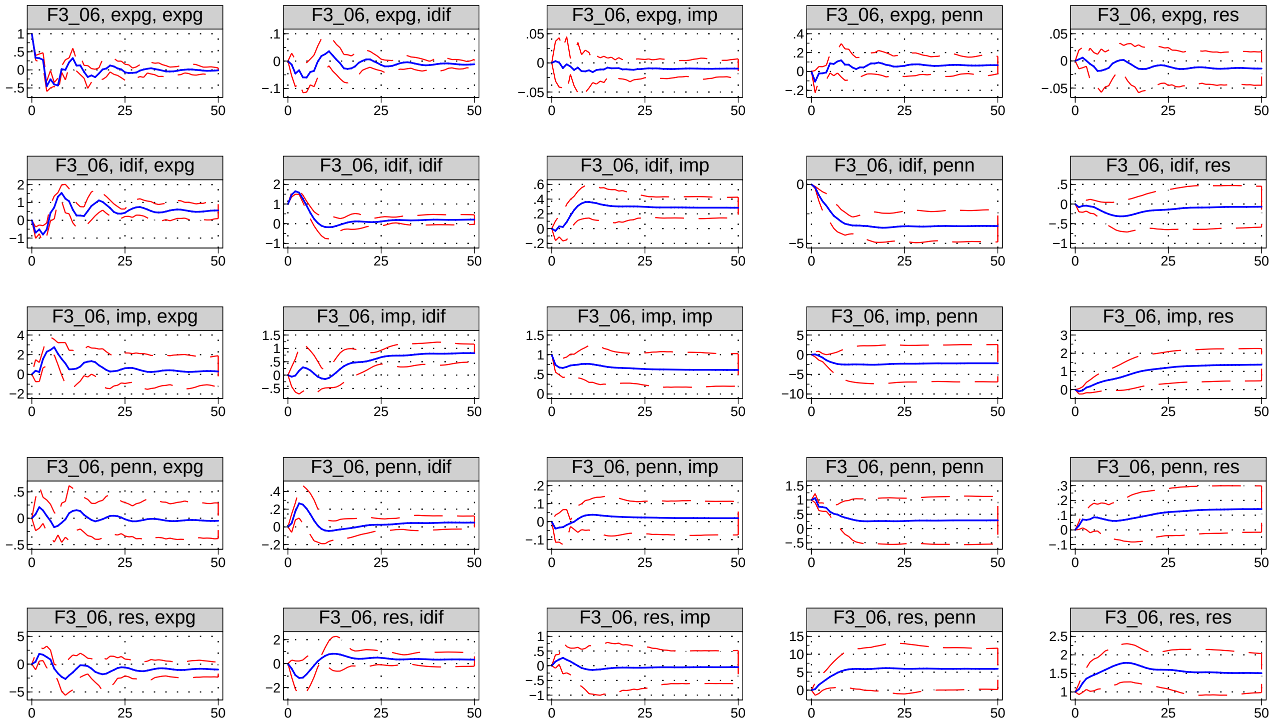
Subtitle: model, shock, response. Std(res)=8.57 Std(imp)=5.43 Std(vcpid)=.34

Figure 3.4 IRF of VEC Model F2_07 (Full Sample)



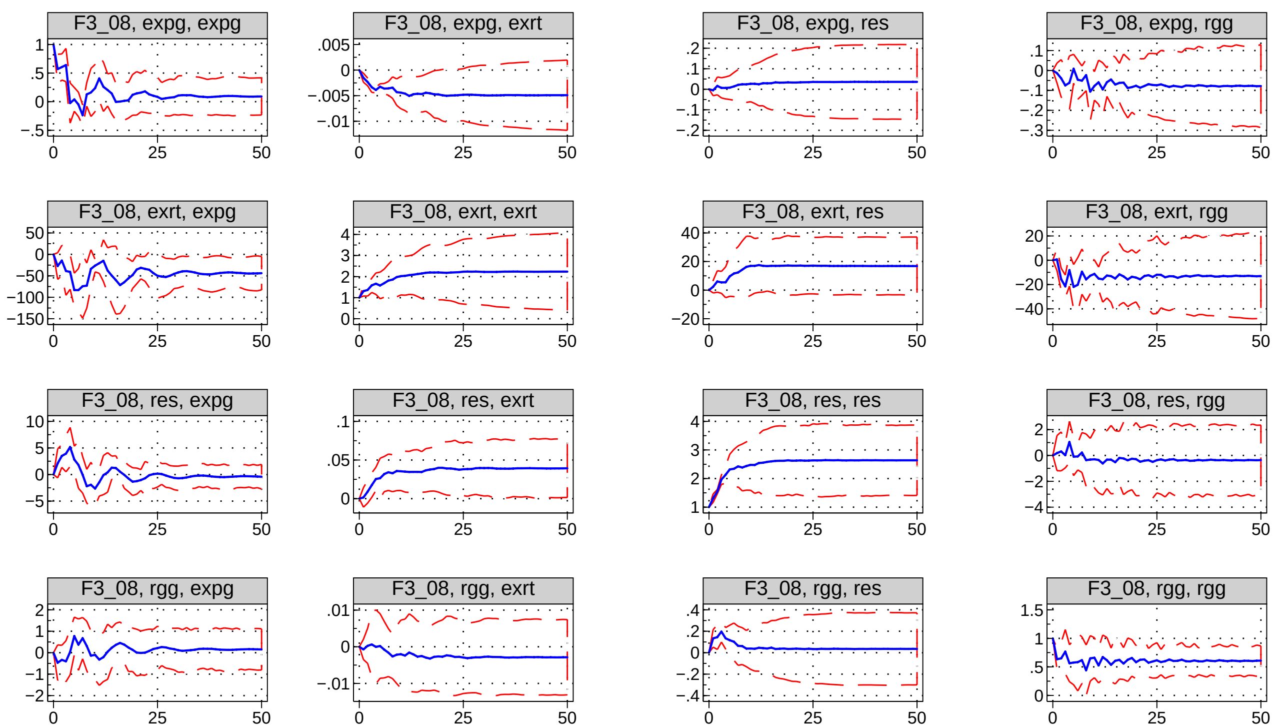
Subtitle: model, shock, response. Std(res)=8.57 Std(imp)=5.43 Std(idif)=6.05 Std(vcpid)=.34

Figure 3.5 IRF of VEC Model F3_06 (Full Sample)



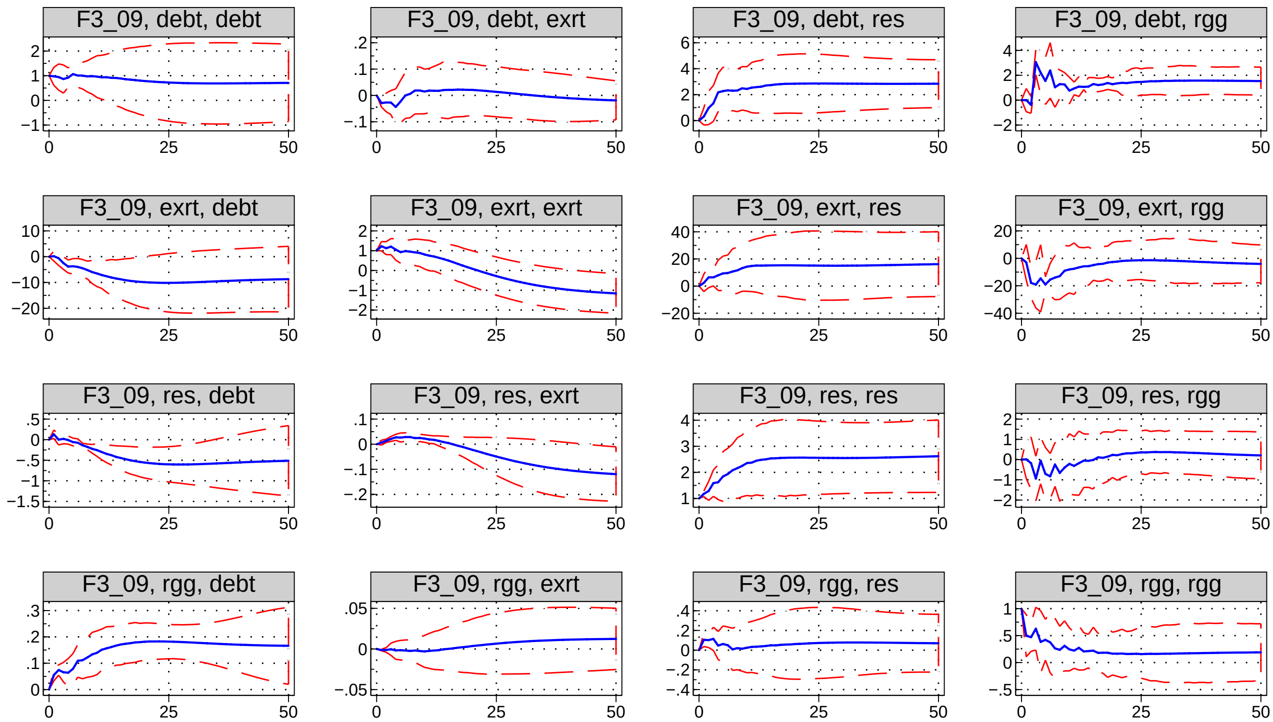
Subtitle: model, shock, response. Std(res)=8.57 Std(imp)=5.43 Std(idif)=6.05 Std(penn)=30.03 Std(expg)=13.11

Figure 3.6 IRF of VEC Model F3_08 (Full Sample)



