
Dynamics of Exchange Rate Volatility and Macroeconomic Indicators: A Panel VAR Study

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Abstract

The paper intends to discuss the exchange rate volatility dynamics with respect to the macro-economic variables of GDP, interest rate, equity and foreign reserves. It models both the short and long-term relationships as a Panel Vector Autoregression (Panel VAR) model by allowing it to explore the way the economic shocks are transmitted by the networks through the interconnected markets. In the stationarity, the secondary panel data were first and then tested and lastly tested the unit root tests and impulse response functions with variance decomposition were also tested to find out the direction, the persistence and magnitude of these effects. It has been demonstrated that the interest rates and equity market movements are good predictors of the exchange rate volatility, whereas the foreign reserves are stabilizing factors in mitigating the effects of exchange volatility. The findings demonstrate the applicability of the right monetary and fiscal measures in achieving macroeconomic stability and decreasing the sensitivity to exchange rate risks, and meaningful information worth responding to financial strength to react to global economic shocks.

Keywords: Panel Var model, Macroeconomic Variables, Exchange rate volatility

Introduction

1.1 Introduction and Background

The most researched variable in international macroeconomics is the exchange rate volatility and to a larger level this can be explained by the fact that it has a monetary policy implication, investment behaviour, competitiveness in international trade and financial stability. The exchange rate variation would have some impact on the main macroeconomics variables such as inflation, interest rates and GDP growth since the financial system is highly globalized. This two-way interaction is especially needed in the new and open economies where the external shocks and capital flows may become more unpredictable and destabilize the efforts of the policy (Nwanneko et al. 2023).

In the current empirical studies, the relationship between the macroeconomic variables and the volatility of the exchange rate have been studied with the application of the Panel Vector Autoregressive (PVAR). The PVAR technique is especially effective in terms of cross-sectional heterogeneity and time dynamics between countries (Shaikh et al., 2024). Some macroeconomic responses to the currency shock have been demonstrated to be different among the countries, such as Egypt, Turkey, and members of the OECD based on the structural characteristics and the policy regime (Ucar, 2024; Buyun, 2024).

The studies performed on the GARCH and PVAR models all lead to a similar conclusion that the volatility of the exchange rates can primarily be explained by macro-economic fluctuations, inflation shocks, political risk, and the fluctuation in interest rates (Ozcelebi, 2018; Abid and Rault, 2021). To exemplify this, the increased volatility has been observed to lower the inflow of foreign direct investment

and reduce bank lending in prospective economies which is an indicator of risk aversion among foreign and domestic investors (Buyun, 2024; Mbuyi and Kakasi, 2022).

1.2 Problem Statement

Although there is a significant amount of empirical research, the factors by which exchange rate volatility can affect macroeconomic variables within a panel framework are inconclusive and situation specific. Specifically, the direction, magnitude and persistence of shocks differ across economies and time. In addition, although the literature considers this relationship either in a time-series, or single country contexts, there are paucity of panel-based evidence on the relationship where both developed and developing countries with various monetary regimes have been included.

Given the recent economic turmoil in the world, such as trade wars, geopolitical risks, and post-pandemic recovery exchange rate volatility has become the more urgent issue of macroeconomic policy making. These linkages are urgently in need of empirical investigation with powerful models such as PVAR to inform academic knowledge and policy reaction (Yabu & Kimolo, 2020; Anjum and Malik, 2020).

1.3 Research Objectives

This study aims to achieve the following objectives:

- To assess the impact of exchange rate volatility on key macroeconomic indicators—namely real GDP, interest rates, official reserves, and equity index—across selected countries.
- To analyze the dynamic interactions among these variables using the Panel VAR framework.
- To investigate the magnitude and direction of impulse responses to exchange rate shocks over time.
- To determine the variance contributions of exchange rate volatility to macroeconomic fluctuations.

1.4 Research Questions

The research is guided by the following key questions:

1. How does exchange rate volatility affect real GDP, interest rates, reserves, and equity indices in the selected countries?
2. What is the nature and duration of impulse responses in macroeconomic variables following an exchange rate shock?
3. Which macroeconomic variables contribute most to exchange rate volatility, and vice versa?
4. Are these relationships consistent across developed economies?

1.5 Rationale of the Study

Understanding the role of exchange rate volatility in shaping macroeconomic performance is vital for policymakers, investors, and researchers. Policymakers need to gauge how currency fluctuations transmit to inflation, interest rates, and investment, especially in open economies (Uçar, 2024; Dagume, 2022). Investors require clarity on how macroeconomic shocks impact asset prices and currency risks, particularly in times of uncertainty (Amaliawiati et al., 2023; Dayıoğlu & Aydın, 2019).

This study adds to the growing literature by employing a Panel VAR model that simultaneously captures cross-country variation and time-series dynamics. While prior studies have analyzed these relationships in isolation or via time-series methods, few incorporate multi-country panel analysis with comprehensive variance decomposition (Shaikh et al., 2024; Abid & Rault, 2021). Hence, this research fills a methodological and empirical gap in understanding how exchange rate volatility interacts with macroeconomic variables in a panel setting.

1.6 Hypotheses

Based on the theoretical and empirical literature, the study proposes the following hypotheses:

- **H1:** Exchange rate volatility has a significant negative impact on real GDP.
- **H2:** Exchange rate volatility influences interest rates through monetary transmission channels.
- **H3:** Official reserves respond positively to exchange rate volatility due to central bank interventions.

- **H4:** Equity indices are significantly influenced by exchange rate volatility due to valuation and foreign investor behavior.
- **H5:** The impact of exchange rate volatility varies across macroeconomic indicators and countries.

Literature Review

The volatility of exchange rate and its relation to macroeconomic indices has been a subject of concern amongst international finance, particularly in an era where the world economy has been becoming increasingly integrated with trade and capital flows. A growing empirical literature has adopted a Panel Vector Autoregressive (PVAR) model to deal with this nexus between countries with respect to the dynamic and endogenous nature of macroeconomic responses. Shaikh et al. (2024) used a PVAR model and implemented it on seven developing economies and concluded that the responsiveness to short-run interest rates and the response to inflation shocks is rather strong on the volatility of the exchange rate, but the response on GDP and reserves is not that significant. Such results demonstrate the different impact of various macroeconomic variables on currency variations, and indicate, therefore, that the monetary policy is among the variables that determine the exchange rates process.

