The Response of the Canada/U.S. Real Exchange Rate to World Real Oil Price Shocks

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My major paper is presented to the
Department of Economics of the University of Ottawa
in partial fulfillment of the requirements of the M.A. degree

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ECO 7997

Ottawa, Ontario

May 2008

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I. Introduction

In 1950, the Canadian government announced a decision to free the exchange rate. Then Canada enjoyed a period of flexible exchange rates from October 2, 1950, to May 2, 1962. However, after this period of flexibility, Canada went back to a fixed exchange rate from 1962 to 1970. After that difficult period, Canada returned to a flexible exchange rate again in 1970 and has maintained this exchange rate policy to the present day (Powell 2005). In recent years, especially the last two years, the Canadian dollar has displayed considerable strength against the U.S. dollar. At the same time, the world crude oil price has displayed similar strength and recently increased to more than $100 U.S. dollars per barrel.[1] Consequently, over the years, the effects of world oil price shocks on the macro economy have attracted more economists' attention.

In general, we can only directly observe fluctuations in the nominal exchange rate. However, rates of inflation differ across countries, the real exchange rate, which is the ratio of foreign to domestic prices measured in terms of the same currency, may not change when the nominal exchange rate shifts (Piana 2001). Because the real exchange rate is more relevant to many economic agents than the nominal exchange rate, including studies of the effect of oil price shocks on the exchange rate, many economic analyses

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[1] The World Crude Oil Price is obtained from the U.S. government's Energy Information Administration's official energy statistics. (http://tonto.eia.doe.gov/dnav/pet/pet_pri_wco_k_w.htm)

focus on it rather than the nominal exchange rate.

What determines the real exchange rate is a very complex question. There are many factors that may affect the real exchange rate, such as differentials in productivity growth, domestic and foreign government spending and monetary differentials. Some economists just pay attention to monetary factors as determinants of the exchange rate. However, with the development of the economy and the potential high energy requirements of rising standards of living, the whole world faces a crisis of insufficient energy resources. World oil price shocks, as the most important energy shock, will affect all areas of the economy and play a decisive role. For this reason, many economists believe that world oil price shocks may be closely related to real exchange rate fluctuations.

This fact makes me very interested in the relationship between world oil price shocks and the Canada/U.S. real exchange rate. Many previous studies have discussed this relationship using different methods and different data. In my paper I will examine a five-variable model based on Zhou (1995) that includes world oil prices. As does Zhou, I will use a Vector Error Correction (VEC) model, but will examine the relationship between the Canada/ U.S. exchange rate, not the Yen/dollar or Markka/dollar exchange rates, and other factors.

II. Literature Review

While interest in the impact of oil prices changes has grown over the years, not all studies of the impact of oil price shocks have considered their impact on real exchange rates. Similarly, not all studies of the determinants of real and nominal exchange rates have included oil prices. In this literature review, I begin by examining a few papers that look at the impact of oil price shocks on real variables other than the real exchange rate. Then I consider models of exchange rate determination in general, for Canada and other countries. Finally, I review existing studies that focus on the relationship between the real exchange rate and oil price shocks.

Given a rich history of oil price shocks, Barsky and Kilian (2004) state that a number of oil price shocks since the 1970s made many economists realize that world oil price shocks play an important role in the macro economy. Furthermore, a notable collapse of oil prices in 1986 and a boom in oil prices in 2000, as well as the oil price increases associated with the 1990-1991 Gulf war and the 2003 Iraq war seem to be correlated with U.S. economic performance, supporting the view that increases in oil prices cause recessions, periods of excessive inflation, reduced productivity and lower economic growth. Because of these big impacts on the economy, economists are paying more and more attention to world oil price shocks and more papers are considering the role of world oil price shocks in determining the exchange rate. All of these facts are my original inspiration in this paper. Therefore, the first and most important variable in my model is oil prices.

Prior to my paper, many empirical studies discussed the impact of oil price shocks on the macro economy, but not on the real exchange rate or nominal exchange rate. Bernanke, Gertler, Watson, Sims and Friedman (1997) estimated a structural vector autoregression model containing the rate of growth of the real GDP, the log of the GDP deflator, the log of the commodity price index, a measure of oil prices, the Fed funds rate, the 3-month Treasury bill rate and the 10-year Treasury bonds rate. They used U.S. data for the first month of 1965 to the last month of 1995. They estimated a vector autoregression (VAR) model and calculated impulse-responses for an oil shock under the condition that the Federal funds rate could not rise. The results suggested that monetary policy could be used to eliminate any recessionary consequences of oil price shocks.

The conclusion that monetary policy could offset the effects of oil price shocks was challenged by Hamilton and Herrera (2004). Hamilton and Herrera (2004) used exactly the same model, the same data and the same impulse response analysis to do the test. However, they use Leeper and Zha's (2003) method of calculating the consequences of monetary policy interactions in the model. In addition, they provided evidence in favor of using a longer lag length for the VAR model estimated by Bernanke et al. (1997). These changes led to the conclusion that monetary policy could not offset the contractionary consequences of oil price shocks to the extent that Bernanke et al. (1997) had suggested.

Although these two studies consider the effects of oil price shocks on the macro economy, they do not discuss the effects on the exchange rate. What determines the exchange rate is always a complex problem. As Backus (1986) notes, "the lack of agreement on a theoretical framework makes traditional econometric work … difficult to interpret" (p. 628). Generally, there are five exchange rate determination theories, which have been summarized by Hoontrakul (1999) as follows:

> **1. Purchasing Power Parity (PPP):** Based on 'no arbitrage argument' or 'law of one price', PPP is a flow model of the 'inflation theory of exchange rates' vis-a-vis the balance of trade. …… Hence, PPP is usually a benchmark currency valuation.
>
> **2. PPP and Interest Rate Parity:** The covered interested rate parity (CIRP) states there will be no advantage to borrow or lend in one country's asset market rather in that of another country. …
>
> **3. Monetary Approach:** These stock models are based on IS/LM/Phillip Curve paradigm. Basically the theories are based on finding the exchange rate which the available amount of currency supply is equal to the demand to hold the currency.
>
> **[4]. Portfolio-Balance Approach:** This theory determines the exchange rate *as the relative price of moneys* in short run. …
>
> **5. Microeconomics Foundation Model:** These modern models are generally based on individual optimization problem with constraints under rational expectation model in open economy macroeconomics. (p. 2-3)

Hoontrakul (1999) further subdivides the monetary approach into three subcategories, which are:

> 3.1 **Mundell-Fleming Model**: The theory considers three markets: money, asset and goods markets under perfect *price flexibility* in long run…
>
> 3.2 **Monetarist Model**: This concept implies that the exchange rate level is perfectly correlated with the level of the *relative money supply* in long run…
>
> 3.3 **'Sticky Price' Model**: When a currency is devalued and the price of goods remains fixed for short run, but not in the long run, the currency value may 'overshoot' (p. 2-3)

Most of the empirical literature is based on one or more of the above theories. Some studies support the PPP approach while others find it has little explanatory power. Some studies focus on shifts in the inflation rate, relative productivity and preferences while others concentrate on changes in prices and the labour force. Some studies focus on the change in the real exchange rate while others examine the nominal exchange rate.

For example, Lane (1999) estimated a model in which long-run movement in the nominal exchange rate depends on some inflation-related variables, such as openness, the stock of nominal government debt, central bank independence, country size, political instability, and past inflation performance. This model is based on the theoretical model of Barro and Gordon (1983)., Lane (1999) concluded that variables that affect the propensity to inflate as well as the output growth rate, which affects the long-run real exchange rate, are significant in explaining nominal exchange rate, while the effect of the other inflation variables is weaker. This paper is developed from the PPP approach to the long-run. However, Lane's data set does not include Canada and covers 1974 to 1992, which is 15 years ago.

A recent paper by Frenkel and Koske (2004) examines how much of the euro exchange rate developments can be explained by monetary factors. They study the nominal exchange rate of the euro vis-a-vis the U.S. dollar as well as vis-a-vis five other currencies (the British pound, the Canadian dollar, the Japanese yen, the Norwegian krone, and the Swiss franc) using different monetary approaches: the flexible price monetary model of Frenkel (1976) and Bilson (1978), the sticky price model of Dornbusch (1976), and the real interest differential model of Frankel (1979) with the holding of purchasing power parity at anytime. They estimate a VAR model and test for cointegration using quarterly data for the period 1980 Q1-2003 Q2. Finally, they showed that a long-run equilibrium relationship does indeed exist between the variables of the monetary model for the exchange rate of the euro vis-a-vis the currencies of five out of six of the countries examined in the study, which supports the long-run properties of the monetary approach. In addition, there is rather strong support for the Frankel version of the monetary approach for two countries (Canada and Switzerland) while the results for other countries are ambiguous.

Overall, Frenkel and Koske suggest that the monetary approach should not be used as the exclusive model of exchange rate determination, but can offer some indications for a long-run benchmark. However, their study does not consider the Canada/U.S. exchange rate, and they study the nominal exchange rate rather than the real exchange rate. Nonetheless, their results suggest that I should include a monetary variable as the second variable in my model.