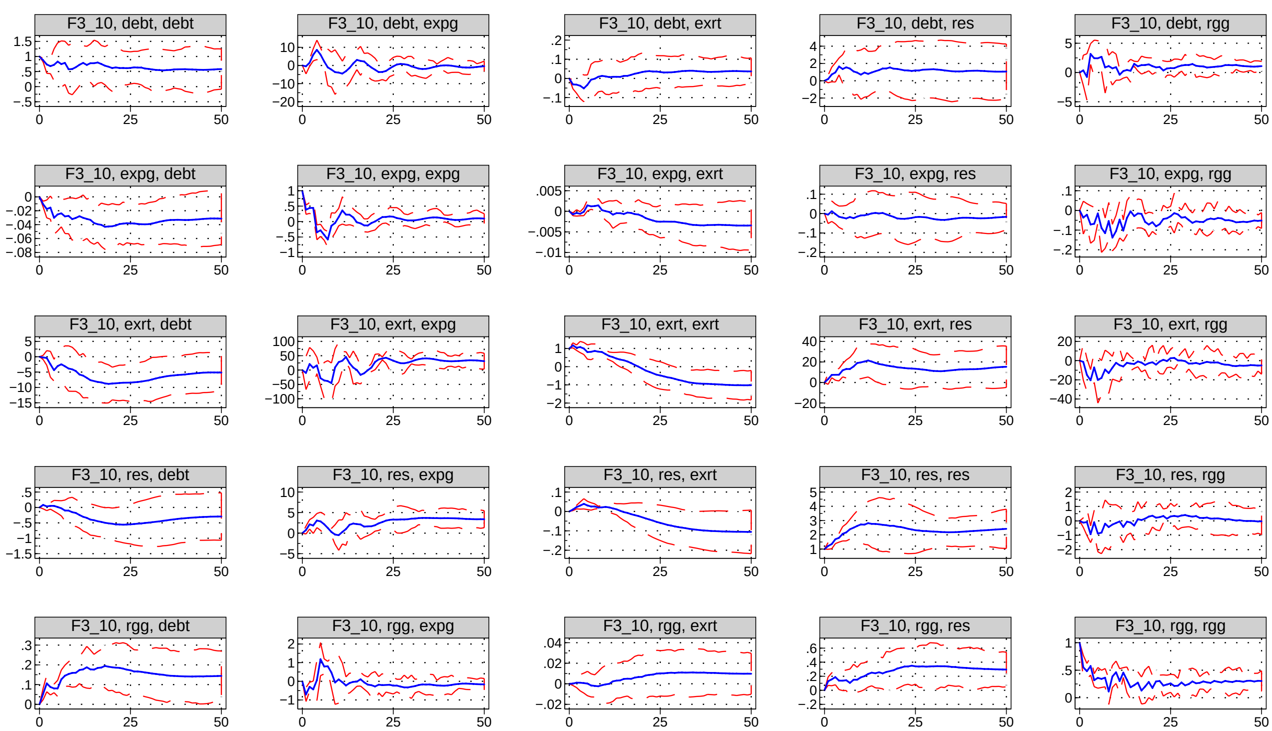
Subtitle: model, shock, response. Std(res)=8.57 Std(rgg)=3.52 Std(exrt)=.3 Std(expg)=13.11

Figure 3.7 IRF of VEC Model F3_09 (Full Sample)



Subtitle: model, shock, response. Std(res)=8.57 Std(rgg)=3.52 Std(debt)=2.08 Std(exrt)=.3

Figure 3.8 IRF of VEC Model F3_10 (Full Sample)



Subtitle: model, shock, response. Std(res)=8.57 Std(rgg)=3.52 Std(debt)=2.08 Std(exrt)=.3 Std(expg)=13.11

Figure 4   Prediction Errors by VEC Model (F1_01)

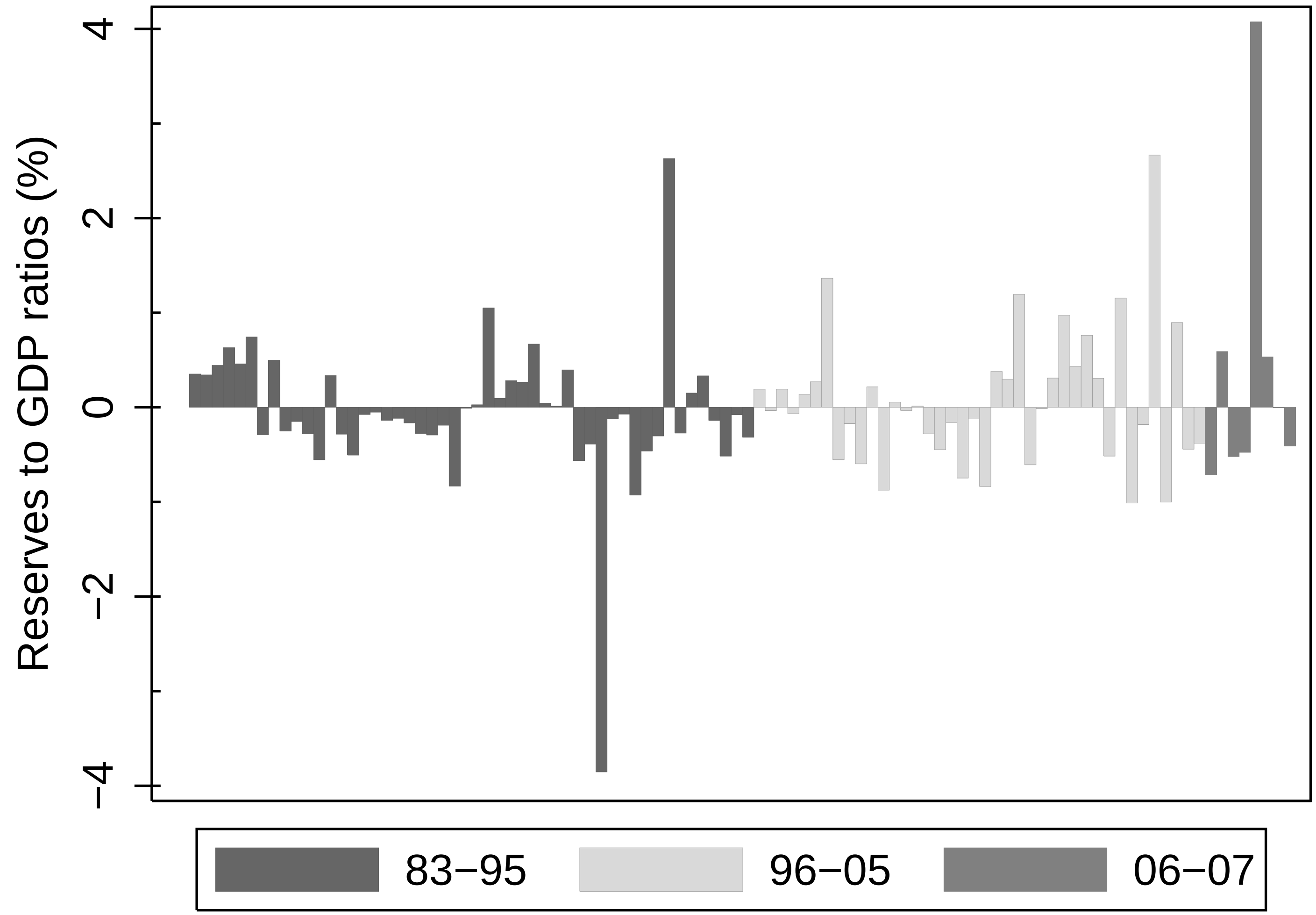
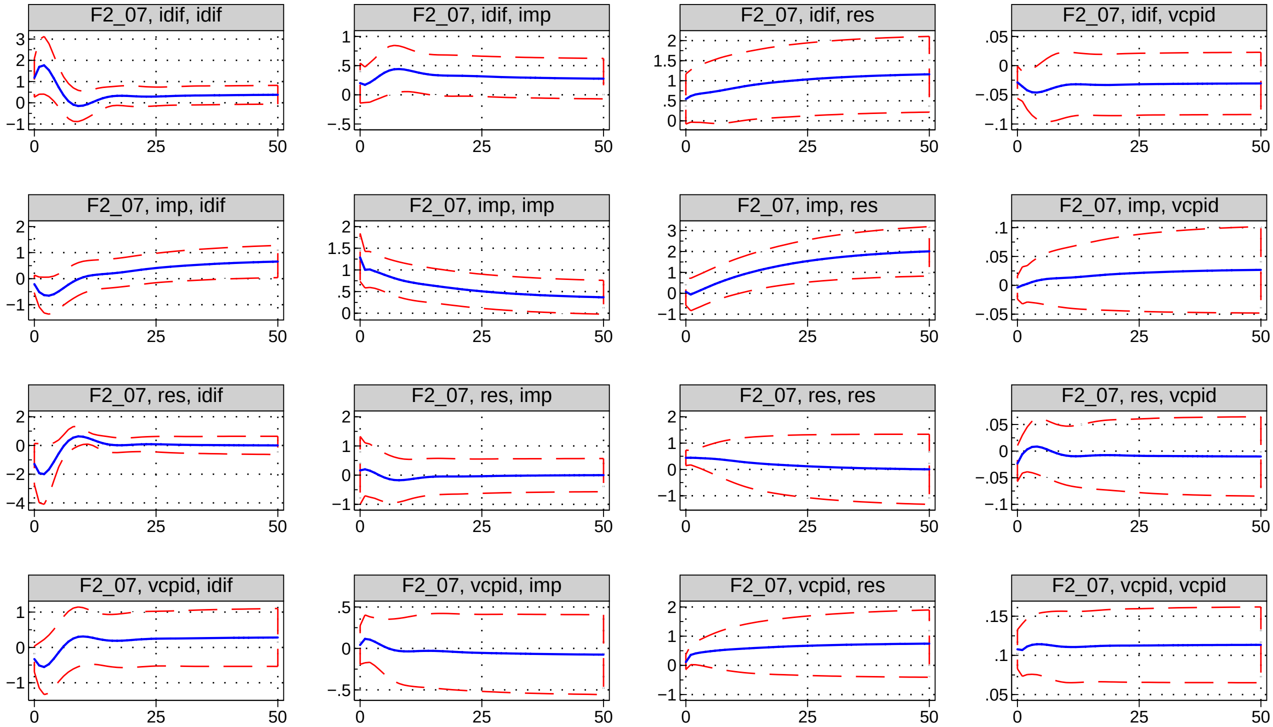
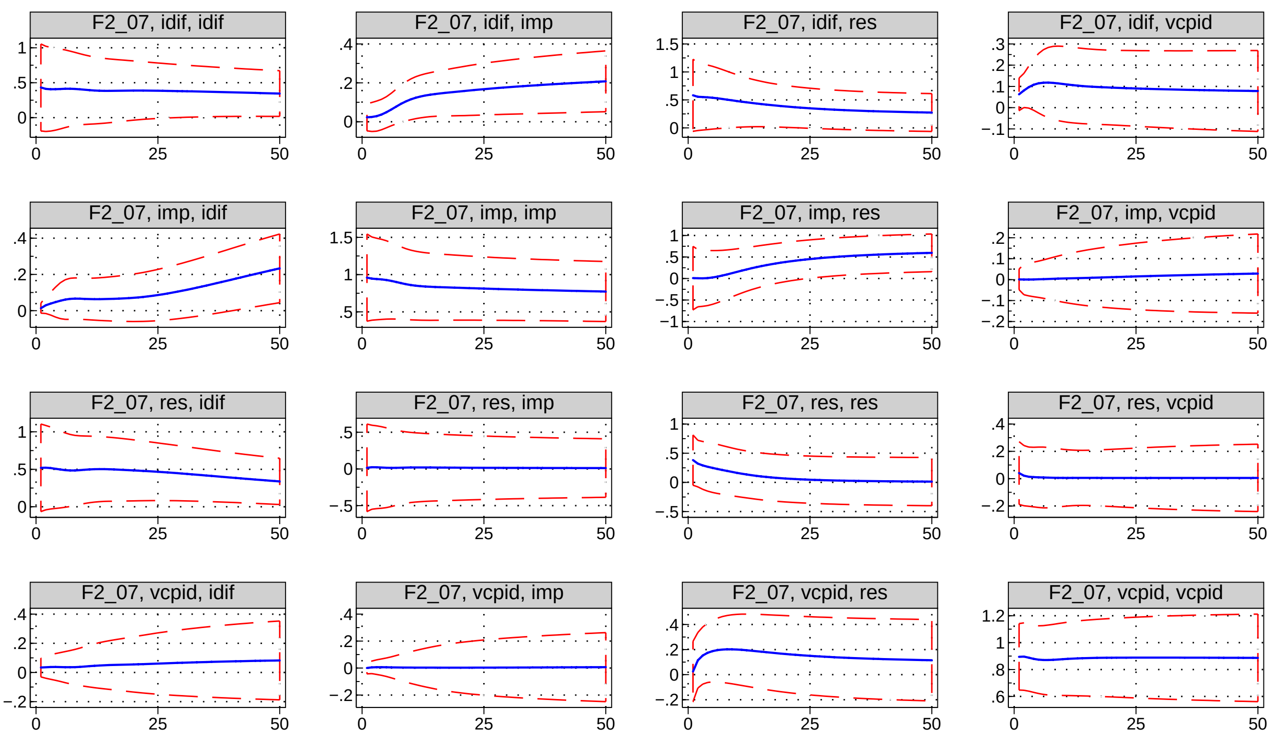