This finding is in line with the results reported by Ozcelebi (2018), who applied PVAR to analyze OECD economies and showed that exchange rate volatility rises with the tightening of monetary policy conditions, which is manifested in the increase in the interest rates. The findings of this point to the fact that monetary policy tightening brings about uncertainty in the foreign exchange markets particularly in those instances where the tightening of the monetary policy is not buttressed by the good macroeconomic fundamentals. This can also be seen in the East African economies that the research by Yabu and Kimolo (2020) found that the exchange rate volatility has a negative impact on the foreign direct investment and exports performances. This study has restated that poor institutional capacity and low reserves are factors that bring about currency shocks in between nations and in that respect, it has further supported the application of macroeconomic stability to address the exchange rate movements.

The monetary transmission mechanism is the most significant channel through which the exchange rate volatility is transmitted to the other sectors of the economy. Buyun (2024) discussed this channel in the Turkish banking sector, which showed that the volatility level is high, thus deterring bank lending as financial institutions are more inclined to reduce risk. This undermines the efficiency of the overall monetary policy of interest rates, particularly in the emerging markets which have less robust financial systems. To reinforce this result, Panda et al. (2023) have discovered that exchange rate shocks have a significant impact on the performance of equity markets in BRICS nations, which implies that the returns on financial assets are vulnerable to the risks of currency. Such research indicate the significance of exchange rate management in maintaining financial markets stability and facilitating successful monetary interventions.

Currency volatility also affects the real economy, especially via output and trade channels. In an investigation that spans across Nigeria, Ghana, and Cameroon. Nwanneako et al. (2023) have employed a PVAR methodology to reveal that GDP is a negative responder to persistent exchange rate shocks, albeit with varying effects across various countries. Gevorkyan (2019) also provided a corresponding contribution to this by studying the situation in commodity-exporting countries, indicating that the global price adjustment leads to the exchange market pressure, which is transferred to the pro-cyclical macroeconomic adjustment through the exchange rate channel. The outcomes are particularly relevant to the economies which rely heavily on the exports of the natural resources in their growth since the external shocks can have disastrous effects on the national production and labor.

Exchange rate fluctuations are also related to the dynamics of inflation. Aftab et al. (2024) observed that exchange rate volatility increases due to the economic policy uncertainty and in the short run, the result is an inflationary pressure. Inflation-targeting regimes are especially vulnerable to such volatility because it has a direct impact on the inflation expectations and prices of imports. Abid and Rault (2020) also demonstrated that uncertainty in the global economy, particularly that of the U.S., is transmitted to emerging markets through the exchange rate mechanisms that make it difficult to control inflation and monetary policies. All these studies indicate that currency volatility is the symptom and cause of macroeconomic instability.

Political economic dimensions have also been drawn towards the exchange rate volatility. Yao et al.

(2025) conducted a study of the U.S. election cycle and exposed the fact that the currency markets had significant effects of the partisanship. In their analysis, they discovered that investor actions and anticipations would shift based on the attitude of incoming administrations towards fiscal and money policies and this led to greater volatility in the run-up to elections. Even though the paper does not focus on the emerging economies, it brings out the total effect of political uncertainty on the exchange rates and the macroeconomic measures.

Another important channel through which exchange rate volatility is transmitted is through financial markets especially equity indices. Amaliawiati et al. (2023) demonstrated in the Indonesian case that exchange rate shocks cause asymmetric effects on stock market volatility- depreciation shocks cause more significant effects compared to appreciations. Similar trends were observed in Turkey (Dayioglu and Aydin, 2019) whereby the exchange rates were real-time indicators of macroeconomic wellbeing, driving the investor sentiment and the stocks prices. These results justify considering equity markets in macro-financial analysis of the exchange rates.

At the external sector level, the exchange rate volatility has a great impact on the balances of trade and capital movements. Aslan et al. (2024) discovered that real exchange rate shocks have an effect on the performance of exports, especially where there is less export diversification in the economy. Volatility lowers the price competitiveness and dishearten long term trade contracts. Moazzam (2023) further remarked that, in South Asia, the outward debt promotes currency volatility, thus impacting on the performance of trade and GDP. Finally, Boduri and Kripa (2024) examined the case of Albania and found that the exchange rate balance is not very responsive to the exchange rate fluctuations, but that other externalities (like FDI, remittances) determine the macroeconomic effects of exchange rate volatility.

When combined, the literature gives consistent evidence that exchange rate volatility is a cause as well as an effect of macroeconomic conditions. As it considers the feedback loops and heterogeneity among countries, the PVAR model provides useful information regarding when, which way, and how long these effects can be observed. Majority of the studies have concurred that the key to reducing the disruptive effect of currency volatility is having stable macroeconomic fundamentals, policy frameworks that are trusted and diversified economies.

Methodology

The purpose of the present study is to examine the dynamic relationship between exchange rate volatility and major macroeconomic indicators applying the Panel Vector Autoregression (Panel VAR) framework with the help of Eviews software. The use of the Panel VAR approach is justified by the fact that it takes into account dynamic cross-country or regional interdependencies and heterogeneities, especially when the time factor is relatively short, but the cross-sectional dimension is the large one (Canova and Ciccarelli, 2013; Serio, 2018). This model is also used to forecast, decomposing the variance, and impulse response, hence it is appropriate in analyzing the transmission mechanism between exchange rate variability and the macroeconomic variables like GDP, inflation, interest rate, and reserves.

The methodology started with the data collection, which mainly involved secondary panel data of several countries within a given time. The macroeconomic variables in the analysis are based on past empirical literature that continually finds them to be important determinants in the dynamics of the exchange rate. Such variables usually consist of the real GDP growth, inflation rate (CPI), short-term interest rates, official reserves, and exchange rate indices (Shaikh et al., 2024; Abid and Rault, 2021).