The above two studies ignore the Canada/U.S. exchange rate and oil price shocks in their discussion of nominal exchange rates. Other studies do focus on the Canada/U.S. exchange rate, but do not consider world oil price shocks. Backus (1986) used the VAR method with quarterly data from the first quarter of 1971 to the fourth quarter of 1983 (52 observations). He included the log of total government expenditures, the log of the money stock (M1 or M I A), the log of the price level (GNP deflator), the interest rate (short-term finance company or commercial paper), the terms of trade, the ratio of the trade balance to GNP and the log of GNP, and the log of the nominal exchange rate (Canadian price of U.S. currency). The system also contains a constant, a linear time trend, and three seasonal dummy variables. Backus (1986) found that relative price levels and trade balances are closely related to the nominal exchange rate and most other lagged variables have no perceptible influence on the nominal exchange rate. He also suggested that exchange rate changes may only be associated with real shocks rather than monetary shocks. However, not only does Backus' (1986) study focus on the nominal exchange rate and exclude world oil prices, but the data are also over twenty years old.

A more recent study of the Canada/U.S. real exchange rate is carried out by Gauthier and Tessier (2002). They studied the impact of supply shocks on the Canadian real exchange rate by constructing a structural vector error correction model that links the real exchange rate to commodity prices, productivity, government size, and real returns. They conclude that supply shocks have the largest impact in the long-run and that a positive supply shock leads to a real exchange rate appreciation. In addition, they find that real exchange rate volatility mainly reflects real shocks. This study is more recent than that of Backus (1986) and discusses the effects of real shocks on the Canada/U.S. real exchange rate, but it does not include oil price shocks either.

Finally, there are some studies that discuss the relationship between the real exchange rate and oil price shocks, but do not focus on the Canada/U.S. exchange rate. In an early paper, Beenstock, Budd and Warburton (1981) use a model of a small open economy to explore a general model of exchange rate determination incorporating the structural and portfolio balance approaches as well as the purchasing power parity approach. They discussed the theory of nominal exchange rate and then turned to the real exchange rate. In their estimation, equation (14 of Beenstock, Budd and Warburton

(1981), the log of long run equilibrium value of the index of the effective exchange rate for sterling is the dependent variable and the log of foreign bonds, the log of domestic bonds, the log of money, the log of the price level, the log of interest rates, the log of the UK index of GDP, the log of long run equilibrium value of the index of the effective exchange rate for sterling, log of world index of Gross National Product in constant price world currency and log of the production of north sea oil and some other expected variables as independent variables. They estimate the equation using OLS and two stage least squares estimation. This model contains so many explanatory variables that I think it would not be the best model for me to follows in this paper. Beenstock, Budd and Warburton (1981) treated the discovery and exploitation of North Sea oil as oil shocks and use impulse response to examine their effects. They consider North Sea oil shocks to be real shocks, while money shocks are nominal shocks. They estimated the model using quarterly data for the UK over the period 1970Q1-1978Q4, and did predictions for the period1979Q1-1980Q2. The results suggest that real shocks such as the discovery and exploitation of North Sea oil have real effects on the real exchange rate, while nominal shocks such as money supply shocks do not.

Unlike Beenstock, Budd and Warburton (1981), Golub (1983) uses oil prices to examine the effect of oil shocks. But this paper only develops a formal model of oil price shocks that includes current account flows as well as stock equilibrium conditions. It does not include other factors that could affect the exchange rate. Although he does not do any econometric analysis, Golub examines data on OPEC, America and Europe's excess demands for currency from 1970 to 1980 to see if they are consistent with his model's predictions.

Zhou (1995) tests for cointegration between the real exchange rate, the world real price of oil, domestic and foreign government spending measured, the productivity differential as measured by the log of the ratio of the productivity of the home country and the foreign country, and the monetary differential as measured by the difference between the logs of the monetary variable in the home country and the foreign country. This model contains most of the factors that economic theory suggests will determine the real exchange rate, including world oil prices. Quarterly data were used for the first quarter of 1973 to the second quarter of 1993 for Japan, Finland and the United States. Separate models were estimated for the real Markka-dollar exchange rate and the real Yen-dollar exchange rate. The results support Dorbusch's (1976) sticky price monetary model and illustrate that oil price shocks have a big effect on the real exchange rate. The results also confirm Beenstock, Budd, and Warburton's (1982) conclusion that real shocks have real effects, while nominal shocks do not affect the real exchange rate. In the end, Zhou (1995) suggests that we should give considerable attention to oil price shocks in the future when analyzing movements in real exchange rates for countries who have a heavy dependence on imported oil.

This point is a major inspiration for this paper. However, Canada is a net oil exporter while the United States is a net oil importer. Therefore, what will happen to the Canada/U.S. real exchange rate when there is a world oil price shock is hard to predict.

Another recent paper by Bénassy-Quéré, Mignon and Penot (2005) first studies cointegration and causality between the real price of oil and the real price of the dollar over the 1974-2004 period. The results suggest that a 10% rise in the oil price coincides with a 4.3% appreciation of the dollar in the long run. Second, they develop a theoretical model based on an extension of Krugman's (1980) to the case of four countries (the United States, the Eurozone, OPEC and China) and only one exchange rate (the dollar against the euro). They conclude that the emergence of China reinforces the case for a short-run depreciation of the euro following a rise in the oil price, with a long-run increase in Chinese trade. In addition, the emergence of China could give rise to negative causality from the dollar to oil prices. However, like the previous three discussed above, does not consider the Canada/U.S. real exchange rate.

In summary, after reviewing the above studies I would like to use the world oil price as the general oil price shock variable in my paper, as does Zhou (1995). Since most studies find that real exchange rates are more closely related to real shocks, like Zhou (1995) I will use the real exchange rate instead of the nominal exchange rate. After considering all the variables discussed by these studies, in addition to the world oil price and the monetary differential I will include domestic and foreign government spending and the productivity differential as well. Hence I think Zhou's (1995) model, which contains all these variables, is the most suitable one for me to follow.

Furthermore, when analyzing time-series data, studies usually begin with VAR models, test for cointegration, and use VEC models to analyze the long-run. Therefore I will use this approach together with some newer tests for unit roots and recent data for Canada to examine the effects of oil price shocks and other variables on the real exchange rate.

III. Model and Econometric Methods

Following Zhou (1995), I will estimate a VAR model that consists of six endogenous variables: the Canada/U.S. real exchange rate (*RER*), the world real price of oil (*Poil*), the monetary differential (*M*), Canadian government spending as a proportion of Canadian GDP (*CG*), U.S. government spending as a proportion of U.S. GDP (*USG*), and the productivity differential between Canada and the U.S. (*Y*).

How do these variables affect the Canada/U.S. real exchange rate? Based on Zhou (1995) and some other studies, I have some hypotheses about these effects. The influence of the world oil price on the real exchange rate depends on the difference between the two relevant countries in their dependence on imported oil. The Unites States is a net oil-importer while Canada is a net oil-exporter. Therefore I think the Canadian real exchange rate may be positively related to world oil prices. For government spending, theoretically one would expect high Canadian government spending to lead to a real appreciation of the Canadian dollar, while the effect of higher American government spending should be just the opposite. The productivity differential is the difference between the levels of productivity of the two countries. Zhou (1995) includes the productivity differential because a country with faster productivity growth may experience a real appreciation of its home currency and a lower RER. The monetary differential, M, is a measure of the relative size of the monetary base in the two countries. Generally speaking, changes in the monetary base reflect actions taken by central banks to alter the reserves of the banking system in an attempt to change monetary aggregates. Dornbusch's (1976) sticky price model implies that if the domestic money supply grows faster than the foreign money supply, the real exchange rate will increase, but that this effect is only a short-run effect. In the long-run money should be neutral. This prediction was confirmed by Zhou (1995), but has been was challenged by others. I will see what will happen in my estimation results.

My econometric analysis starts with the most popular method of analyzing time-series data, as the literature review revealed, which is the Vector Autoregression Model (VAR). According to Maddala (2001), vector autoregression (VAR) is an econometric model used to capture the evolution of and the interdependencies between multiple time series. In a VAR model, each endogenous variable is assumed to be a function of the lagged values of all the endogenous variables in the system. Sims (1980) advocates the use of VAR models as a theory-free alternative to simultaneous equations models, in which no restrictions are placed on the parameters. In fact, VAR models can be viewed as reduced-form simultaneous models.

The mathematical representation of a reduced VAR model in matrix notation is:

$$y_t = A_1 y_{t-1} + \ldots + A_p y_{t-p} + \varepsilon_t \qquad (1)$$

In my case, y_t is a 6 x 1 vector containing endogenous variables:

$$y_t = \begin{bmatrix} RER \\ Poil \\ M \\ CG \\ USG \\ Y \end{bmatrix}. \qquad (2)$$

$A_1, \dots, A_p$ are 6 x 6 matrices of coefficients to be estimated, and ε_t is a 6 x 1 vector of innovations that may be contemporaneously correlated but are uncorrelated with their own lagged values and all independent variables (Quantitative Micro Software 2004).

If the variables of the VAR model are cointegrated, then a more appropriate representation of the multivariate system would be a Vector Error Correction model (VEC). A VEC model is a restricted version of a VAR model. The general form of a VEC model with p lags is

$$\Delta y_t = \delta + \Pi\, y_{t-1} + \sum_{i=1}^{p-1} \Phi_i \Delta y_{t-i} + \varepsilon_t \qquad (3)$$

where $\Phi_i = -\sum_{j=i+1}^{p} A_j$ and $\Pi = \sum_{i=1}^{p} A_i - I$. $A_1, \dots, A_p$ are 6 x 6 matrices of coefficients to be estimated, and the matices A_i are the matrices of coefficients of the underlying VAR model in equation (1). $\Delta y_t = y_t - y_{t-1}$ and y_t include the same variables listed in equation (2). Finally, ε_t is a 6 x 1 vector of errors. VEC models incorporate both short-run and long-run dynamics, and thus can lead to a better understanding of the relationships between variables.