Figure 5.1.1 Structural IRF of VEC Model F2_07 (Full Sample)



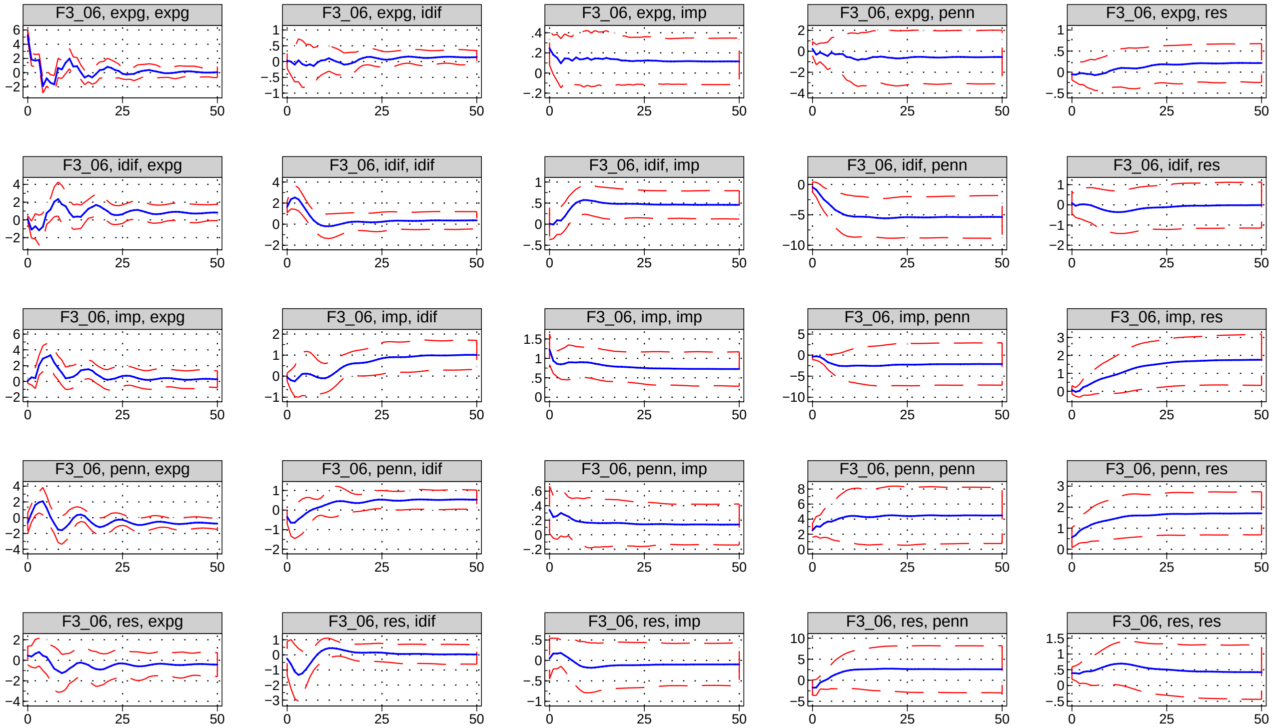
Subtitle: model, shock, response.

Figure 5.1.2 Forecast Error Variance Decomposition of VEC Model F2_07 (Full Sample)



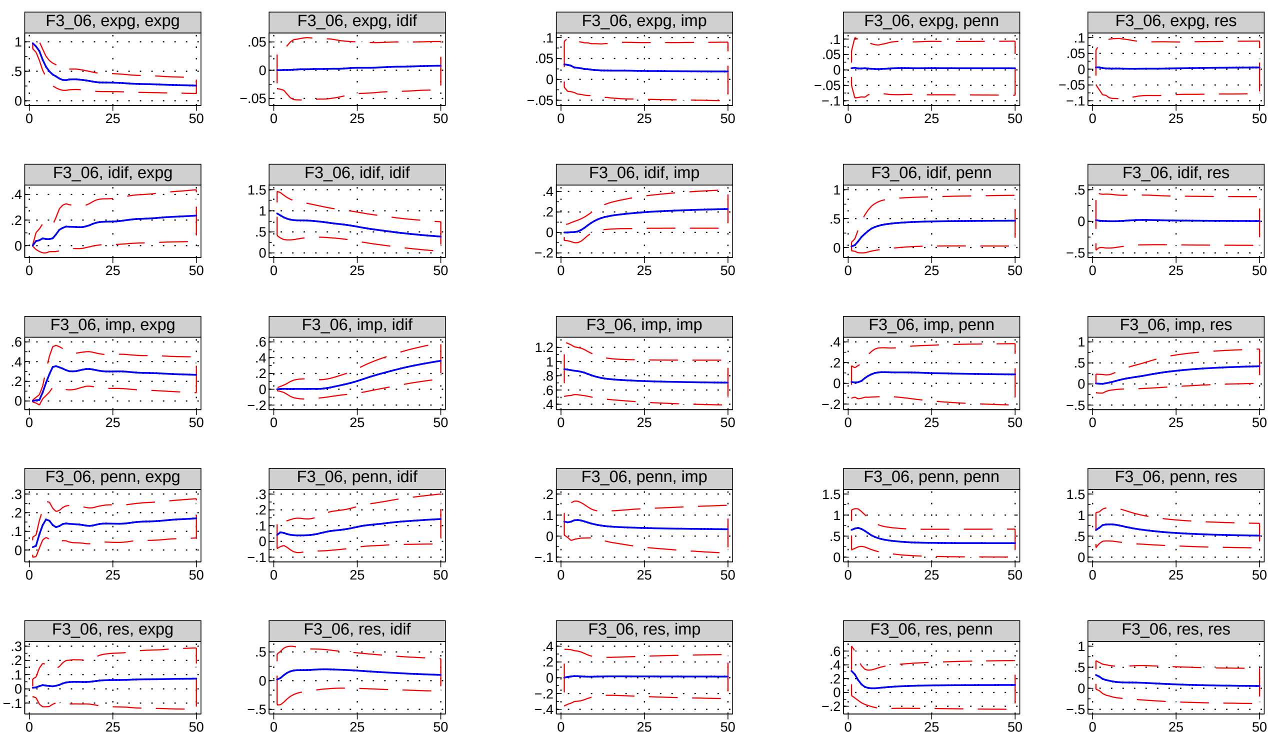
Subtitle: model, shock, response.

Figure 5.2.1   Structural IRF of VEC Model F3_06 (Full Sample)



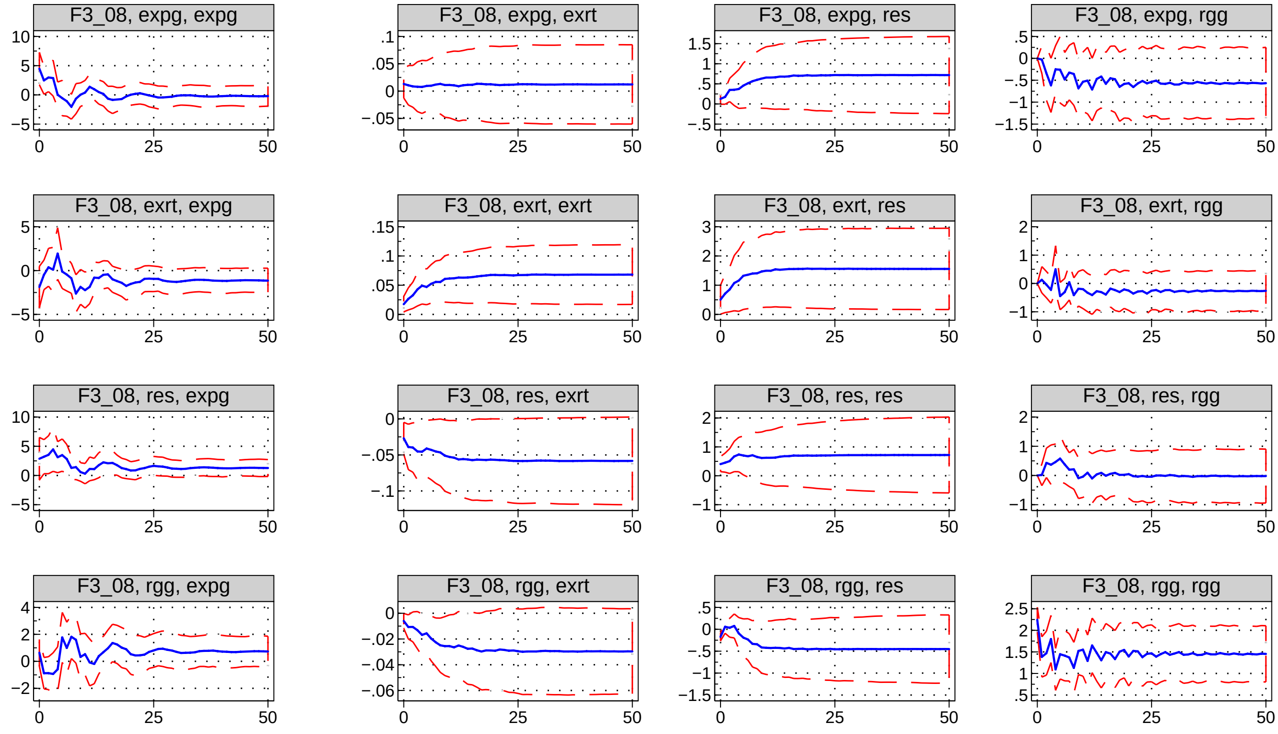
Subtitle: model, shock, response.