The data was unit root tested before estimation to either test the stationarity, where Levin, Lin, Chu (LLC) test, and the Fisher-type Augmented Dickey-Fuller (ADF) test were used. In case variables were discovered to be non-stationary at levels but stationary at first difference, the series are differenced to satisfy the stationarity criteria (Nwanneako et al., 2023). This has been found to be essential in order to prevent spurious regression outcomes, as time series econometrics literature has highlighted.

Once the stationarity was established, the second step was to test cointegration to determine whether there was a long-run equilibrium relationship between the variables. Pedroni or Kao tests are generally used to do this. Without cointegration, one may specify a first-differenced form of Panel VAR system; otherwise, it may be replaced by a Vector Error Correction Model (VECM) (Altinisik and Yucememis, 2023). In the analysis, cointegration is not present and thus the panel VAR framework is used in the first differences.

The estimation of the Panel VAR model was done via the Generalized Method of Moments (GMM),

specifically, system GMM, which is popular in endpointing endogeneity, bias due to omitted variable, and measurement errors (Love and Zicchino, 2006). Lagged levels and differences were used in the estimation of the GMM estimator, and, as such, the estimation is robust and efficient. In addition, country-specific effects were included to measure the unobserved heterogeneity among countries and time dummies are included to measure global shocks.

The dynamics and strength of the relationships among the variables are interpreted with the help of the impulse response functions (IRFs) and forecast error variance decomposition (FEVD). IRFs demonstrate the impact of a single shock to a variable on others through time, whereas FEVD measures the share of movements in a variable that can be ascribed to its own shocks in comparison to those of others (Boruku et al., 2022; Panda et al., 2023). These instruments enable the researchers and policy makers to make inferences on the trend and size of the macroeconomic responses to exchange rate volatility.

The model diagnostics are essential to confirm the stability of the results of the Panel VAR. The roots of the characteristic poly are also inverted to test the stability of the model; a VAR is said to be stable when the roots are all within the unit circle (Tugan, 2021 Tuğan). Also, the tests of residual serial correlation and heteroscedasticity are conducted to confirm the strength of the results.

In order to be more robust, sensitivity analysis is incorporated to the study by modifying the lag lengths and re-estimating the model with subsets of data. To test the stability of the results, alternative specifications with the switching of variables or the usage of other control variables such as trade openness or financial development index are examined (Bilgili et al., 2021; Model and Zhang 2019). The influence of external policy uncertainty shocks on exchange rate volatility has been identified to be very strong in the emerging market economies and, therefore, the necessity to include them to perform robustness checks (Abid and Rault, 2020).

Concisely, the study approach integrates both sound panel data and sound statistical and econometric analysis since the exchange rate-macroeconomic relationships can be described as being complex and dynamic. The Panel VAR approach provides a holistic prism within which these interdependencies are empirically explored with the assistance of suitable diagnostic and robustness tests.

Results and Analysis

4.1 Unit Root Testing

First, the variables were tested whether these are stationary or non-stationary. All the variables were analyzed using augmented Dickey-Fuller (ADF) Fisher and Choi Z -statistics within the panel. The results confirmed that Real GDP (RGDP), Official Reserves (OREC), and Interest rate (IR) had to remain at the level, but Equity Index (EI) and Volatility (VOL) had to be first differenced to be at the level. This type of mixed order of integration conforms to several macro-financial panel studies that necessitate first differencing of certain financial series due to its long-term trends over time (Kong et al., 2021); (Amassoma 2016).

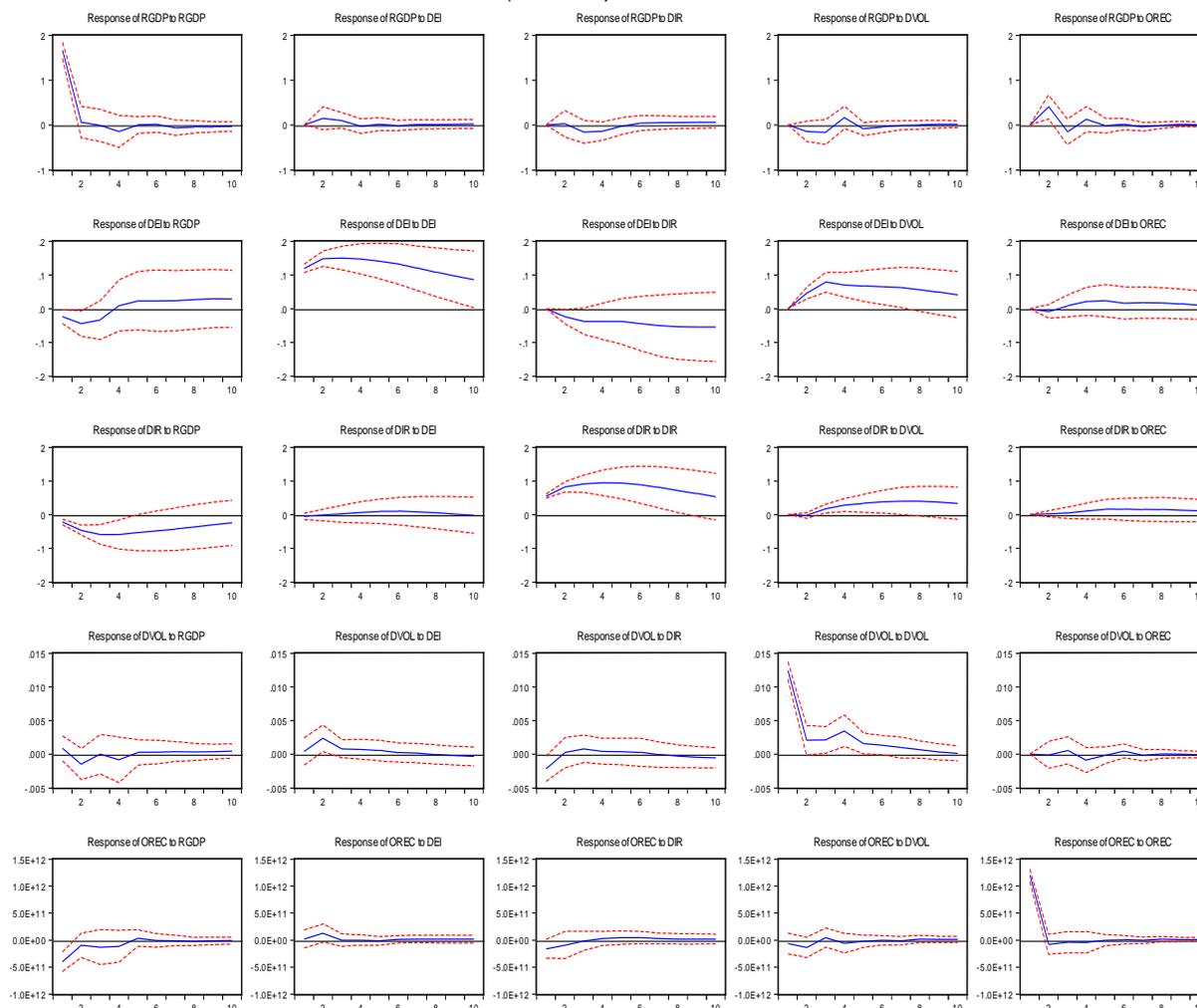
When using panel VAR and VAR models, we should ensure that we have stationarity to prevent spurious regression results. The standard errors can be inflated by dynamic data and subsequently give biased estimates, which is particularly detrimental in dynamic modeling (Alhassan and Kabir, 2019).