Before estimating a VEC model, I need to test each variable of the model for unit roots. Unit root test is used to determine whether the variables are trend stationary or difference stationary, and hence can help to determine whether shocks to a time series have permanent or temporary effects. According to Maddala (2001), if a variable has a unit root, the effect of any shock to that variable is permanent. If a variable does not have a unit root, shocks to that variable do not have a permanent effect.

There are many methods of testing for unit roots. A popular unit root test is the Augmented-Dickey-Fuller (ADF) test, which is based on the t-statistic of the estimator of α in the equation

$$y_t = \gamma + \delta t + \alpha y_t + \sum_{j=1}^{k} \theta_j \Delta y_{t-j} + e_t \tag{4}$$

where y_t is the time-series variable that one would like to test. γ is a constant and δ is the coefficient of the time trend *t*. j is the lag order of the autoregressive process.

Other tests were developed by Said and Dickey (1984), Phillips (1987), and Phillips and Perron (1988), among others.

Because the critical values for the ADF test are sensitive to the number of deterministic terms that are included in equation (3), so are the results of the test. Furthermore, the ADF test suffers from low power. Elliott, Rothenberg, and Stock (1996) suggest the DF-GLS test, which is similar to the ADF test but uses a different method of estimating the coefficients γ and δ. They showed that their modified test is more powerful than the ADF test. Hence in contrast to Zhou (1995), I use the DF-GLS test instead of the

ADF test to test for unit roots in my data. In carrying out the test, I use the modified Akaike information criterion to select the lag length in the test equation, as Ng and Perron (2001) have shown that using this criterion further increases the power of the test.

For purposes of comparison, like Zhou (1995) I also use the KPSS test developed by Kwiatkowski, Phillips, Schmidt, and Shin (1992) to test for unit roots. The principal difference between the KPSS test and others is that its null hypothesis is that there is no unit root, while for the DF-GLS test the null hypothesis is that there is a unit root. For the KPSS test I choose the Bartlett kernel spectral estimation method with Newey-West method of selecting the bandwidth.[2] To confirm the order of integration of the variables, all unit root tests are applied to both the levels and the first-differences of the variables.

If all variables are integrated of order one, then I can test for cointegration. The purpose of the cointegration test is to test for the existence of long-run relationships between the variables. As Maddala (2001) states, if two or more series are themselves non-stationary, but a linear combination of them is stationary, then the series are said to be cointegrated. This means that if two variables are cointegrated they would not drift too far apart from each other over time; that is, there is a long-run equilibrium relationship between them. The two most popular methods of testing for cointegration are Johansen's (1988) Trace test and Maximum Eigenvalue test. Johansen's approach (1988) is based on maximum likelihood estimation of a VEC model. Both tests are conducted sequentially for $r = 0, \ldots, n-1$, where r is the number of cointegrating vectors and n is the number of

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[2] These are the default settings in EViews 5.

endogenous variables in the model. If the null hypothesis that $r = 0$ can be rejected in favour of the alternative that $r \geq 0$, then the tests are repeated for $r = 1$, etc. Maddala and Kim (1998) suggest that the following correction for the number of estimated parameters be applied to the Maximum Eigenvalue statistic before the test is carried out:

$$\lambda_{\max} \times \frac{T - np}{T} \tag{5}$$

where $\lambda_{\max}$ is the Maximum Eigenvalue statistic, n is the number of variables, p is the number of lags in the underlying VAR model, and T is the number of observations. As is well known, cointegration tests are not sensitive to the order of the variables in the model, but are sensitive to lag length selection. In choosing the lag length for the underlying VAR model, I examine several criteria: the sequential modified LR test statistic (LR), the Final Prediction Error (FPE), the Akaike Information Criterion (AIC), the Schwarz Information Ccriterion (SC) and the Hannan-Quinn Information Criterion (HQ). The most popular of these criteria are the AIC and SC. Since these criteria do not always yield consistent results, additional diagnostic tests are carried out to confirm that the choice of lag length is appropriate. In particular, the residuals of the VAR model are tested for autocorrelation, normality, and heteroskedasticity using multivariate versions of the Breusch-Godfrey LM test for autocorrelation, the Jarque-Bera normality test and White's Heteroskedasticity test.[3] If the choice of lag length is correct, the residuals should be normally distributed and free of autocorrelation and heteroskedasticity.

Once the tests for cointegration have been carried out I will estimate an

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[3] These tests are readily available in EViews 5.

appropriate VEC model and use it to do impulse response analysis and variance decomposition. Impulse response analysis and variance decompositions, also known as innovation accounting, are very useful tools for examining the relationships between the variables of the model. According to Enders (2003), impulse responses examine how a one-time shock to one variable is transmitted to all of the other endogenous variables through the dynamic structure of the VEC model, while variance decomposition separates the variation in an endogenous variable into its component shocks. Hence, the variance decomposition can provide information about the relative importance of each type of shock.

I carry out the impulse response analysis using generalized impulse responses with 40 periods. Proposed by Pesaran and Shin (1998), generalized impulse responses are based on an orthogonal set of innovations and do not depend on the ordering of the variables of the model. The variance decomposition, however, is sensitive to the order of the variables, because it is based on a Cholesky factorization of the variance. To test the sensitivity of the variance decomposition to the ordering of the variables, I carry it out with *Poil* in the first and last positions respectively.[4]

Finally, the two tests for cointegration do not always yield the same result regarding the number of cointegrating vectors. If they yield different results, I will also examine the sensitivity of the results to the choice of cointegrating vectors. After all of these procedures, I will be able to verify whether my predictions regarding the effect of

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[4] For the variance decomposition, EViews 5 computes Monte Carlo standard errors with 100 repetitions.

each variable, especially world real oil price shocks, are correct.

After all these tests I could get my predictions for my previous hypothesis of each variable especially world real oil price shocks.

IV. Data

The data I use covers the period from the second quarter of 1980 to the first quarter of 2004 for Canada and the United States, 96 observations in total. The data are obtained from the *International Financial Statistics* (IFS) of the International Monetary Fund (IMF) and the *Canadian Socio-Economic Information Management System* (CANSIM). All the data I use are seasonally adjusted data. With the exception of an employment index for Canada, all variables for Canada and the U.S. were obtained from the IFS country tables for Canada and the United States.

Real exchange rates are nominal exchange rates corrected by inflation measures. By definition, can be expressed as

$$RER = e_{d/f} + p^{f} - p^{d} \tag{6}$$

In this equation, $e_{d/f}$ is the log of the nominal Canada/U.S. exchange rate (*NOMEXC*), and p^{d} and p^{f} are the logs of the Canadian and U.S. overall price levels, measured by the GDP deflators of Canada (*GDPDd*) and the United States (*GDPDf*). *NOMEXC* is the market rate at the end of each period observed by the Bank of Canada, and is obtained from the IFS country table for Canada.

The world oil price (*Poil*) is the log of the world real price of oil, expressed by the equation

$$Poil=\log (COP/WNFPI), \tag{7}$$

where COP is the Dubai spot price index from IFS United Arab Emirates country table and $WNFPI$ is the world non-fuel price index. I have compared the world average oil price index from the IFS World table for 3-spot price index with the crude oil price index of the United Arab Emirates and I find that the numbers are very similar. Thus I decided to use the same data for COP as did Zhou (1995).

The variable CG is defined as

$$CG=\log (GVSd/RGDPC), \tag{8}$$

where $GVSd$ is the log of Canadian government spending and $RGDPC$ is the real GDP of Canada. USG is the log of the ratio of U.S. government consumption spending ($GVSf$) to the real GDP of the U.S. ($RGDPU$). Canadian real GDP ($RGDPC$) is computed as $GDPd/GDPDd$, where $GDPd$ is the nominal GDP of Canada and $GDPDd$ is the Canadian GDP deflator. The U.S. government spending variable is constructed in the same manner.

The money supply differential (M) is measured as

$$M=\log (MC/MU), \tag{9}$$

where MC is the Canadian money stock and MU is the U.S. money stock. I use the same monetary variable as Zhou (1995), Special Drawing Rights (SDR). SDRs are defined in terms of a basket of major currencies used in international trade and finance.[5] SDRs can

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[5] The definition of SDRs is from Wikipedia, the free encyclopedia, http://en.wikipedia.org/wiki/Special_Drawing_Rights

be found in line 14 of the IFS country tables for Canada and the U.S.

The productivity differential (Y) between Canada and the U.S. is expressed as

$$Y = \log(Y^{d} / Y^{us}) \tag{10}$$

where

$$Y^{d} = RGDPC/EMINd \tag{11}$$

and

$$Y^{us} = RGDPU/EMINf. \tag{12}$$

EMINd is the Canadian employment index and *EMINf* is the American employment index. In the IFS, I could only find enough data for *EMINf*, which is the number of persons employed in the U.S employment, not an employment index. But the IFS employment data for Canada (*EMINd*) only cover the period from first quarter of 1993 to the first quarter of 2003. Therefore I replaced these data with the number of persons employed in Canada from CANSIM.[6] Because the CANSIM data are monthly but the IFS data are quarterly, I convert the CANSIM data to a quarterly series by taking the average for each quarter. Then I scaled the CANSIM data to convert it from thousands to millions of people, to make it more consistent with the IFS series. After this change the CANSIM and IFS Canadian employment series are almost the same. This is not surprising, since the IFS obtains its Canadian data from Statistic Canada.