Figure 5.2.2   Forecast Error Variance Decomposition of VEC Model F3_06 (Full Sample)



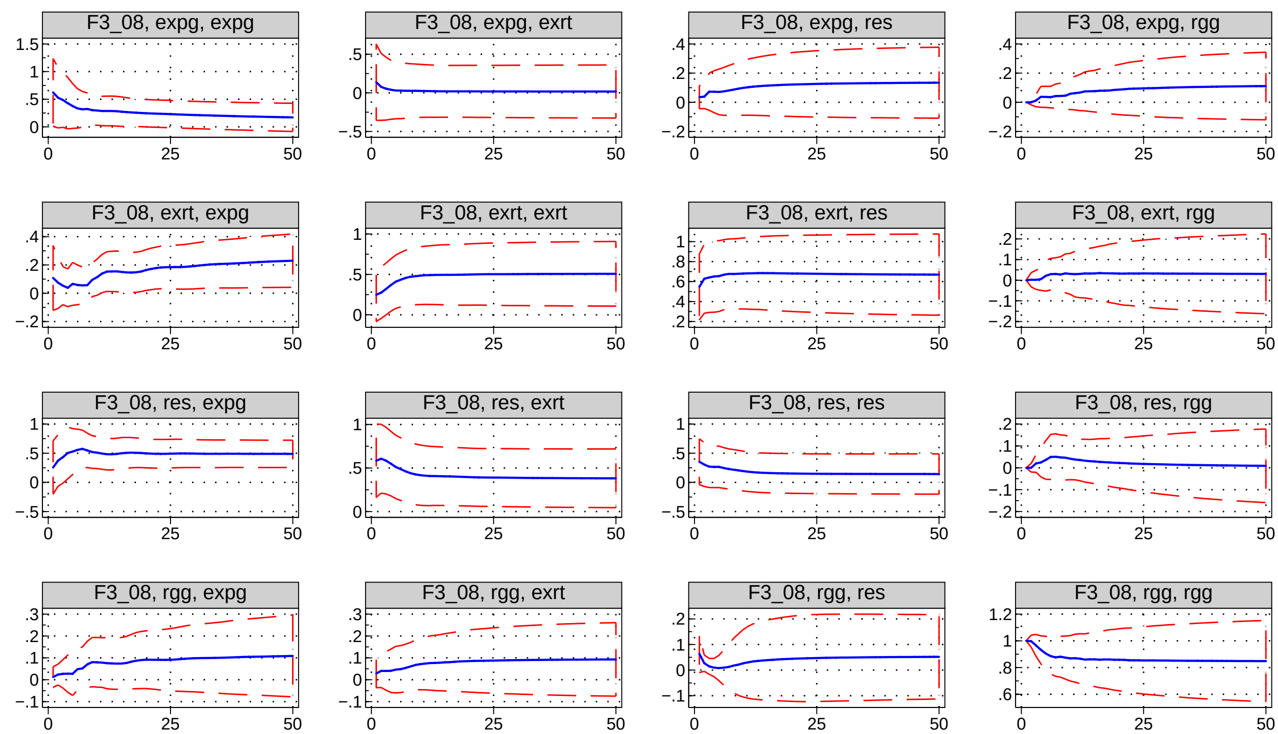
Subtitle: model, shock, response.

Figure 5.3.1 Structural IRF of VEC Model F3_08 (Full Sample)



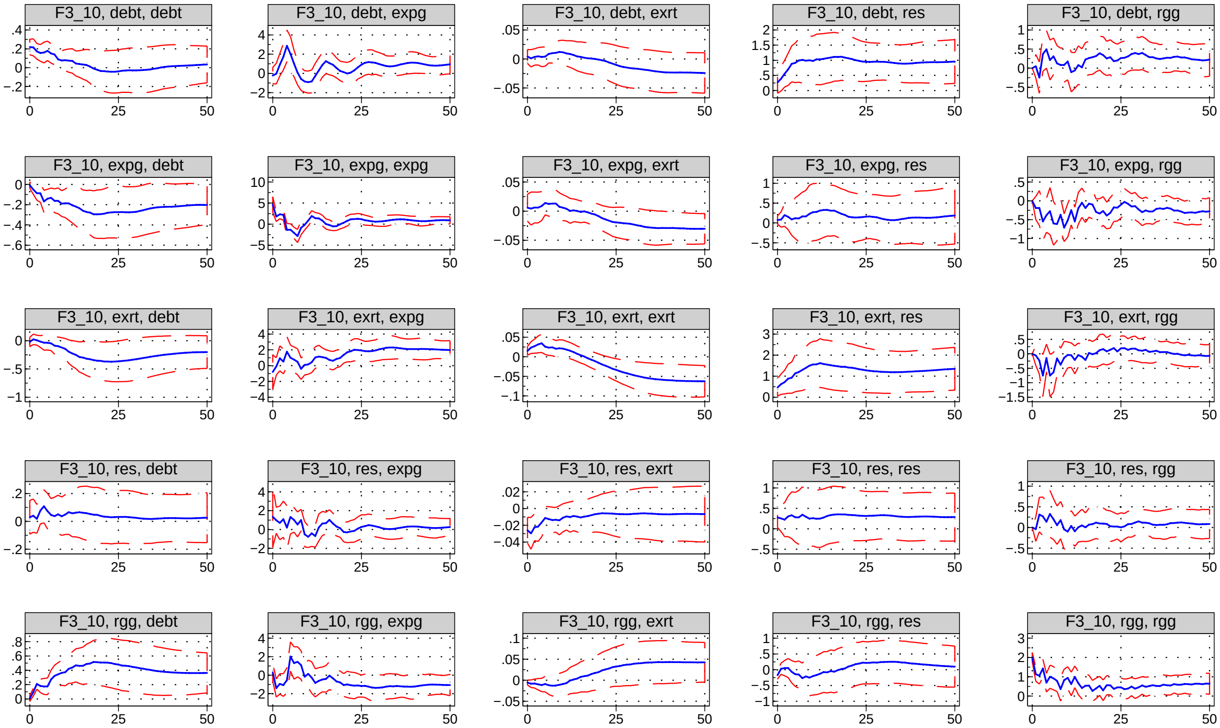
Subtitle: model, shock, response.

Figure 5.3.2 Forecast Error Variance Decomposition of VEC Model F3_08 (Full Sample)



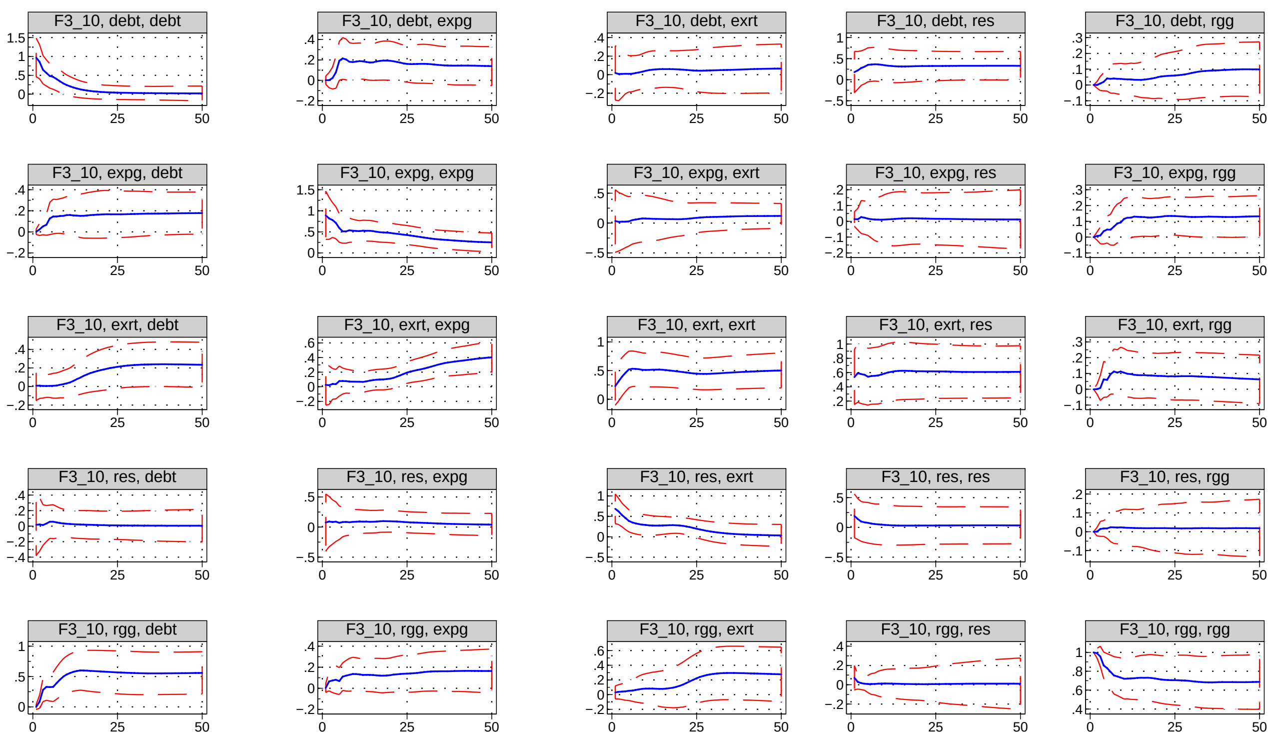
Subtitle: model, shock, response.