4.2 Impulse Response Functions (IRFs)

The impulse response analysis provides the dynamical perspective of the impact of shocks in one macroeconomic variable on the rest with time. An example of this is that the response of Interest rate to a shock in Equity Index is negative initially but levels off with time. This negative correlation implies that the growth in equity market returns can lead to a decrease in the need to make safer fixed-income investments, which can, in turn, ease the interest rates, which is also consistent with the theory of financial market substitution (Wang and Dunne 2021).

The other prominent IRF is the=)periodic response of the Real GDP to Equity Index shock. The effect is initially negative but turns out to be positive in four quarters, which shows a significant transmission of stock market confidence to output growth but at a lag. This is consistent with the hypothesis of the wealth effect, as the greater equity performance the better investment in a firm and consumer sentiment (Qamruzzaman et al., 2021).

Response to Cholesky One S.D. Innovations ± 2 S.E.



The Interest Rate reaction to shocks in Real GDP indicates that it first falls before stabilizing meaning that central banks may respond to output shocks with accommodative monetary policy, but they would normalize interest rates in the long run. This trend has been found in panel VAR research and OECD countries (Korkmaz, 2020).

Curiously, the shocks in Volatility failed to exhibit robust dynamic responses in other macroeconomic variables, suggesting a localized or lagging impact of the uncertainty over the exchange rates on the real variables. This is in accordance with recent empirical studies in which the exchange rate volatility does not necessarily translate to macro aggregates in the short-term (Nasir et al., 2021).

4.3 Variance Decomposition

Variance decomposition further quantifies the extent to which forecast error variance in each variable is explained by innovations in other variables. For Real GDP, over a 10-period horizon, the largest external contributor was Official Reserves, followed by Volatility. This suggests that reserves play a stabilizing role in economic activity, as supported by the buffer stock theory of foreign reserves (Allegret & Allegret 2018).

The decomposition of Interest Rate shows Real GDP and Volatility as major influencers. GDP explains around 21% of the interest rate variance by the 10th period, reflecting the real economy's role in shaping monetary policy actions. Volatility's contribution rises to about 10%, suggesting that exchange rate uncertainty modestly affects interest rate settings—a finding in line with inflation-targeting literature (Umaru et al., 2018).

The Equity Index's variance is increasingly explained by Volatility, which accounts for over 15% by

period 10. This underlines the critical sensitivity of financial markets to currency risk, validating theories linking exchange rate fluctuations to capital market behavior (Bahmani-Oskooee & Saha, 2021).

For Official Reserves, over 83% of the variance remains self-explained, but GDP contributes modestly, indicating that stronger output performance allows accumulation of reserves. Similarly, Volatility accounts for just over 1.5%, revealing a mild, indirect effect of exchange rate shocks on reserve behavior. Lastly, the decomposition of Volatility shows a dominant self-explained component (~90%), but both Real GDP and Equity Index explain increasing portions of its variance over time. This result suggests a feedback loop—economic performance and capital market behavior both shape and are shaped by exchange rate uncertainty (Ito & Kawai, 2020).

Comprehensively, the discussion supports the fact that exchange rate volatility and macroeconomic indicators in a dynamic panel VAR model are mutually dependent. Monetary and financial variables are particularly sensitive to real GDP and the equity markets and volatility is increasingly becoming a factor in expectations and future behavior. The results confirm the importance of reserves and macroprudential instruments dealing with volatility spillovers and draw attention to the equity market being sensitive to exchange rate shocks

Conclusion

This paper has investigated the dynamic nature of exchange rate volatility and four main macroeconomic variables; real GDP, interest rates, official reserves and equity indices in a Panel Vector Autoregression (PVAR) model. It was found that macroeconomic fundamentals have a strong effect on the exchange rate volatility, with the strongest contribution being made by the interest rates and the inflationary trends. The effect of shocks to equity markets and GDP on the interest rates and volatility showed that the variables are not connected directly, and their feedback scheme is complex. The decomposition of variance also proved that the volatility of the exchange rates is not independent but caused by the dynamics of both real and financial sectors such as reserves and output shocks.

These findings are in line with the theoretical expectations and the contemporary empirical studies and therefore would lead into the argument that; macroeconomic stability, sound monetary policy and the reserve management style can act as buffers against excessive currency volatility. Notably, the paper notes the relevance of using dynamic panel data model in determining the interdependency of the macroeconomy relationship over time that can be easily lost under a simple framework.