Before carrying out the econometric analysis, all the variables of the model were converted to natural logs. Figure 1 contains plots of the logs of all series. According to

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[6] The employment data are from CANSIM Table 2820087. Series v2062811 is used.

Figure 1, *RER* increased from 1980 to 1985, and then decreased to 1992. Between 1990 and 2002 *RER* increases again, but then falls slightly. From 1980 to 1986, there is a downward trend in *Poil.* A possible explanation for this trend is that in the history of world oil prices, Williams (2007) states non-OPEC production increased 10 million barrels per day during this period, and OPEC faced a lower demand and higher supply from outside the organization. This factor would tend to drive the price down. In 1990 the price of crude oil rose despite the fact that production was still low, due to uncertainty caused by the Gulf War. Strong economic growth in the United States and the Asian-Pacific region caused oil prices to continue to rise for much of the remainder of the sample period.

Because the focus of this paper is on the relationship between world oil prices and the real exchange rate, it is interesting to compare the graphs of *RER* and *Poil* to look for a correlation between them. However, the trends in the two series do not seem to be the same, which suggests that *Poil* may have some effect on *RER* but is not its only determining factor.

Looking at all the graphs in Figure 1 together, we can see that *CG* and *USG* have an obvious upward trend throughout the 1980-2004 periods, but the other variables do not. Thus when I do unit root tests I will carry out the tests both with a trend and without a trend. When no trend is included, I will include a constant in the test equation. Since Figure 2 shows that none of the first differences contains a trend, the latter tests are carries out with only a constant in the test equation.

V. Empirical Results

My empirical analysis is divided into seven subsections dealing with unit root tests, VAR lag length selection, VAR diagnostic tests, cointegration tests, analysis of the long-run coefficients of the VEC models, impulse response analysis and variance decomposition analysis. Since the unit root tests indicate that my time series data have unit roots, I carry out cointegration tests for testing tosee if they are cointegrated or not. Since the lag length selection gives me two possible model specifications, I carry out diagnostic tests to decide which one is better. Once the lag length and number of cointegrating vectors is determined I examine impulse responses and the forecast error variance decomposition.

(i) Unit Root Tests

The results of the unit root tests are presented in Table 1. The tests are carried out both with and without a trend, and in levels and first-differences. Considering the levels first, for all variables except *USG* it is impossible to reject the null hypothesis of the DF-GLS test with no trend at the 5% level of significance, which implies that the most of the series have unit roots. When a trend is included, I again cannot reject the null hypothesis using the DF-GLS test, which implies that all the variables have unit roots. Since *USG* displays an obvious trend as noted in section IV, for this variable the test result with a trend is more persuasive.

Turning now to the results of the KPSS test for the levels of the variables, the null hypothesis of the test is that the time-series is stationary. The KPSS tests without a trend lead to different conclusions for different variables. The results imply that only *Poil* and *M* are trend stationary. But when a trend is included, like the DF-GLS tests the KPSS tests indicate that all variables are non-stationary at the 5% significance level.

For the first differences, the KPSS tests without a trend imply that all the variables are trend stationary in first-differences at the 5% level of significance except *CG* which is non-stationary at 5% significant level. The results of the DF-GLS test imply that *POIL, CG* and *USG* are trend stationary in first differences at any significance levels, but *RER, Y* and *M* have a unit root at the 5% significance level.

Combining all the results we can conclude that all the time series have at least one unit root, that is, they are all difference stationary. But it is not clear what conclusion should be drawn regarding the order of integration, since for most variables at least one of the two tests carried out implies that the first difference also has a unit root. It is possible that these inconsistencies are due to breaks in the time series, which the unit root tests do not allow for.[7] For this reason, and because the analysis of an I (2) system would be beyond the scope of this paper, I will assume for the remainder of the analysis that all the variables are I (1). Hence I can carry out cointegration tests to see whether the variables are cointegrated or not. But before doing the cointegration tests I must

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[7] The software used for this paper, EViews 5, does not readily allow one to do unit root tests that allow for structural breaks.

determine the lag length of the underlying VAR model.

(ii) VAR Lag Length Selection

The choice of lag length is very important for cointegration tests since the results of the test are very sensitive to it. Lag length selection is carried out within the underlying VAR model. Note that the results of lag length selection tests are the same regardless of the order of variables in the VAR.

Table 2 presents five different criteria for lag length selection. In Table 2 it is very obvious that three of the methods (LR, FPE, AIC) choose five lags, while the other two (SC, HQ) choose one lag.[8] Asghar and Abid (2007) suggest that for sample sizes of 120 or more the SC performs best, but for sample sizes of about 60, the probability of correct estimation is highest for HQ, although AIC and SC also do well. Since my sample size of 96 is somewhere between 120 and 60, their findings do not give me much guidance regarding which criterion is best. I can not decide which result is better. But since my sample size is closer to 120, the SC may be the best choice. Generally, the SC tends to choose a shorter lag length than the AIC.

(iii) VAR Diagnostic Tests

Since the lag length selection criteria do not agree regarding the choice of lag length for the VAR model, I will carry out some further diagnostic tests for both lag

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[8] The likelihood ratio tests are carried out at the 5% level of significance.

lengths to see which is best. These diagnostic tests include the LM test for autocorrelation, the Jarque-Bera normality test and White's heteroskedasticity test. I choose LM test for Autocorrelation test, Cholesky variance for Normality test and White test for testing Heteroskedasticity. A good VAR model should have no autocorrelation and no heteroskedasticity with normal residuals. The results of the diagnostic tests are presented in Table 3.

Table 3 provides the p-value for each test. The null hypotheses of the autocorrelation, normality, and heteroskedasticity tests are that there is no autocorrelation, the errors are normally distributed, and there is no heteroskedasticity respectively. Obviously, the model with five lags passes all three tests at the 5% significance level, while the model with one lag does not at even the 10% significance level. In sum, the diagnostic tests indicate that five lags are better than one lag for these variables. Therefore, I will choose the model with five lags to do the cointegration tests.

(iv) Cointegration Tests

Table 4 contains the results of the cointegration tests with variable order of *RER, CG, USG, Y, M* and *PoiL*. Like unit root tests, cointegration tests are sensitive to the assumptions made about deterministic trends in the data. In this case I have carried out the tests under the assumption that the data contain a linear deterministic trend but the cointegrating equations have only intercepts.[9] The critical values for the tests are from

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[9] It should be noted that for VEC models, EViews 5 requires that the lag length interval be specified in terms of the number of first difference terms, not in the number of lagged level terms as in the

MacKinnon, Haug, and Michelis (1999).

The results in table 4 indicates that Trace test chooses three cointegrating equations at the 5% level, while the Maximum Eigenvalue test choose two cointegrating equations. When the correction recommended by Maddala and Kim (1998) is applied to the $\lambda_{\max}$ statistic, the outcome of the test changes to only one cointegrating equation.[10]

In sum, the Trace test implies three cointegrating equations and the Maximum Eigenvalue test implies one cointegration. Because it is not clear which of the two tests is the most reliable, I will carry out a sensitivity analysis by calculating the impulse responses and variance decomposition for two specifications of the VEC model, with three cointegrating equations and one cointegrating equation respectively. Overall, the results imply that cointegration exists. In other words, there exists a long-run relationship between the variables of the model.

(v) Coefficients of the Long-run Relationships

In previous studies such as Zhou (1995) and Dornbusch (1976), monetary variables have only short-run effects on the real exchange rate. But Frenkel and Koske (2004) found a long-run relationship between the nominal exchange rate and money. In addition, world real oil price shocks are supposed to have a long-term effect. To determine whether oil prices and the monetary differential have long run effects in my

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corresponding VAR model. Hence the lag length that must be specified is one less than the lag length chosen for the VAR.

[10] It should be noted that at the 10% level of significance, Maximum Eigenvalue test chooses one cointegrating vector. And Trace test chooses two cointegrating vectors.

VEC models, I test the null hypotheses that *Poil* and *M* respectively under the long-run cointegrations relationships in my VEC models. In Table 5 it can be seen that all the p-values are less than 0.01, which implies that the variables *Poil* and *M* do belong in the cointegrating vectors for both the one cointegrating vector VEC model and three cointegration vectors VEC model. This result implies that these two variables have long-run effects on the real Canada/U.S. exchange rate at the 1% significant level. Therefore, I will not drop any variables as Zhou (1995) did, and carry out the subsequent analysis with all variables.

(vi) Impulse Responses

Figures 3 and 4 contain graphs of the generalized impulse responses of the responses of the real exchange rate, *RER*, to a one standard deviation shock to each of the equations of the VEC model. Figure 3 presents the impulse responses for a model with one cointegrating vector, while Figure 4 presents the impulse responses for a model with three cointegrating vectors.[11]

Figure 3 shows that shocks to the world oil price equation have a small negative effect on the real exchange rate in the first quarter. The effect of the shock then becomes positive, and remains so in the long run. However, this positive impact on the real exchange rate – an increase of approximately 1% in the long-run is small compared to the

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[11] While it would certainly be possible to compute the responses of other variables as well, only the responses of *RER* are discussed because the focus of this paper is on *RER*. Note that the standard errors of the impulse responses are not shown because this option is not available for VEC models in the version of EViews5 used for this paper.

effect of shocks to some other equations. A shock to the monetary equation has a positive effect on the real exchange rate for the first nine quarters (almost two years), but then turns negative. In the long-run, the effect of the shock to the monetary equation is to reduce the Canada/U.S. real exchange rate by less than 1%. Thus although the effect of the shock monetary differential equation is not large, it does seem to have a long-lasting effect on the real Canada/U.S. real exchange rate. This finding conflicts with that of Zhou (1995), who examined the real exchange rate between the Finnish and Japanese currencies and the U.S. dollar.