Figure 5.4.1 Structural IRF of VEC Model F3_10 (Full Sample)



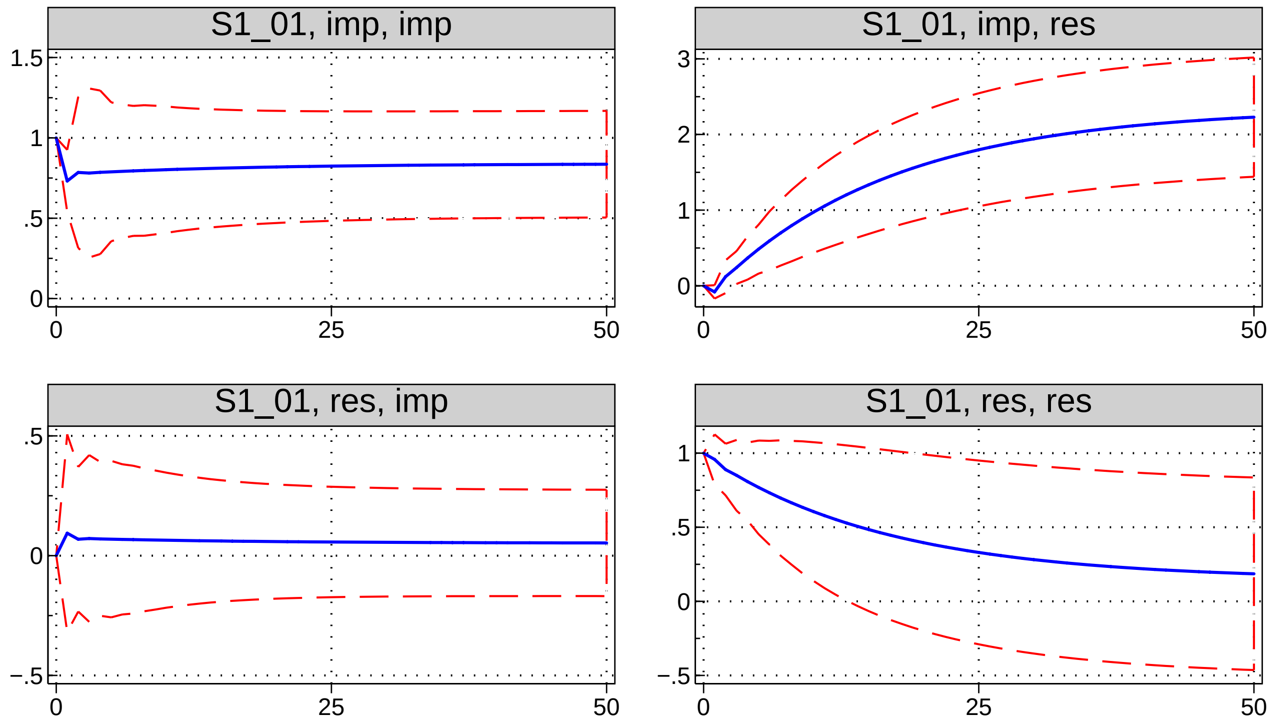
Subtitle: model, shock, response.

Figure 5.4.2 Forecast Error Variance Decomposition of VEC Model F3_10 (Full Sample)



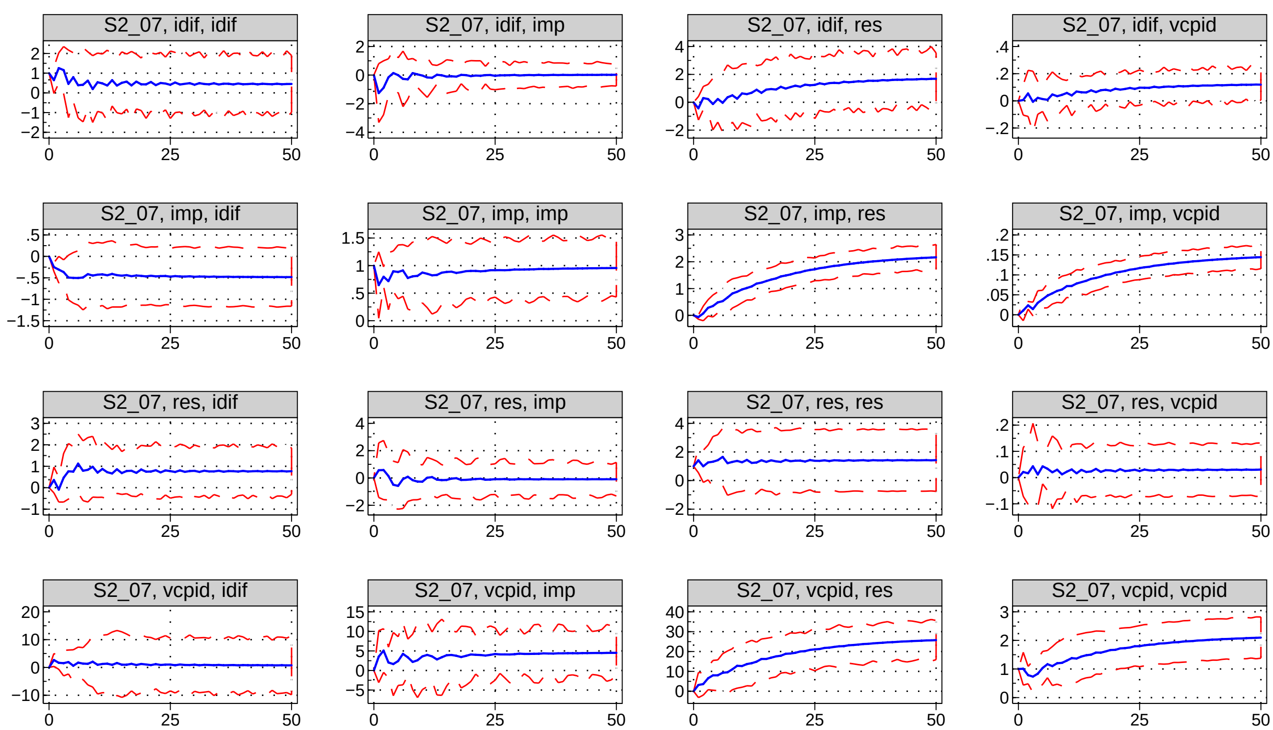
Subtitle: model, shock, response.

Figure 6.1 IRF of VEC Model S1_01 (Subsample)



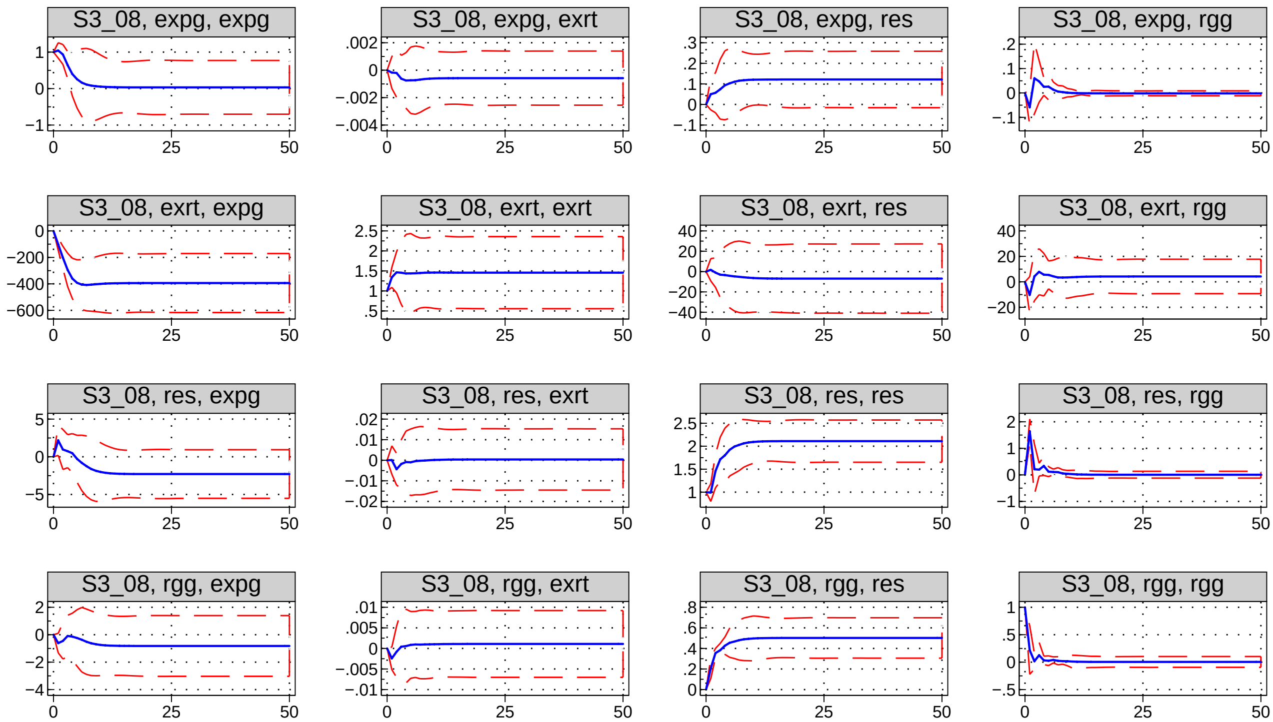
Subtitle: model, shock, response. Std(res)=7.05 Std(imp)=5.66

Figure 6.2 IRF of VEC Model S2_07 (Subsample)



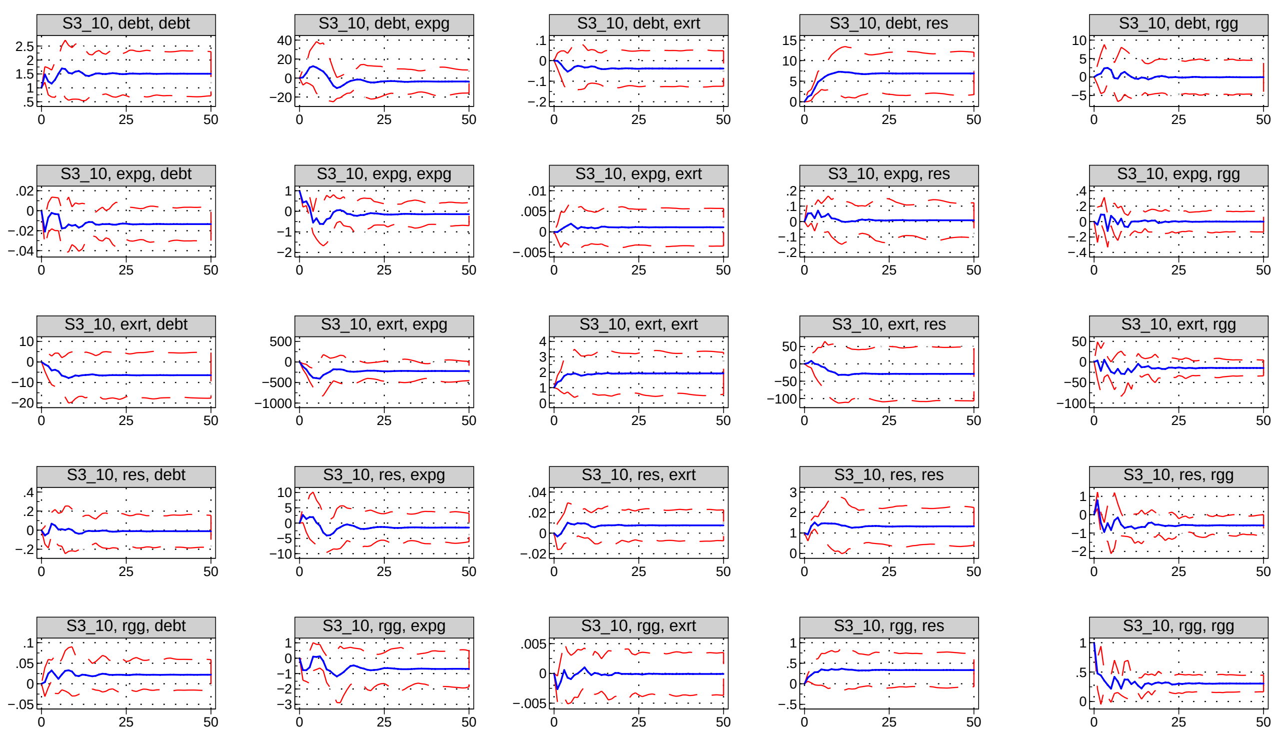
Subtitle: model, shock, response. Std(res)=7.05 Std(imp)=5.66 Std(idif)=1.61 Std(vcpid)=.34