In general, the findings indicate that policy coordination of fiscal, monetary, and financial policies is important to check the negative impact of exchange rate volatility. This analysis might be further expanded in future studies by including structural shocks or evaluating the regional heterogeneities in the economies at various levels of development.

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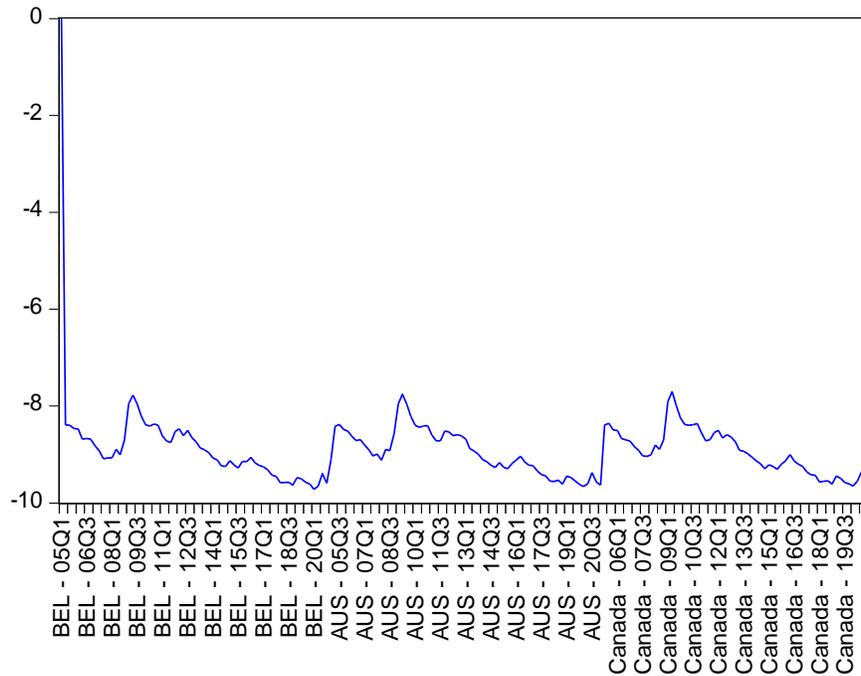
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Appendix

Graph For Equity index

EI

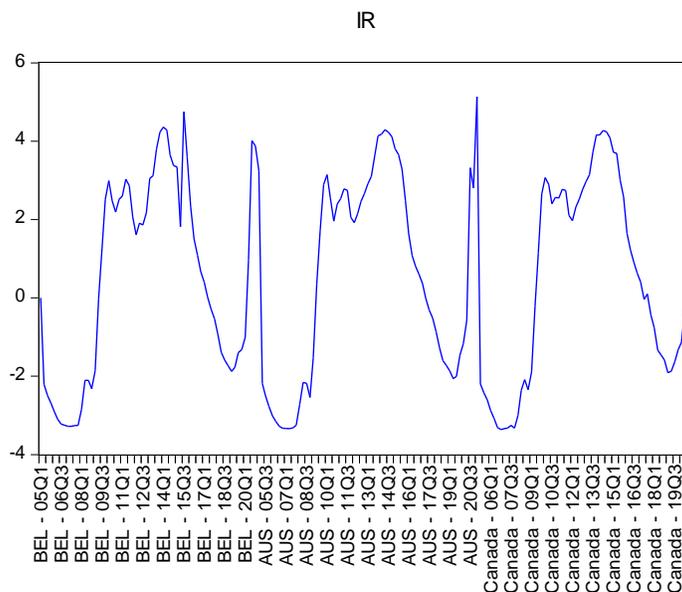


Null Hypothesis: Unit root (individual unit root process)				
Series: EI				
Date: 12/27/22 Time: 14:06				
Sample: 2005Q1 2020Q4				
Exogenous variables: None				
Automatic selection of maximum lags				
Unit Root Test For EI				
Automatic lag length selection based on SIC: 0 to 2				
Total number of observations: 186				
Cross-sections included: 3				
Method		Statistic		Prob.**
ADF - Fisher Chi-square		1.13257		0.9801
ADF - Choi Z-stat		1.74400		0.9594
** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.				
Intermediate ADF test results EI				
Cross				
section	Prob.	Lag	Max Lag	Obs
BEL	0.7209	0	10	63
AUS	0.9035	1	10	62
Canada	0.8714	2	10	61

Unit Root Test For EI at 1st Difference

Null Hypothesis: Unit root (individual unit root process)				
Series: D(DEI)				
Date: 12/27/22 Time: 14:07				
Sample: 2005Q1 2020Q4				
Exogenous variables: None				
Automatic selection of maximum lags				
Automatic lag length selection based on SIC: 0 to 1				
Total number of observations: 182				
Cross-sections included: 3				
Method		Statistic		Prob.**
ADF - Fisher Chi-square		349.666		0.0000
ADF - Choi Z-stat		-16.3049		0.0000
** Probabilities for Fisher tests are computed using an asymptotic Chi				
-square distribution. All other tests assume asymptotic normality.				
Intermediate ADF test results D(DEI)				
Cross				
section	Prob.	Lag	Max Lag	Obs
BEL	0.0000	0	10	61
AUS	0.0000	0	10	61
Canada	0.0000	1	10	60

Graph for Interest Rate



Unit Root Test For Interest rate

Null Hypothesis: Unit root (individual unit root process)

Series: IR				
Date: 12/27/22 Time: 14:08				
Sample: 2005Q1 2020Q4				
Exogenous variables: None				
Automatic selection of maximum lags				
Automatic lag length selection based on SIC: 0 to 1				
Total number of observations: 187				
Cross-sections included: 3				
Method		Statistic		Prob.**
ADF - Fisher Chi-square		9.41920		0.1513
ADF - Choi Z-stat		-1.37038		0.0853
** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.				
Intermediate ADF test results IR				
Cross				
section	Prob.	Lag	Max Lag	Obs
BEL	0.3292	0	10	63
AUS	0.1304	1	10	62
Canada	0.2099	1	10	62