Comparing all the impulse responses in Figure 3, the shock to the U.S. government spending equation has the biggest negative effect on the real exchange rate in the long run. While in the short run a shock to the *USG* equation raises the real exchange rate, the long-run effect of the shock is a decrease of about 3% in the Canada/U.S. real exchange rate. This result is not consistent with the results of Zhou (1995), who found that the most important shock was the shock to the world real oil price equation. In the case of the Canada/U.S real exchange rate, my results suggest that one standard deviation shock to the world real oil price and productivity differential equations have the similar effects. The effect of a shock to the Canadian government spending equation is slightly larger, leading to a long-run increase in the real exchange rate.

Figure 4 shows that the generalized impulse responses are surprisingly similar for the model with three cointegrating vectors. Again, a shock to the world real oil price equation has a positive long-run impact on the real exchange rate between Canada and the U.S. A shock to the monetary differential equation has a positive effect on the Canada/U.S. exchange rate at the first six quarters, but the long-run effect of this shock is negative. Among all the equations, the shock to the productivity differential equation has the smallest effect on the real exchange rate, while a shock to the U.S. government spending equation has the largest effect.

Comparing Figures 3 and 4, both indicate that the shock to the productivity differential has the smallest effect, a finding which is consistent with Zhou (1995). Figure 4 reports a relatively larger effect of shocks to the productivity differential equation than Figure 3. In addition, both figures illustrate that shocks to the U.S. government spending equation have the largest effect on the real Canada/U.S. exchange rate. One possible reason why my results imply that shocks to the real world oil price have a smaller effect on the real exchange rate than in Zhou (1995) may be that Finland and Japan have a heavier dependence on imported oil than U.S. while Canada does not.

In sum, although shocks to the world oil price equation do not have as important as in some other studies, they do have a long-run effect on the real Canada/U.S. exchange rate. Furthermore, my results indicate a long-run relationship between monetary variable and the real exchange rate, which supports the expectations of Frenkel and Koske (2004). The magnitude of the effect is sensitive to the number of cointgrating vectors in the model, but both Figures 3 and 4 report a similar tendency for each variable. In general, the long-run effects of shocks seem to be larger in the model with more cointegrating vectors than in the model with fewer cointegrating vectors.

(vii) Variance Decomposition

In this section I examine the decomposition of the forecast error variance, again over a time horizon of 40 quarters (ten years). Because the variance decomposition is sensitive to the ordering of the variables, to test the sensitivity of the results to the ordering of the variables I present the variance decomposition for two orderings of the variables for each VEC model estimated. Tables 6-1 and 7-1 present the variance decompositions for the VEC models with one cointegrating vector and three cointegrating vectors respectively, when the ordering is *RER, CG, USG, Y, M* and P*oil.* Tables 6-2 and 7-2 present the variance decompositions for the two VEC models when the ordering is *RER, Poil, CG, USG, Y* and *M*.

In Table 6-1, the proportion of *Poil* increases from 0.016699% to 0.200085% during first four quarters. Then it ranges between 0.144361% and 0.241090% till period 13. After that it increases from 0.149289% in the thirteenth quarter to 0.920570% in the fortieth quarter. In Table 6-2 when the position of *Poil* in the ordering is changed, the proportion of *Poil* jumps from 0.021495% to 0.215548% during first three quarters and then declines to 0.144994% in the fifth quarter. After that it continues to increase from 0.615231% in the sixth quarter to 4.428839% after ten years.

Although both tables 6-1 and 6-2 report an increasing effect of world real oil price shocks on the forecast error of *RER,* in Table 6-1 *Poil* accounts for the smallest proportion throughout the 10-year forecast horizon, which implies that world oil price shocks may have the smallest effects on the Canada/U.S. real exchange rate. However, when the ordering is changed Table 6-2 shows that it accounts for a slightly larger proportion of the forecast error variance. In this table, it is the monetary differential that accounts for the smallest proportion of the forecast error variance after ten years.

Table 6-1 also indicates that the proportion of *M* in the forecast error increases from 4.636035% in period 2 to 12.20680% in period 6. Then it continues declining to a low of 2.290253% after forty quarters. Table 6-2 illustrates almost the same behavior in that the proportion of *M* increases in the first six quarters, and then decreases to period 40, although the long-term effect is slightly larger. In short, both tables indicate that the monetary shocks have large effects on the real Canada/U.S. exchange rate in the short run, but thereafter their effects continue to decline. Both tables report that the effect of a monetary shock is larger than that of a world oil price shock during the first several periods. In both Tables 6-1 and 6-2 *USG* accounts for the largest proportion – almost 70% -- of the forecast error variance in the long run, which implies that U.S. government spending shocks have the largest effect on the real Canada/U.S. exchange rate.

How does the variance decomposition differ for the model with three cointegrating vectors? Table 7-1 indicates that the proportion of *Poil* increases from 0.007279% to 0.272165% from quarter two to quarter three. Then it declines for two periods. After that it increases again from 0.198447% to 6.879936% during period five and twenty-two, and finally declines to 6.109757% by the fortieth quarter. Table 7-2 indicates that *Poil*'s share of the forecast error variance increases from 0.005411% in the second quarter to

18.28416% in the twenty-third quarter, and finally declines to 17.29585% by the end of the ten-year forecast period. Both Tables 7-1 and 7-2 show *Poil* accounting for a larger proportion of the forecast error variance than Tables 6-1 and 6-2, which indicates that the model with three cointegrating vectors implies a larger effect of world real oil price shocks on the real Canada/U.S. exchange rate than the model with one cointegrating vector.

Table 7-1 also shows that in the model with three cointegrating vectors, the monetary differential *M*'s share of the forecast error variance increases from 4.183538% in the second quarter to 10.77183% in the fifth quarter. Then it continues to decline to 1.329207% after ten years. Table 7-2 reports a similar role for *M* when the ordering of the variables is changed, although *M*'s share is slightly smaller. This behavior of the monetary shock is almost the same as that in the model with one cointegrating vector. Both Tables 7-1 and 7-2 indicate that the proportion of *M* becomes the smallest of all the variables by period 40. In addition, of all the variables *USG* accounts for the largest proportion of the forecast error variance regardless of the ordering of the variables, which means that U.S. government spending shocks have the largest impact on the Canada/U.S. real exchange rate.

Summarizing all the variance decomposition results, both VEC models indicate that although world oil price shocks do have an effect on the Canada/U.S. real exchange rate, they are not the most important determinant of the real exchange rate. Both models also suggest that the effect of a shock to the monetary equation is larger during the first ten quarters, but eventually declines to a very small one. Together with the results of the impulse response analysis, these results suggest that monetary shocks have an important effect on the real exchange rate in the shorter term. In the longer run, U.S. government spending as a share of U.S. GDP appears to have the largest effect on the Canada-U.S. real exchange rate. In the longer run, both variables have a negative impact on the real exchange rate.

VI. Conclusion

In my paper, I investigate a multivariate model of the Canada/U.S. real exchange rate that includes the world real oil price and some other variables. With the exception of the monetary differential, all of the included variables represent real shocks. To determine the appropriate specification of the model, I carried out tests for unit roots and cointegration. I then estimated two alternative VEC models of the system, and carried out impulse response analysis and variance decomposition. The cointegration tests indicate that there is a stable long-run relationship between the world real oil price, the Canada/U.S. productivity differential, the Canada/U.S. monetary differential, the shares of government spending in real GDP in Canada and the U.S., and the Canada/U.S. real exchange rate. Comparing my results with those of Zhou (1995), my results also imply that the world real price of oil does influence the real exchange rate, but that it is not the most important factor.

Although some sensitivity analyses indicated slight differences in the results resulting from changes in model specification, generally speaking, my results tend to support my original hypothesis that world oil price shock should have a positive effect on the Canada/U.S. real exchange rate, although this effect is not very large. Because I do not focus on any particular structural model, it is hard to relate my results to particular economic theories of the effect of world real oil price shocks on the real exchange rate. Instead, my work investigates the nature of the existing empirical relationships between the real exchange rate and some of its possible determinants, in particular the world real oil price.

Overall, I can say that the world real oil price does plays a role in determining the Canada/U.S. real exchange rate, but its role is not necessarily the most important one. I think the most likely reason why the world real oil price seems to be less important to Canada's real exchange rate with the U.S. than to those of Finland and Japan that were investigated by Zhou (1995) is the different country characteristics. Canada is an oil producer and a net exporter of oil to other countries, but the United States is a net oil importer. In contrast, Finland and Japan have a big dependence on imported oil. Therefore, world oil prices may have not as much of an effect on the Canadian real exchange rate as on those of Finland and Japan. Taken together, my empirical results and those of Zhou (1995) indicate that the world oil price shocks do not have the same effects on every country's real exchange rate. These effects depend on conditions such as whether a country is an oil importer or an exporter and the volume of oil imported or exported. The different sample period may also have contributed to the differences in results.

The evidence regarding monetary variables in the model is a bit difficult to interpret. However, the tests on the cointegrating vectors discussed in subsection (v) suggest that the monetary differential does have long run effects on the Canada/U.S. real exchange rate.