Figure 6.3 IRF of VEC Model S3_08 (Subsample)



Subtitle: model, shock, response. Std(res)=7.05 Std(rgg)=2.28 Std(exrt)=.05 Std(expg)=14.36

Figure 6.4 IRF of VEC Model S3_10 (Subsample)



Subtitle: model, shock, response. Std(res)=7.05 Std(rgg)=2.28 Std(debt)=1.48 Std(exrt)=.05 Std(expg)=14.36

Figure 7.1 Prediction Errors by VEC Model (S1_01)

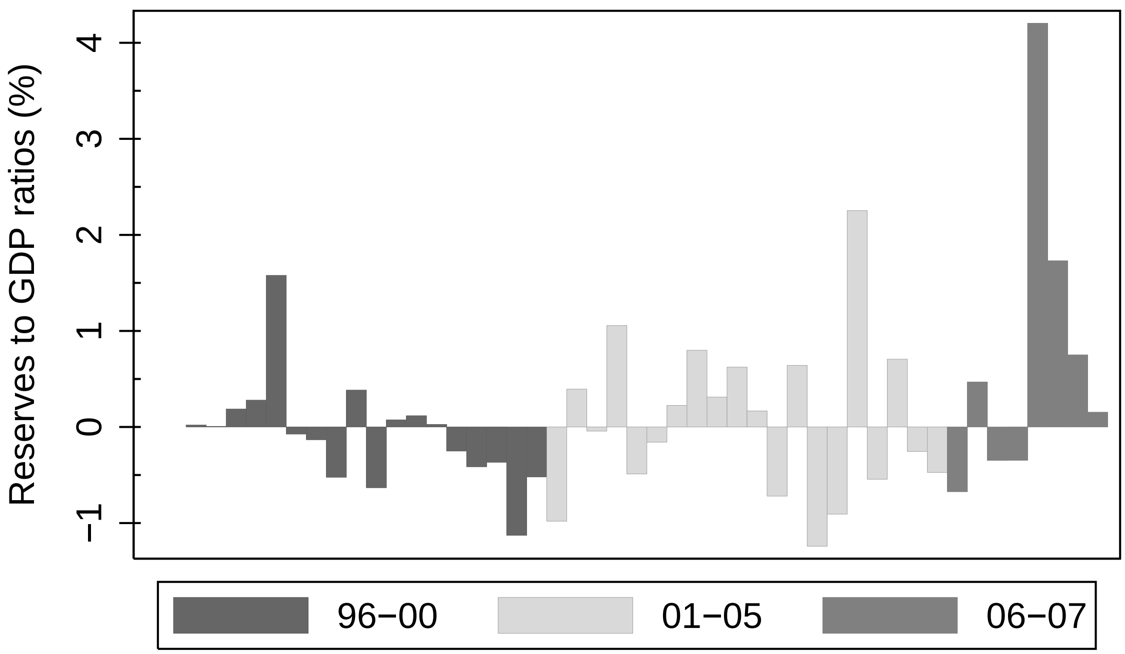


Figure 7.2 Prediction Errors by VEC Model (S3_10)

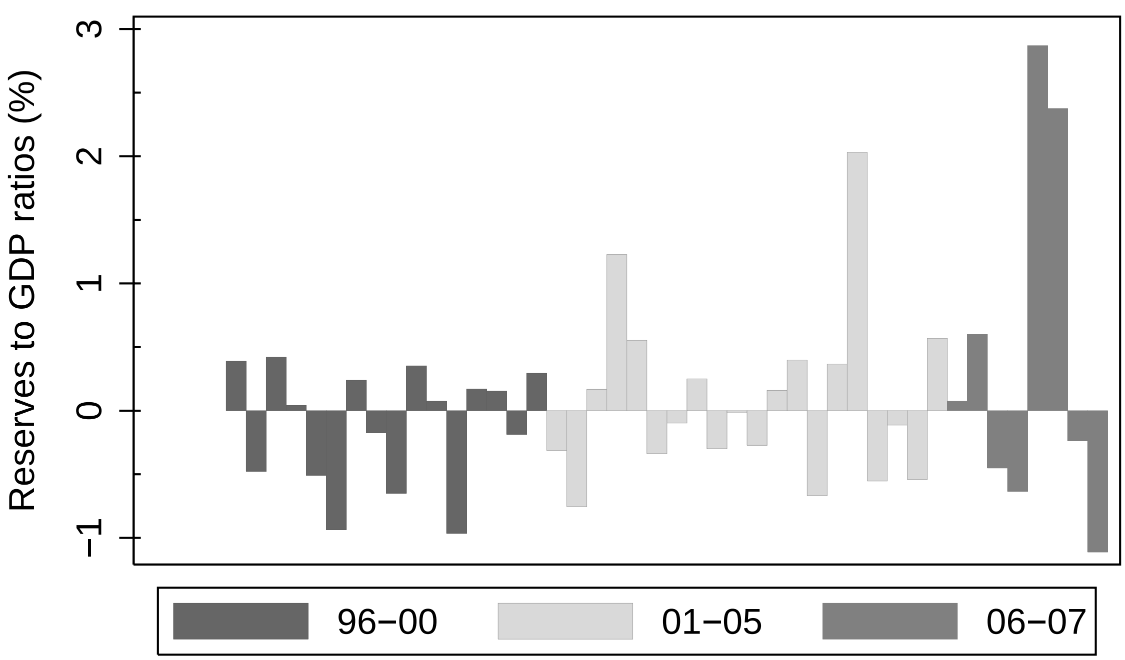
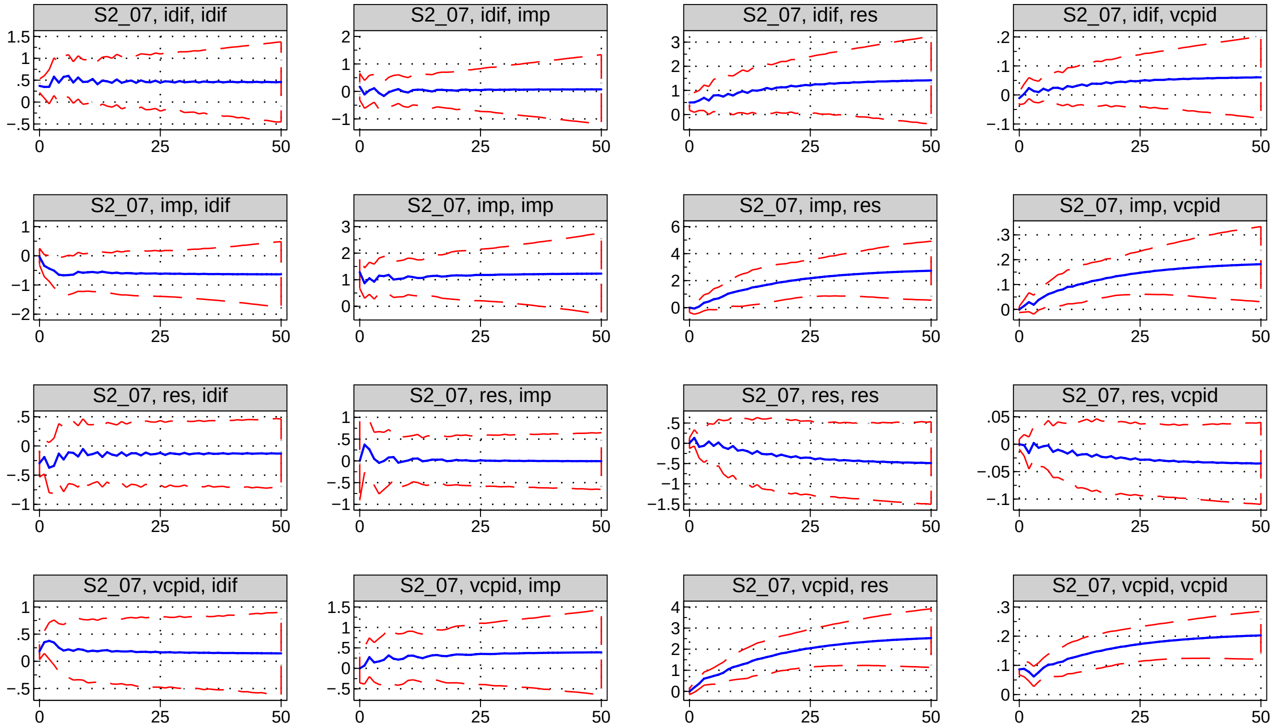
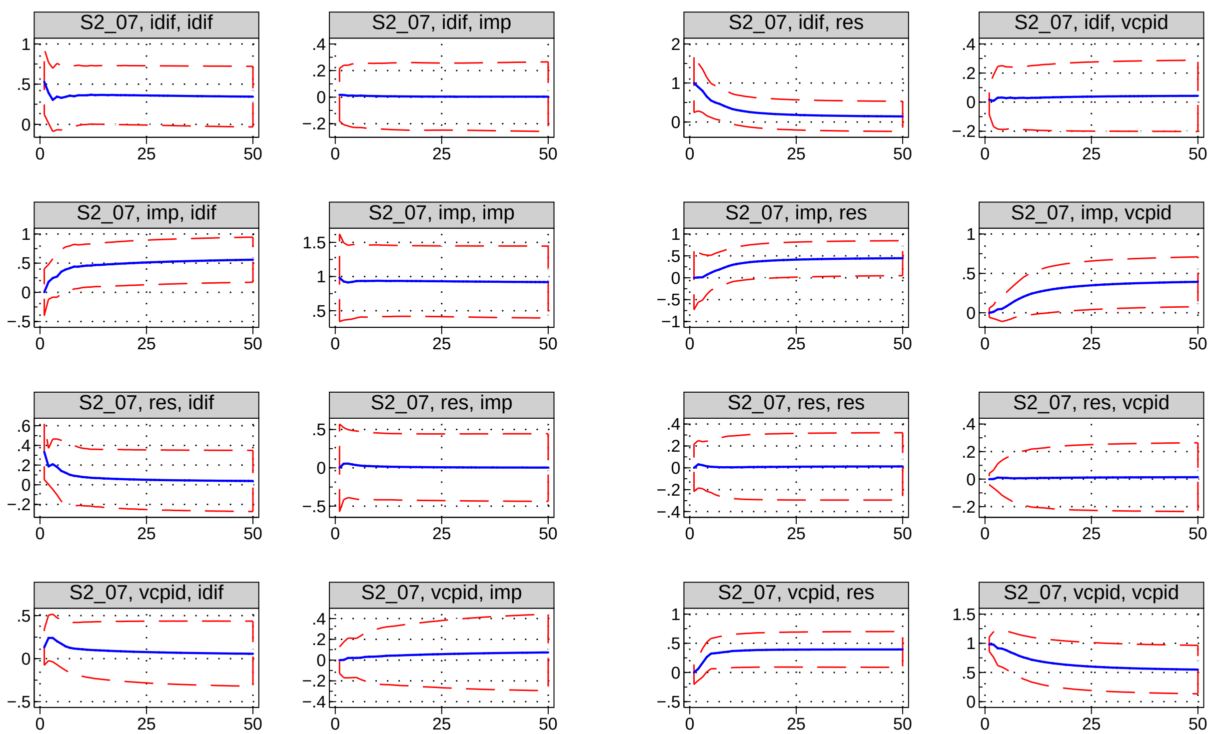