Unit Root Test For Interest rate at 1st difference

Null Hypothesis: Unit root (individual unit root process)

Series: D(DIR)

Date: 12/27/22 Time: 14:08

Sample: 2005Q1 2020Q4

Exogenous variables: None

Automatic selection of maximum lags

Automatic lag length selection based on SIC: 0

Total (balanced) observations: 183

Cross-sections included: 3

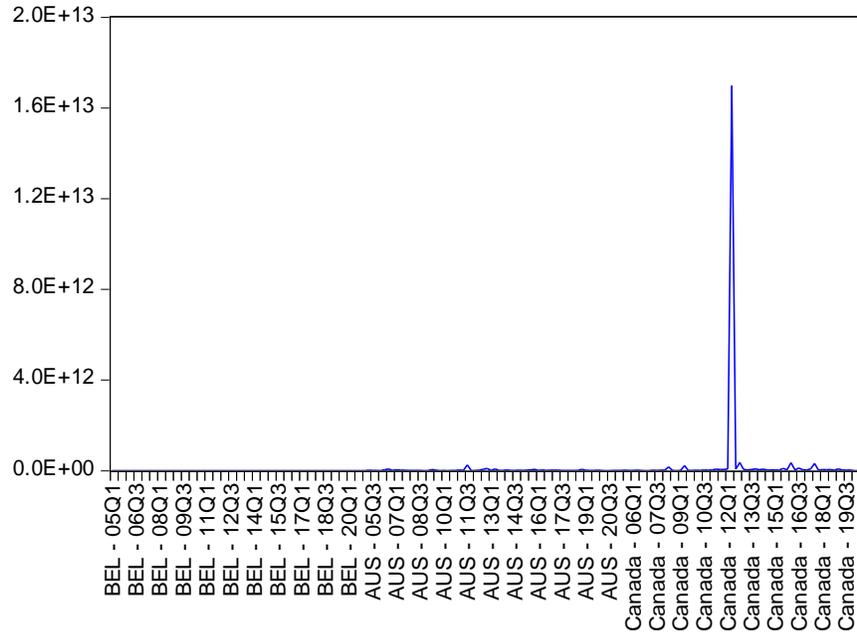
Method	Statistic	Prob.**
ADF - Fisher Chi-square	346.772	0.0000
ADF - Choi Z-stat	-16.1038	0.0000

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Intermediate ADF test results D(DIR)

Cross section	Prob.	Lag	Max Lag	Obs
BEL	0.0000	0	10	61
AUS	0.0000	0	10	61
Canada	0.0000	0	10	61

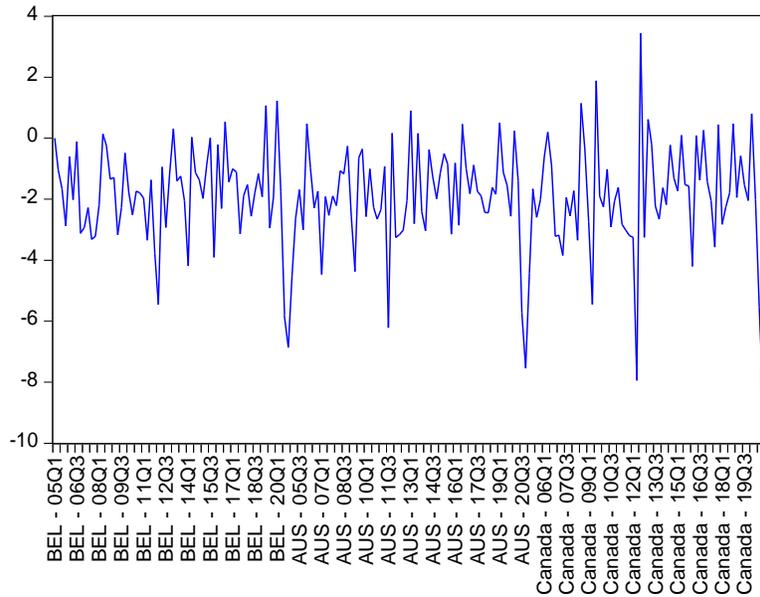
Graph for OREC
OREC



Unit Root Test For OREC

Null Hypothesis: Unit root (individual unit root process)				
Series: OREC				
Date: 12/27/22 Time: 14:09				
Sample: 2005Q1 2020Q4				
Exogenous variables: None				
Automatic selection of maximum lags				
Automatic lag length selection based on SIC: 0 to 1				
Total number of observations: 188				
Cross-sections included: 3				
Method		Statistic		Prob.**
ADF - Fisher Chi-square		141.668		0.0000
ADF - Choi Z-stat		-10.4559		0.0000
** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.				
Intermediate ADF test results OREC				
Cross section	Prob.	Lag	Max Lag	Obs
BEL	0.0000	0	10	63
AUS	0.0021	1	10	62
Canada	0.0000	0	10	63