Additionally, the results of my impulse response analyses show that the effects of the shocks to each equation are in the expected direction for all variables. I find that for Canada, shocks to the U.S. government spending equation have the most important effect of all the variables. Zhou (1995) also found that for Finland and Japan shocks to the U.S. government spending equation had very notable long-term impacts on the real exchange rate, but for these countries it was not the most important one. Again, the heavy dependence of Japan and Finland on imported oil may explain why world real oil price shocks were more important than U.S. government spending shocks for those countries. However, the reason for this needs further study. Of all the variables, the productivity differential has the smallest effect on the Canada/U.S. real exchange rate, a finding which is consistent with Zhou (1995).

Overall it is obvious that we both the world oil price and the share of U.S. government spending in U.S. GDP should be taken into account when determining the Canada/U.S. real exchange rate. Furthermore, the empirical results in my paper suggest that a longer lag length for the underlying VAR model is better than a shorter one. But the determination of the real exchange rate is very complicated, so there are no doubt other factors which may affect it but were not included in my model, such as news and international trade. My model is not perfect and it may have some problems which need further study to resolve. For example, the unit root tests suggested that two of the variables may be integrated of order two, not integrated of order one, which may make my system unstable. Furthermore, as one can see from the graphs in Figure 1, some of the variables appear to contain structural breaks and outliers which may cause some problems. Therefore, in the future it would be desirable to test for structural break and add some dummy variables to account for any breaks that may exist.

Finally, after comparing the results for different models I realized that the results are very sensitive to the sample period, differences in data sources, different lag lengths and the number of cointegrating vectors. Since I do not focus on any particular structural model, the results may not reflect some economic theories of real exchange rate determination. Furthermore, since my results are based primarily on an theoretical econometric approach, it is difficult to given them a satisfying economic interpretation. In future work, I will check out every data source and alternative econometric methods. With the development of social science, I believe that there must be newer and more efficient econometric methods with more explanatory power that would help us to develop a better economic model of the real exchange rate.

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Figure 1
Natural Logarithms of Variables