Figure 8.1.1 Structural IRF of VEC Model S2_07 (Subsample)



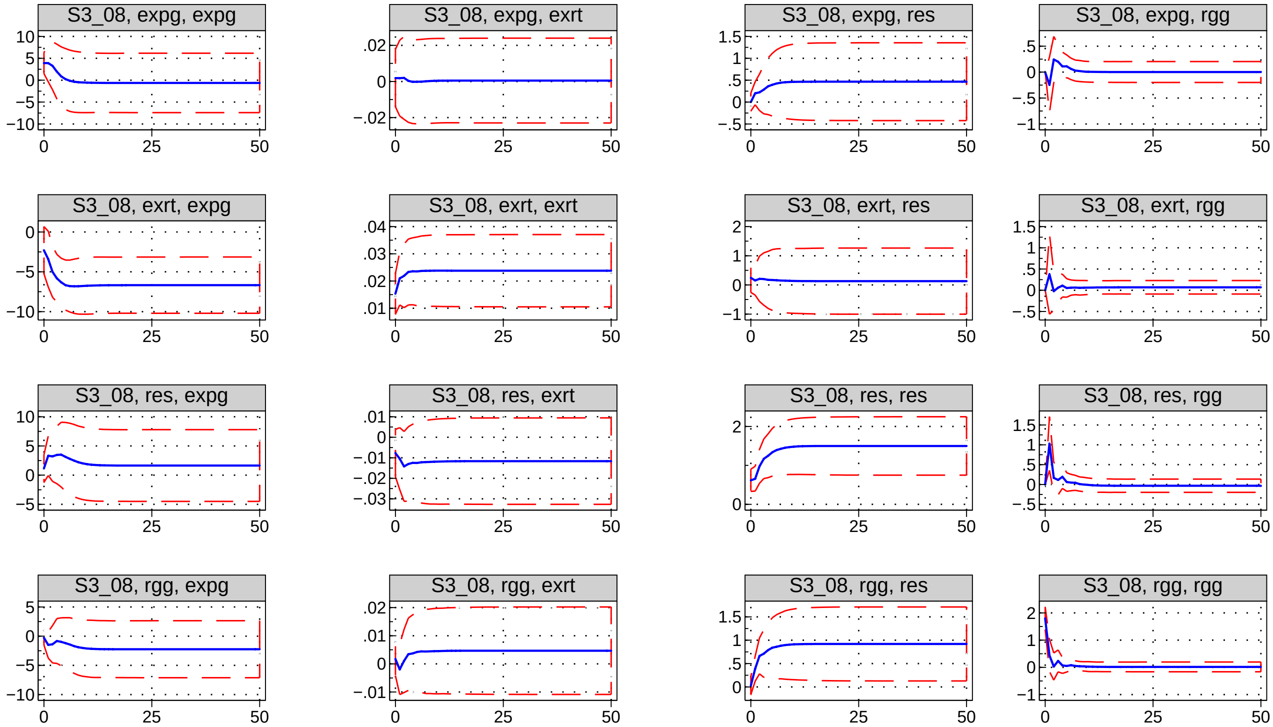
Subtitle: model, shock, response.

Figure 8.1.2 Forecast Error Variance Decomposition of VEC Model S2_07 (Subsample)



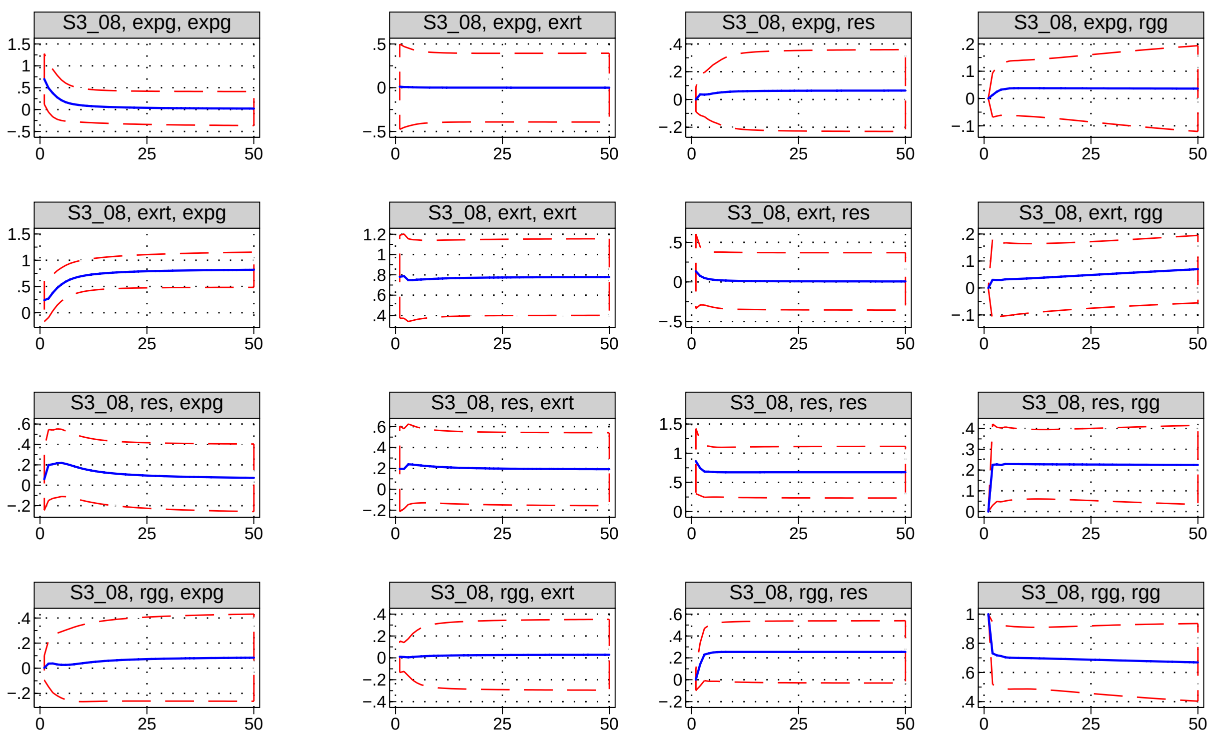
Subtitle: model, shock, response.

Figure 8.2.1 Structural IRF of VEC Model S3_08 (Subsample)



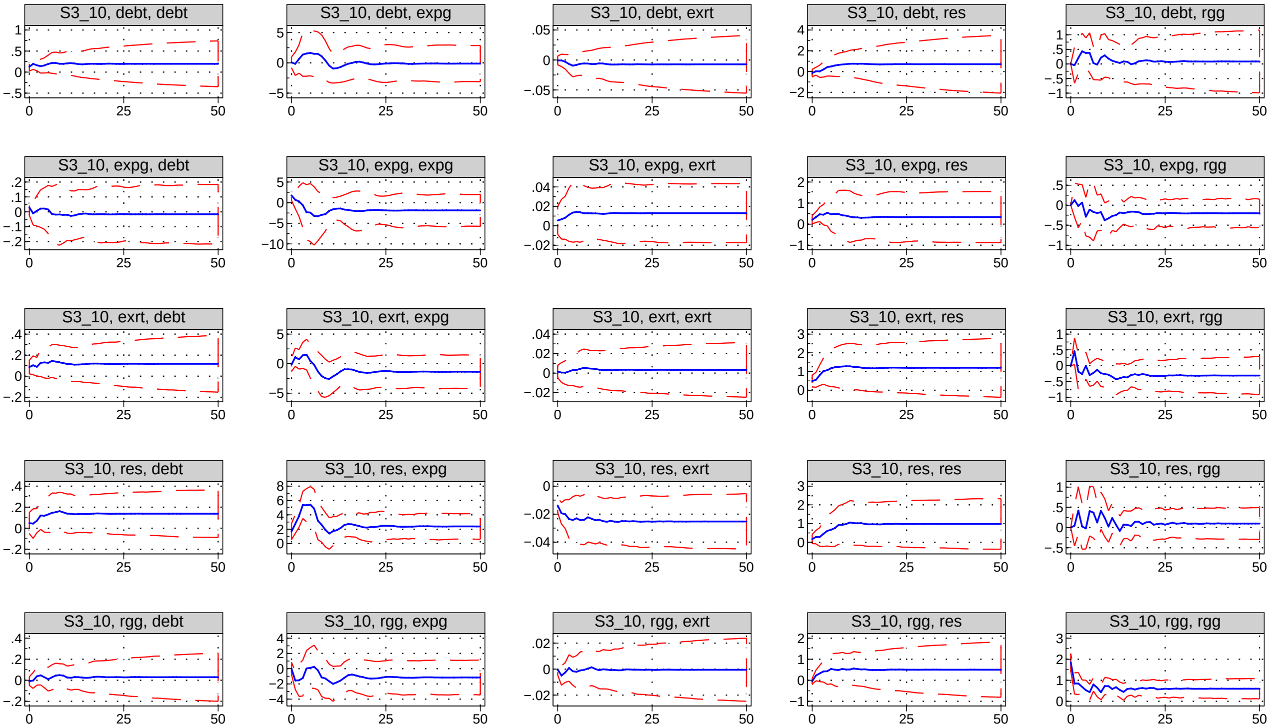
Subtitle: model, shock, response.