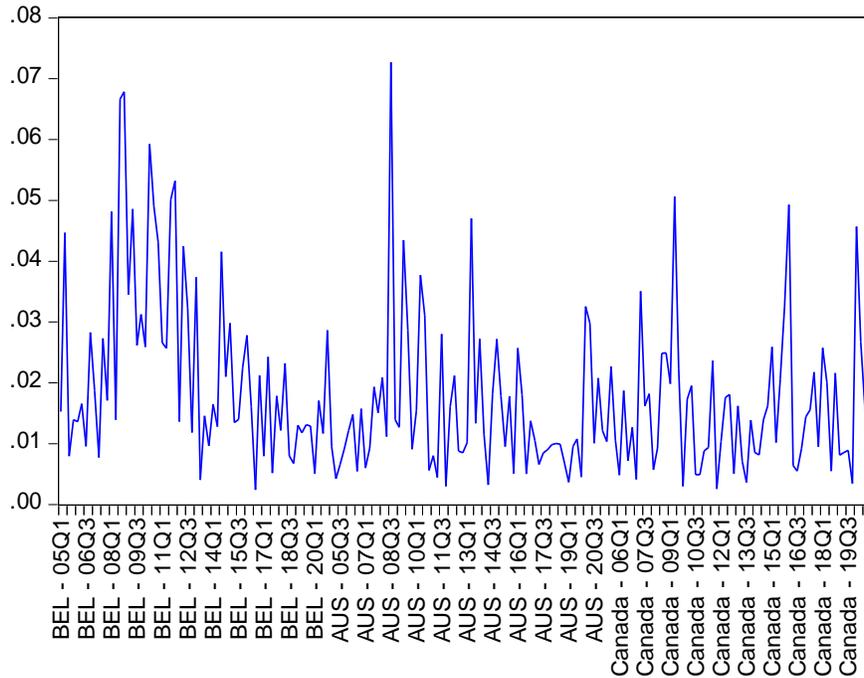
Graph For Real GDP
RGDP



Unit Root Test For Real GDP

Null Hypothesis: Unit root (individual unit root process)				
Series: RGDP				
Date: 12/27/22 Time: 14:10				
Sample: 2005Q1 2020Q4				
Exogenous variables: None				
Automatic selection of maximum lags				
Automatic lag length selection based on SIC: 1				
Total (balanced) observations: 186				
Cross-sections included: 3				
Method		Statistic		Prob.**
ADF - Fisher Chi-square		12.6905		0.0482
ADF - Choi Z-stat		-2.00823		0.0223
** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.				
Intermediate ADF test results RGDP				
Cross section	Prob.	Lag	Max Lag	Obs
BEL	0.1644	1	10	62
AUS	0.1522	1	10	62
Canada	0.0702	1	10	62

Graph for Volatility
volatility



Unit Root Test For Volatility

Null Hypothesis: Unit root (individual unit root process)				
Series: VOLITILITY				
Date: 12/27/22 Time: 14:12				
Sample: 2005Q1 2020Q4				
Exogenous variables: None				
Automatic selection of maximum lags				
Automatic lag length selection based on SIC: 1 to 3				
Total number of observations: 183				
Cross-sections included: 3				
Method		Statistic		Prob.**
ADF - Fisher Chi-square		9.70375		0.1377
ADF - Choi Z-stat		-1.36359		0.0863
** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.				
Intermediate ADF test results VOLITILITY				
Cross section	Prob.	Lag	Max Lag	Obs
BEL	0.1176	1	10	62
AUS	0.4477	3	10	60
Canada	0.1485	2	10	61

Unit Root Test For Volatility at 1st Difference

Null Hypothesis: Unit root (individual unit root process)				
Series: D(DVOL)				
Date: 12/27/22 Time: 14:13				
Sample: 2005Q1 2020Q4				
Exogenous variables: None				
Automatic selection of maximum lags				
Automatic lag length selection based on SIC: 0 to 2				
Total number of observations: 180				
Cross-sections included: 3				
Method		Statistic		Prob.**
ADF - Fisher Chi-square		526.572		0.0000
ADF - Choi Z-stat		-22.1140		0.0000
** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.				
Intermediate ADF test results D(DVOL)				
Cross				
section	Prob.	Lag	Max Lag	Obs
BEL	0.0000	0	10	61
AUS	0.0000	2	10	59
Canada	0.0000	1	10	60

LAG Length Selection

VAR Lag Order Selection Criteria						
Endogenous variables: RGDP DEI DIR DVOL OREC						
Exogenous variables: C						
Date: 12/27/22 Time: 20:32						
Sample: 2005Q1 2020Q4						
Included observations: 165						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	-5161.808	NA	1.09e+21	62.62797	62.72209	62.66618
1	-4730.093	832.0322	7.86e+18	57.69810	58.26281*	57.92734
2	-4676.383	100.2579	5.56e+18	57.35010	58.38542	57.77037*
3	-4642.219	61.70359	4.98e+18*	57.23901*	58.74493	57.85032
4	-4622.026	35.24515	5.30e+18	57.29729	59.27380	58.09962
5	-4607.202	24.97642	6.04e+18	57.42063	59.86774	58.41400
6	-4595.127	19.61245	7.13e+18	57.57730	60.49501	58.76170
7	-4571.019	37.69664*	7.30e+18	57.58811	60.97641	58.96354
8	-4559.994	16.57003	8.80e+18	57.75751	61.61641	59.32397