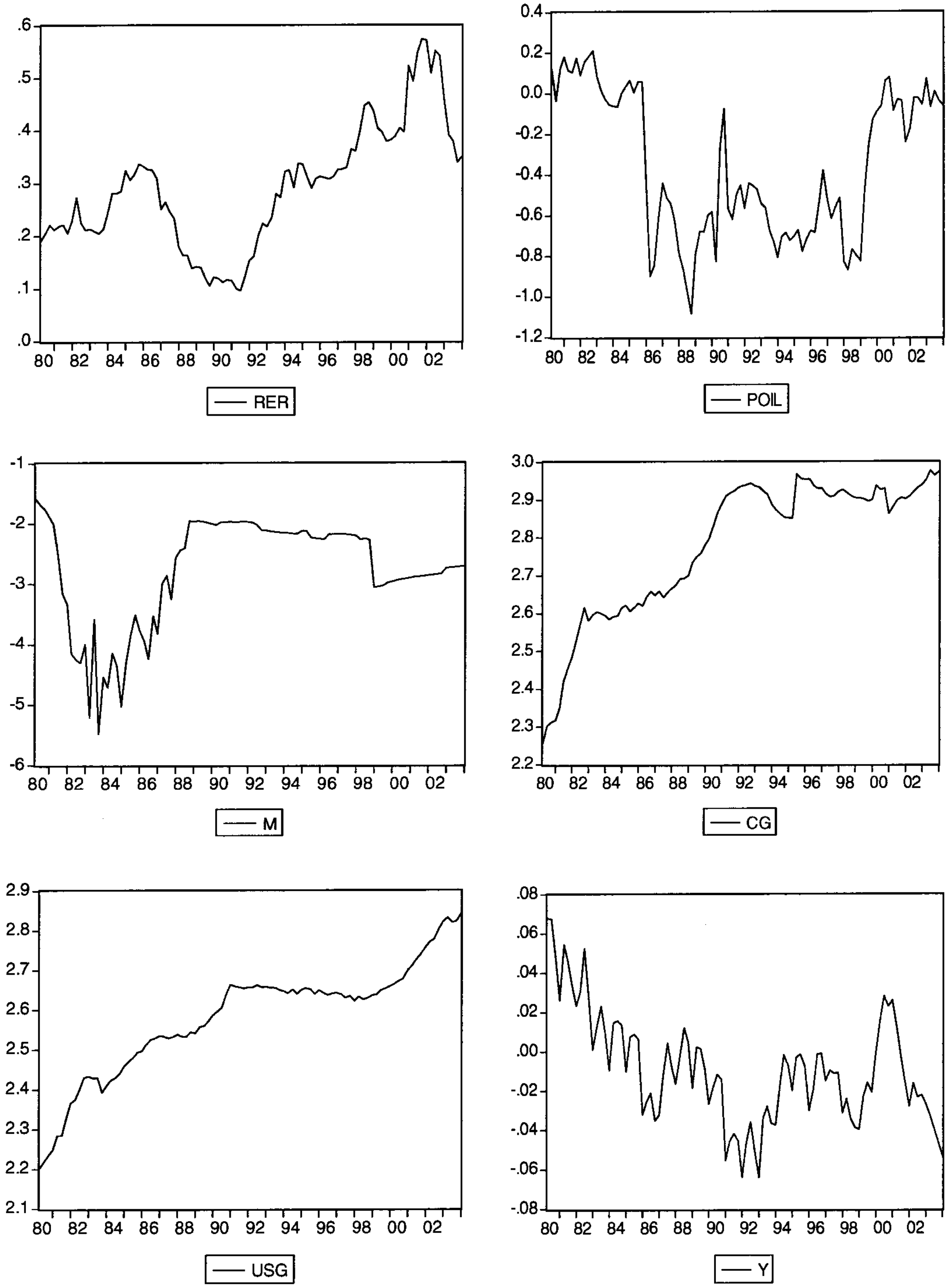

Figure 2
First Differences of Natural Logarithms of Variables

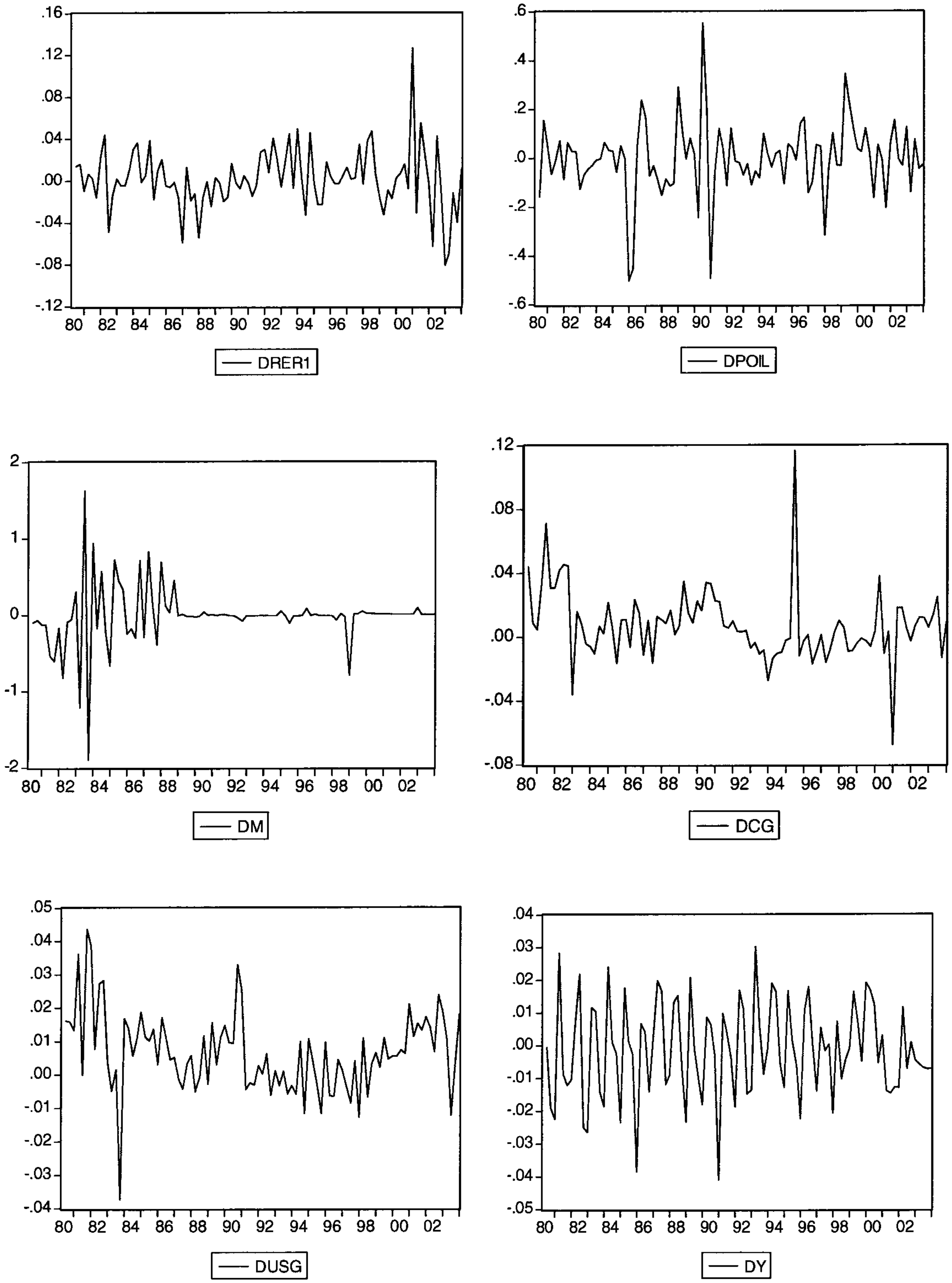

Figure 3
Impulse Responses with One Cointegrating Equation

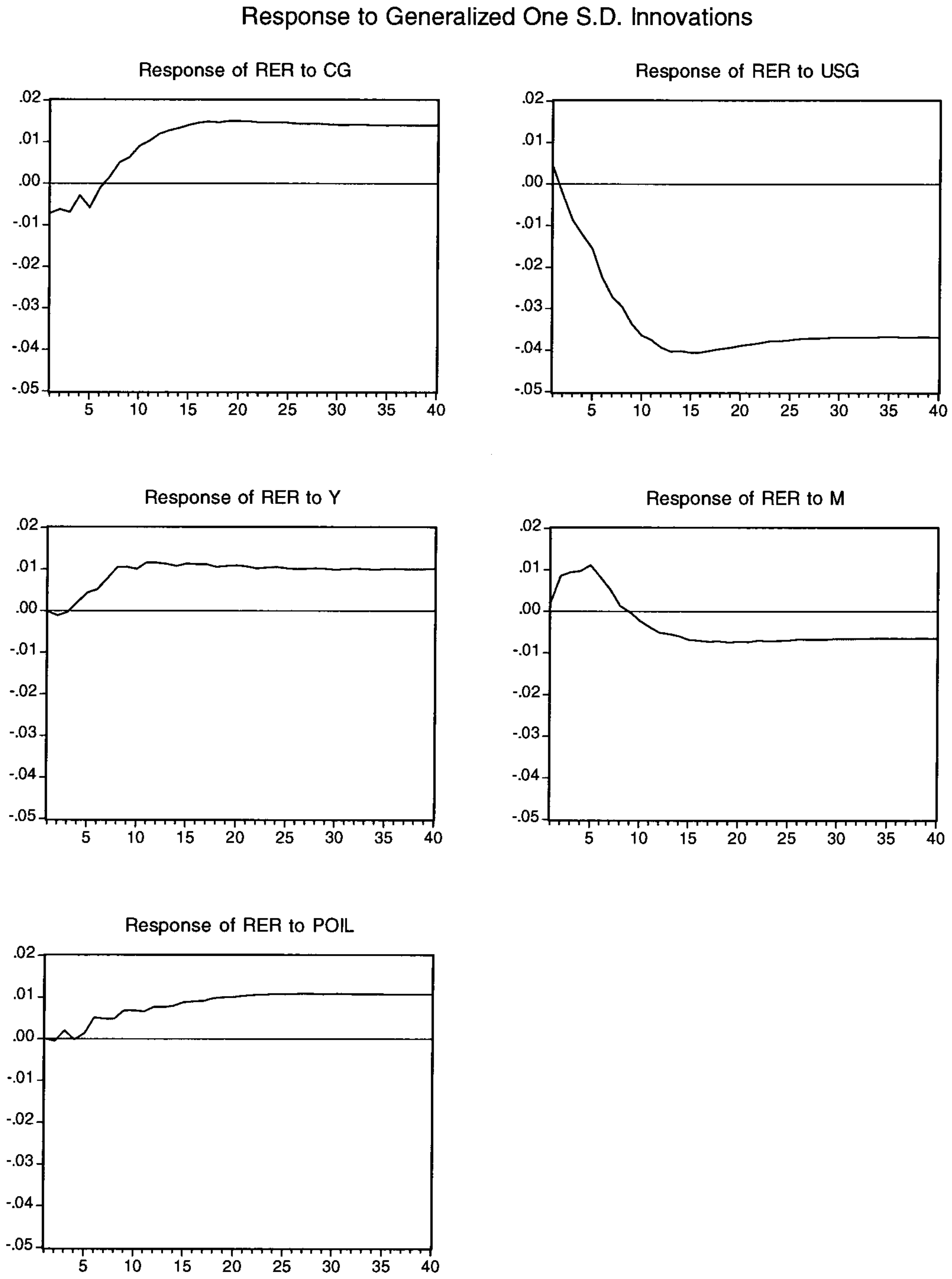

Figure 4
Impulse Responses with Three Cointegrating Equations

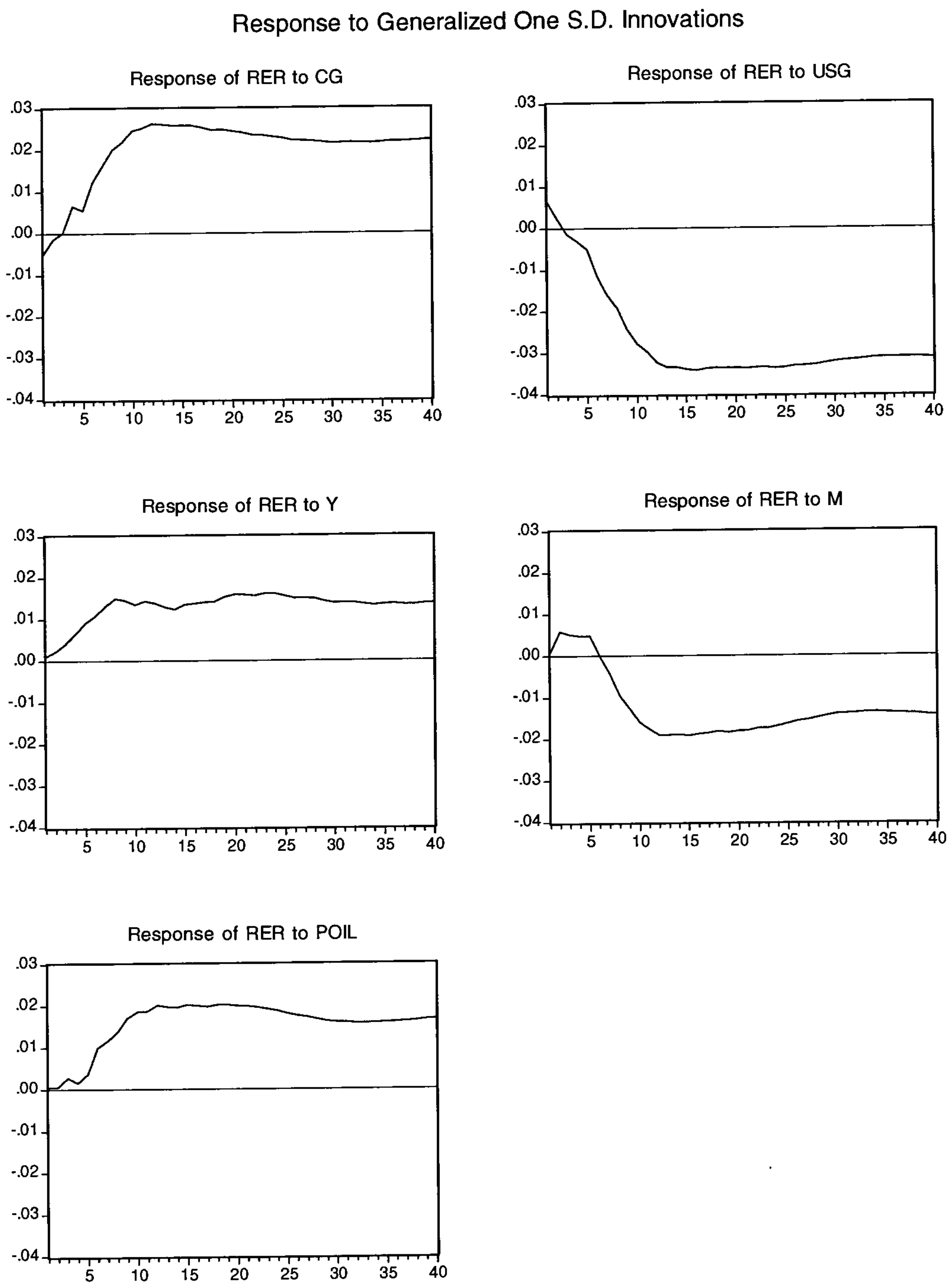

Table 1
Unit Root Tests

	LEVEL						FIRST-DIFFERENCE		
	DF-GLS TEST				KPSS		DF-GLS		KPSS
	constant	lag length	constant + trend	lag length	constant	constant + trend	constant	lag length	constant
RER	-1.11616	5	-1.561173	0	0.730548**	0.203757**	-2.585654**	3	0.077246
Poil	-1.089369	5	-1.210594	5	0.3071	0.263284***	-0.823174	10	0.170689
CG	1.003637	0	-0.770626	0	1.134357***	0.271759***	-1.216328	4	0.479017**
USG	1.731308*	11	-1.354867	10	1.162217***	0.214073**	-1.343145	10	0.293799
Y	-0.027594	6	-1.546366	6	0.603038**	0.221324***	-3.0652***	3	0.350434*
M	-0.905964	1	-1.186556	1	0.32708	0.152526**	-2.242962**	6	0.170930*

Notes: The maximum possible lag length for the DF-GLS test is 11. * means reject null hypothesis at 10% significant level; ** means reject null hypothesis at 5% significant level; *** means reject null hypothesis at 1% significant level

Table 2
Lag Length Selection

Lag	LR	FPE	AIC	SC	HQ
0	NA	1.65e-12	-10.10526	-9.936346	-10.03721
1	1008.991	1.45e-17	-21.74375	-20.56139*	-21.26741*
2	69.62746	1.32e-17	-21.85394	-19.65812	-20.9693
3	67.45211	1.16e-17	-22.01332	-18.80404	-20.72038
4	44.43605	1.37e-17	-21.90047	-17.67774	-20.19924
5	71.02168*	9.78e-18*	-22.32829*	-17.0921	-20.21876
6	29.02284	1.45e-17	-22.07918	-15.82954	-19.56135
7	32.91136	1.96e-17	-21.99236	-14.72926	-19.06624
8	38.54669	2.25e-17	-22.16256	-13.886	-18.82814

Notes: * indicates lag order selected by the criterion; LR: sequential modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ:

Hannan-Quinn information criterion	

Table 3
Diagnostic Tests

	Autocorrelation Test (p-value)	Normality Test (p-value)	Heteroskedasticity Test (p-value)
1 lag model	0.0000	0.0000	0.0083
5 lag model	0.5864	0.0652	0.5061

Table 4
Cointegration Tests

H0	Trace Statistic (p-value)	Max-Eigen Statistic (p-value)	Corrected Max-Eigen Statistic
r=0	145.1500*** (0.0000)	52.99554 (0.0011)***	38.8054**
r=1	92.15445 (0.0003)***	38.80540** (0.0119)	
r=2	53.34904** (0.0140)	25.57551 (0.0884)	

Notes: * means reject null hypothesis at 10% significant level; ** means reject null hypothesis at 5% significant level; *** means reject null hypothesis at 1% significant level.