Figure 8.2.2 Forecast Error Variance Decomposition of VEC Model S3_08 (Subsample)



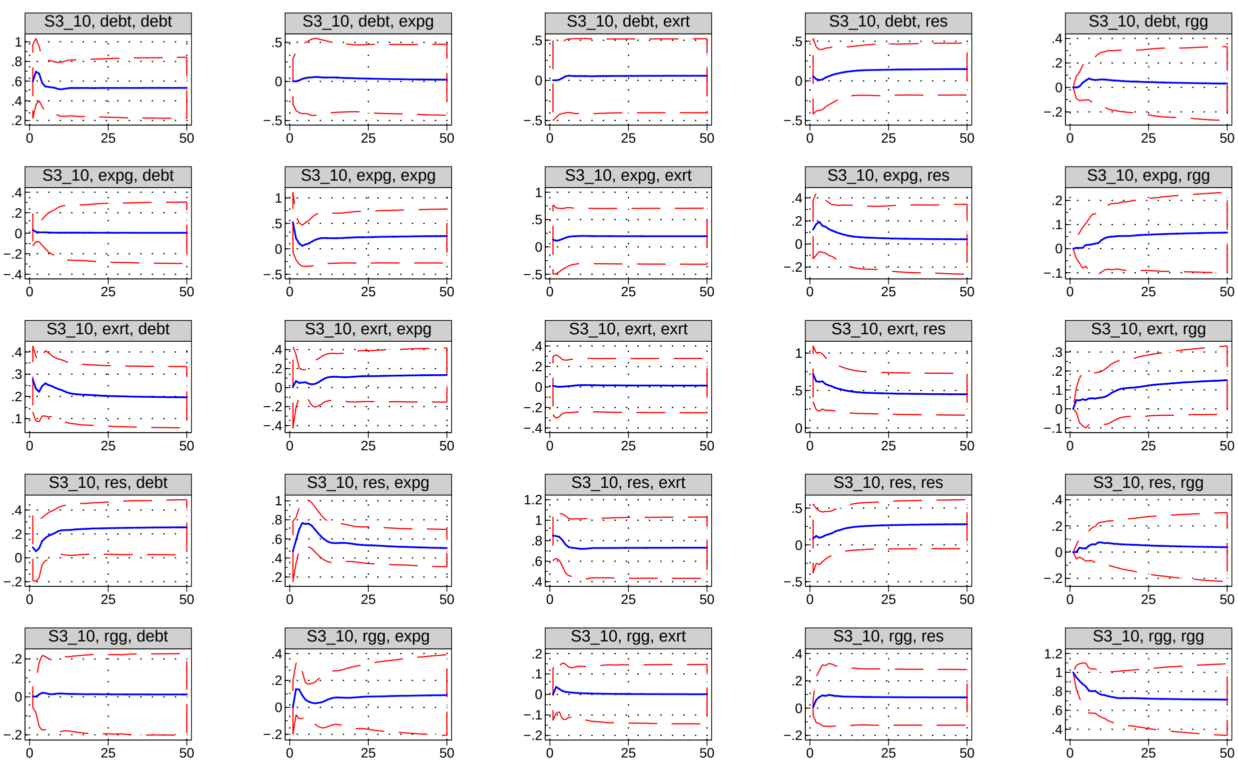
Subtitle: model, shock, response.

Figure 8.3.1 Structural IRF of VEC Model S3_10 (Subsample)



Subtitle: model, shock, response.

Figure 8.3.2 Forecast Error Variance Decomposition of VEC Model S3_10 (Subsample)



Subtitle: model, shock, response.

Appendix

Table A1 Data Sources and Regressors

Data sources:	
[1]	International Financial Statistics, IMF.
[2]	Monthly Bulletin of Statistics-China, July 1985 -, China Statistics Press.
[3]	China Quarterly Gross Domestic Product Estimates 1992-2001, China Statistics Press.
[4]	"Quarterly Real GDP Estimates for China and ASEAN4 with a Forecast Evaluation," Tilak Abeysinghe and Gulasekaran Rajaguru, Department of Economics, Working Paper No. 0404, National University of Singapore, 2003.
[5]	Table 1.7.4. Price Indexes for GDP, GNP and NNP, BEA.
[6]	Federal Reserve Statistical Release H.15, Board of Governers of the Federal Reserve System.

Regressors:	
debt	Total external debts to GDP ratio, %. Total external debts are deflated by the US CPI and GDP are deflated by the Chinese CPI. Sources: [1] [2] [3] [4] [5].
expg	Growth rate of real exports over the same period of last year, %. Nominal exports are deflated by the US CPI. Sources: [1] [5].
exrt	Real effective exchange rate, in logs. Source: [1].
idif	Real interest rate differential between China and the US, percent per annum. For China it is the saving deposit rate and for US it is the 6-month CD rate, both deflated by CPIs. Sources: [1] [2] [5] [6].
imp	Imports to GDP ratio, %. Imports are deflated by the US CPI and GDP are deflated by the Chinese CPI. Sources: [1] [2] [3] [4] [5].
m2gdp	M2 to GDP ratio. Sources: [1] [3] [4].
penn	Deviation of real effective exchange rate from the benchmark value based on the Balassa-Samuelson relation, %. Sources: [1] [2] [3] [4] [5]. Please refer to Table A3 for details of the estimation.
res	Reserves to GDP ratio, %. Reserves are deflated by the US CPI and GDP are deflated by the Chinese CPI. Sources: [1] [2] [3] [4] [5].
rgg	Real GDP growth rate of China relative to the rest of the world, %. The world GDP growth rate is the GDP-weighted average of the high incomes countries and China's top 30 trade partners. Sources: [1] [2] [3] [4] [5].
vcpid	Volatility of inflation rate. It is the standard deviation of detrended changes in inflation rate over the past three years (twelve quarters). Sources: [1] [2].
vexp	Volatility of exports to GDP ratio. It is the standard deviation of detrended changes in exports to GDP ratio over the past three years (twelve quarters). Exports are deflated by the US CPI and GDP are deflated by the Chinese CPI. Sources: [1] [2] [3] [4] [5].

Data are seasonally adjusted.

Table A2 Data Summary Statistics

Full Sample (1983Q1 - 2005Q4)

Obs = 92	Mean	Std.	Min	Max
debt	3.64	2.08	0.602	7.88
expg	13.9	13.1	-15.4	53.2
exrt	4.67	0.303	4.22	5.5
idif	-2.7	6.05	-22.7	5.46
imp	16.4	5.43	6.4	29.8
m2gdp	0.934	0.379	0.378	1.58
penn	1.4	30	-42.1	83.6
res	11.1	8.57	2.89	36.5
rgg	7.42	3.52	-2.26	19.2
vcpid	0.867	0.343	0.302	1.67
vexp	0.928	0.483	0.358	2.25

Obs = 92	*debt*	*expg*	*exrt*	*idif*	*imp*	*m2gdp*	*penn*	*res*	*rgg*	*vcpid*	*vres*
debt	1										
expg	0.13	1									
exrt	-0.63	-0.34	1								
idif	-0.04	-0.12	0.02	1							
imp	0.32	0.56	-0.56	0.12	1						
m2gdp	0.47	0.35	-0.52	0.41	0.81	1					
penn	-0.62	-0.36	1.00	0.00	-0.61	-0.57	1				
res	0.34	0.38	-0.31	0.38	0.83	0.89	-0.37	1			
rgg	0.13	0.16	-0.12	-0.17	0.13	-0.02	-0.12	-0.02	1		
vcpid	0.48	-0.03	-0.43	-0.30	-0.09	-0.23	-0.39	-0.19	0.01	1	
vexp	0.82	0.11	-0.61	-0.22	0.19	0.15	-0.58	0.07	0.20	0.64	1

Subample (1996Q1 - 2005Q4)

Obs =40	Mean	Std.	Min	Max
debt	4.71	1.48	3.04	7.46
expg	15.6	14.4	-13	36.8
exrt	4.59	0.05	4.5	4.68
idif	0.571	1.61	-3.27	3.28
imp	19.8	5.66	13.3	29.8
m2gdp	1.31	0.197	0.926	1.58
penn	-7.68	6.41	-21	3.1
res	19	7.05	11.7	36.5
rgg	6.88	2.28	0.785	13.6
vcpid	0.75	0.339	0.302	1.44
vexp	0.957	0.411	0.533	2.08

Obs = 40	*debt*	*expg*	*exrt*	*idif*	*imp*	*m2gdp*	*penn*	*res*	*rgg*	*vcpid*	*vres*
debt	1										
expg	-0.54	1									
exrt	0.11	-0.44	1								
idif	-0.26	-0.08	0.53	1							
imp	-0.71	0.69	-0.66	-0.10	1						
m2gdp	-0.96	0.64	-0.22	0.27	0.81	1					
penn	0.39	-0.58	0.94	0.40	-0.85	-0.49	1				
res	-0.58	0.58	-0.58	-0.02	0.89	0.69	-0.79	1			
rgg	-0.16	0.17	-0.34	-0.02	0.33	0.15	-0.38	0.28	1		
vcpid	0.80	-0.30	-0.17	-0.23	-0.33	-0.71	0.03	-0.08	0.04	1	
vexp	0.74	-0.41	-0.24	-0.51	-0.38	-0.77	0.02	-0.36	0.02	0.62	1

Table A3 Estimation of the Balassa-Samuel Relation

Regression: log(REER)_it = u_i + b * log(GDPPC_real)_it + e_it

```
Fixed-effects (within) regression               Number of obs      =      3294
Group variable (i): ifscode                     Number of groups   =        44

R-sq:  within  = 0.0872                         Obs per group: min =        30
       between = 0.0397                                        avg =      74.9
       overall = 0.0100                                        max =       100

                                                F(1,3249)          =    310.52
corr(u_i, Xb)  = -0.7713                        Prob > F           =    0.0000

------------------------------------------------------------------------------
       log(REER)|      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
----------------+-------------------------------------------------------------
log(GDPPC_real) |   .1023224   .0058066    17.62   0.000     .0909373    .1137074
       constant |   4.773169   .0076999   619.90   0.000     4.758072    4.788266
----------------+-------------------------------------------------------------
        sigma_u |  .13001741
        sigma_e |  .11058102
            rho |  .58025974   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:       F(43, 3249) =    48.94           Prob > F = 0.0000
```

Table A4 Structural Estimation Results

	a1	a2	a3	a4	a5	a6	a7	a8	a9	a10	σ_1*	σ_2	σ_3	σ_4	σ_5
F2_07	-0.14	-0.5	-2.52	-0.37	2.92	0.05					1.12	1.26	2.77	0.11	
F3_06	-0.14	-0.12	-0.21	0.03	-0.36	-0.07	-0.05	0.61	4.45	0.26	0.80	1.22	1.70	5.02	5.34
F3_08	-24.24	0.04	0.11	-0.01	0.01	106.86					1.18	0.08	5.89	2.24	
F3_10	-30.62	0.02	-0.61	0.13	-0.004	-0.18	0.02	52.52	0.01	1.20	1.08	0.08	4.97	0.23	2.01
S2_07	-0.03	-1.25	2.73	-0.34	51.06	0.02					0.37	1.29	25.87	0.09	
S3_08	-14.89	0.01	0.01	-0.0005	-0.001	149.45					0.74	0.02	4.20	1.80	
S3_10	-211.52	0.55	-0.43	9.85	-1.34	11.73	0.32	121.57	-0.18	1.29	3.99	6.13	2.44	0.15	1.86

* σ's are the standard deviations of the structural shocks in *v*.

Figure A1 Graphs of Data Series (1983Q1−2007Q4)