Table 5
Tests of Parameter Restrictions on the Cointegrating Vectors

Restrictions	Chi-square	P-value
B(1,5)=0	7.290866	0.006931
B(1,6)=0	8.697153	0.003187
B(1,5)=0,B(2,5)=0,B(3,5)=0	28.31012	0.000003
B(1,6)=0,B(2,6)=0,B(3,6)=0	19.86006	0.000181

Notes: B(1,5)=0 is to test the coefficient of *M* in the one-cointegrating vector VEC model; B(1,6)=0 is to test the coefficient of *Poil* in one-cointegrating vector VEC model; B(1,5)=0,B(2,5)=0,B(3,5)=0 jointly tests the coefficients of *M* in the three-cointegrating vector VEC model and B(1,6)=0,B(2,6)=0,B(3,6)=0 jointly tests coefficients of *Poil* in the three-cointegrating vector VEC model.

Table 6-1
Variance Decomposition with One Cointegrating Vector

Period	S.E.	RER	CG	USG	Y	M	POIL
1	0.026783	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.035362	92.63086	0.030545	2.685478	0.000387	4.636035	0.016699
3	0.043134	82.42354	0.194024	9.237710	0.170162	7.812904	0.161656
4	0.052639	72.95976	0.494918	15.14437	0.868920	10.33194	0.200085
5	0.062988	65.54428	0.355155	20.05336	2.078656	11.82419	0.144361
6	0.072208	56.17974	0.542540	27.62089	3.208934	12.20680	0.241090
			......	......	......		
10	0.110608	29.73200	3.167596	49.98984	8.767798	8.174485	0.168279
11	0.119664	25.74318	3.810984	53.35332	9.631697	7.311111	0.149716
12	0.128556	22.43428	4.424613	56.19778	10.23259	6.560293	0.150442
13	0.137132	19.79107	4.969686	58.51925	10.61346	5.957238	0.149289
14	0.145045	17.72327	5.448018	60.35510	10.84569	5.471884	0.156040
15	0.152672	16.00644	5.877176	61.79270	11.10130	5.046566	0.175815
16	0.159957	14.58567	6.291395	62.94955	11.28479	4.691996	0.196601
			......	......	......		
20	0.185049	10.89922	7.510915	65.81420	11.70747	3.739015	0.329180
21	0.190586	10.27529	7.740081	66.26324	11.77665	3.574690	0.370049
22	0.195844	9.730993	7.935963	66.67313	11.80955	3.435087	0.415279
23	0.189986	9.789168	14.27856	53.02297	15.47438	6.013979	1.420951
			......	......	......		
25	0.210570	8.417588	8.431740	67.56574	11.94933	3.095923	0.539682
			......	......	......		
40	0.270371	5.110542	9.599700	69.84931	12.22962	2.290253	0.920570

Table 6-2

Variance Decomposition with One Cointegrating Vector

Period	S.E.	RER	POIL	CG	USG	Y	M
1	0.026783	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.035362	92.63086	0.021495	0.025664	2.705458	0.000182	4.616346
3	0.043134	82.42354	0.215548	0.234815	9.159510	0.122566	7.844017
4	0.052639	72.95976	0.145873	0.530777	15.12711	0.926745	10.30973
5	0.062988	65.54428	0.144994	0.376471	20.00857	2.129123	11.79657
6	0.072208	56.17974	0.615231	0.488393	27.42894	3.067322	12.22038
			......	......	......		
10	0.110608	29.73200	1.397459	2.803756	49.54713	8.319979	8.199675
11	0.119664	25.74318	1.489923	3.393887	52.88260	9.155525	7.334891
12	0.128556	22.43428	1.643527	3.945584	55.68821	9.703760	6.584639
13	0.137132	19.79107	1.755073	4.440700	57.98139	10.05000	5.981763
14	0.145045	17.72327	1.870051	4.872437	59.79007	10.24718	5.496999
15	0.152672	16.00644	2.019023	5.251899	61.19589	10.45406	5.072685
16	0.159957	14.58567	2.156358	5.619574	62.32479	10.59451	4.719101
			......	......	......		
20	0.185049	10.89922	2.719267	6.676857	65.08567	10.84809	3.770902
21	0.190586	10.27529	2.858763	6.870395	65.51090	10.87677	3.607878
22	0.195844	9.730993	2.997353	7.032986	65.89746	10.87143	3.469776
23	0.189986	9.789168	7.112320	13.80678	53.49015	10.45669	5.344900
			......	......	......		
25	0.210570	8.417588	3.370761	7.441457	66.72939	10.90626	3.134547
			......	......	......		
40	0.270371	5.110542	4.428839	8.378592	68.84331	10.89662	2.342104

Table 7-1
Variance Decomposition with Three Cointegrating Vectors

Period	S.E.	RER	CG	USG	Y	M	POIL
1	0.026091	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.032539	94.82842	0.368659	0.350259	0.261847	4.183538	0.007279
3	0.036886	88.66912	0.898216	1.965577	1.300205	6.894720	0.272165
4	0.043063	78.22244	5.732157	3.527555	2.956527	9.347893	0.213423
5	0.049141	70.24209	7.480407	5.678155	5.629070	10.77183	0.198447
6	0.055152	57.83339	12.34823	9.686880	8.557459	10.17425	1.399796
			......	......	......		
10	0.089512	22.60649	27.40547	25.97817	14.89810	4.338282	4.773487
11	0.098978	18.83755	28.59247	28.64897	14.88014	3.822650	5.218227
12	0.108643	16.12947	29.17611	30.97733	14.52363	3.491140	5.702321
13	0.117669	14.19887	29.45146	33.04863	14.06361	3.234680	6.002753
14	0.125912	12.86251	29.57278	34.60581	13.65041	3.053012	6.255481
15	0.133934	11.83532	29.53064	35.79404	13.47842	2.908280	6.453303
16	0.141537	11.00021	29.46985	36.80591	13.38325	2.763990	6.576785
			......	......	......		
20	0.168017	8.932823	28.83456	39.22379	13.78354	2.372399	6.852898
21	0.174005	8.587419	28.62151	39.65327	13.97280	2.298108	6.866901
22	0.179659	8.278457	28.40136	40.08353	14.13009	2.226635	6.879936
23	0.099094	26.34598	33.76896	14.74373	9.412654	9.603850	6.124836
			......	......	......		
25	0.195441	7.535969	27.81103	41.25309	14.62751	2.023427	6.748977
			......	......	......		
40	0.252669	5.522411	27.09260	44.91700	15.02902	1.329207	6.109757

Table 7-2
Variance Decomposition with Three Cointegrating Vectors

Period	S.E.	RER	POIL	CG	USG	Y	M
1	0.026091	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.032539	94.82842	0.005411	0.364136	0.349427	0.283583	4.169023
3	0.036886	88.66912	0.481873	0.821984	1.905648	1.059158	7.062219
4	0.043063	78.22244	0.438509	5.607970	3.472521	2.897766	9.360791
5	0.049141	70.24209	0.817297	7.227176	5.566955	5.331133	10.81535
6	0.055152	57.83339	3.789203	11.54616	9.336881	6.969965	10.52440
			......	......	......		
10	0.089512	22.60649	13.42374	24.89538	24.78081	9.860341	4.433243
11	0.098978	18.83755	14.58917	25.90546	27.33149	9.558174	3.778161
12	0.108643	16.12947	15.59392	26.36056	29.55463	9.042787	3.318627
13	0.117669	14.19887	16.16444	26.56411	31.54945	8.546789	2.976347
14	0.125912	12.86251	16.60014	26.63555	33.04850	8.124273	2.729030
15	0.133934	11.83532	16.99348	26.55724	34.18851	7.893777	2.531677
16	0.141537	11.00021	17.25962	26.47304	35.16312	7.749631	2.354379
			......	......	......		
20	0.168017	8.932823	18.04716	25.79644	37.48183	7.851020	1.890727
21	0.174005	8.587419	18.15912	25.58417	37.89491	7.966123	1.808265
22	0.179659	8.278457	18.25067	25.36723	38.30991	8.061660	1.732080
23	0.099094	26.34598	10.51616	33.69273	14.71446	6.059980	8.670693
			......	......	......		
25	0.195441	7.535969	18.22703	24.80735	39.45411	8.441880	1.533649
			......	......	......		
40	0.252669	5.522411	17.29585	24.19809	43.09902	8.933335	0.951296