* 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				

VAR MODEL

TABLE 1

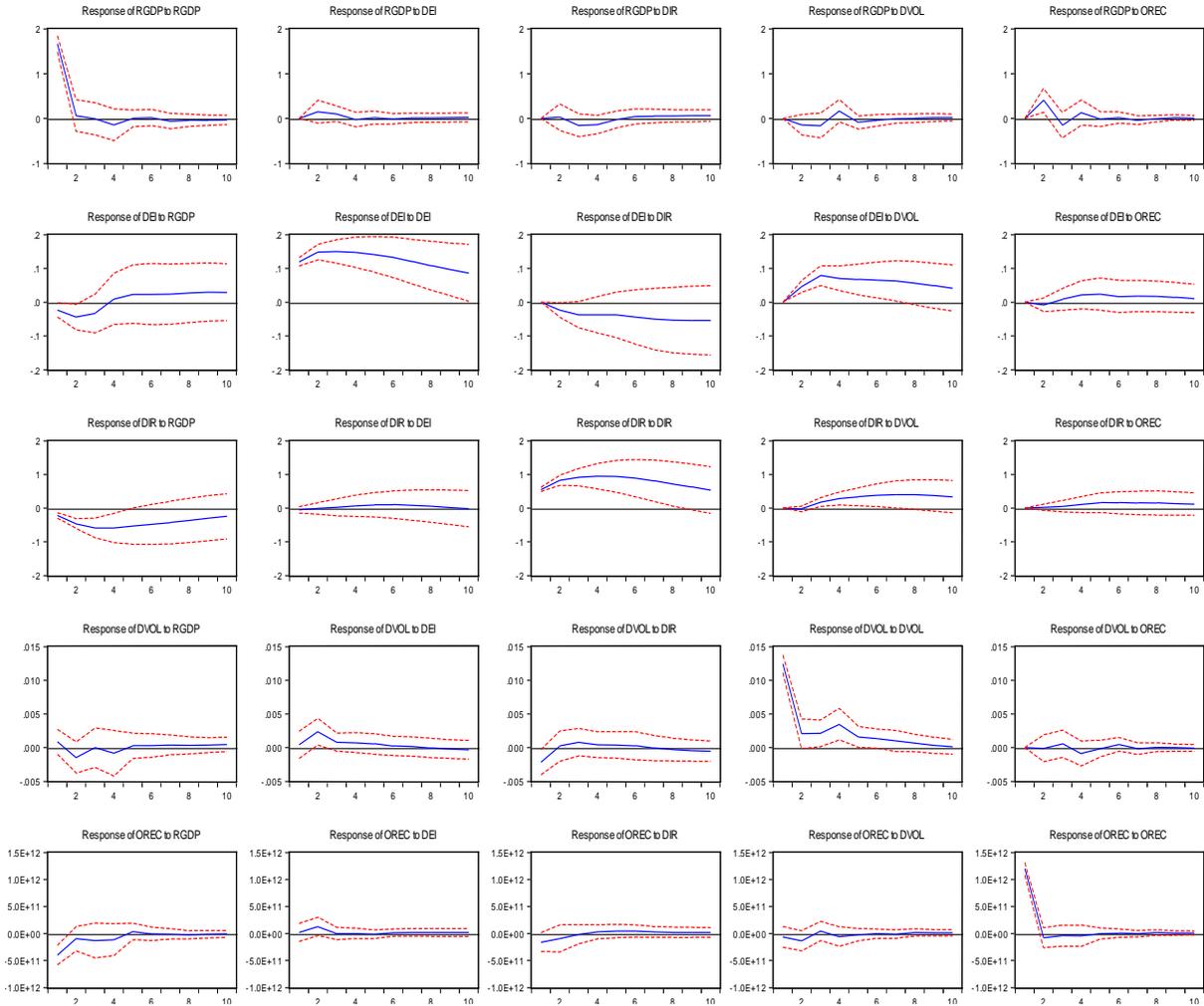
Vector Autoregression Estimates					
Date: 12/27/22 Time: 20:42					
Sample (adjusted): 2006Q1 2020Q4					
Included observations: 180 after adjustments					
Standard errors in () & t-statistics in []					
	RGDP	DIR	DEI	OREC	DVOL
RGDP(-1)	0.158732 (0.09172) [1.73061]	-0.069191 (0.03282) [-2.10840]	-0.017316 (0.00668) [-2.59359]	-8.37E+10 (7.0E+10) [-1.18874]	-0.000575 (0.00070) [-0.82426]
RGDP(-2)	-0.036210 (0.10025) [-0.36122]	0.011188 (0.03587) [0.31192]	0.012941 (0.00730) [1.77346]	-8.90E+10 (7.7E+10) [-1.15625]	0.001012 (0.00076) [1.32701]
RGDP(-3)	-0.085095 (0.09529) [-0.89302]	0.052730 (0.03409) [1.54662]	0.021944 (0.00694) [3.16372]	-6.92E+10 (7.3E+10) [-0.94564]	-0.000636 (0.00073) [-0.87744]
DIR(-1)	0.114636 (0.25582) [0.44811]	1.483030 (0.09153) [16.2025]	-0.030775 (0.01862) [-1.65263]	-2.33E+11 (2.0E+11) [-1.18758]	0.001011 (0.00195) [0.51949]
DIR(-2)	-0.423620 (0.32666) [-1.29684]	-0.442844 (0.11687) [-3.78905]	0.037783 (0.02378) [1.58898]	3.60E+11 (2.5E+11) [1.43665]	0.001237 (0.00249) [0.49743]
DIR(-3)	0.353438 (0.15395) [2.29578]	-0.094656 (0.05508) [-1.71844]	-0.013662 (0.01121) [-1.21915]	-8.78E+10 (1.2E+11) [-0.74275]	-0.002295 (0.00117) [-1.95849]
DEI(-1)	1.306067 (1.01059) [1.29239]	0.556803 (0.36158) [1.53992]	1.218532 (0.07356) [16.5646]	1.04E+12 (7.8E+11) [1.33932]	0.019788 (0.00769) [2.57298]
DEI(-2)	-1.267628 (1.02682) [-1.23451]	-0.525044 (0.36739) [-1.42913]	-0.291257 (0.07474) [-3.89670]	-7.58E+11 (7.9E+11) [-0.96144]	-0.019916 (0.00781) [-2.54865]

DEI(-3)	0.117608	-0.120607	0.001288	-4.81E+10	0.000398
	(0.19967)	(0.07144)	(0.01453)	(1.5E+11)	(0.00152)
	[0.58901]	[-1.68820]	[0.08861]	[-0.31406]	[0.26190]
OREC(-1)	3.37E-13	2.04E-14	-7.08E-15	-0.065036	-9.67E-17
	(1.1E-13)	(3.8E-14)	(7.8E-15)	(0.08214)	(8.1E-16)
	[3.14541]	[0.53176]	[-0.90833]	[-0.79174]	[-0.11870]
OREC(-2)	-1.49E-13	4.30E-14	2.18E-14	0.001680	7.97E-16
	(1.1E-13)	(3.9E-14)	(8.0E-15)	(0.08454)	(8.4E-16)
	[-1.35072]	[1.09017]	[2.72075]	[0.01987]	[0.95131]
OREC(-3)	1.32E-13	1.57E-14	8.57E-16	-0.022847	-1.52E-15
	(1.1E-13)	(3.9E-14)	(8.0E-15)	(0.08404)	(8.3E-16)
	[1.20255]	[0.40128]	[0.10749]	[-0.27184]	[-1.82565]
DVOL(-1)	-9.477109	-1.911208	3.654667	-1.13E+13	0.164604
	(9.87070)	(3.53164)	(0.71851)	(7.6E+12)	(0.07512)
	[-0.96013]	[-0.54117]	[5.08648]	[-1.49586]	[2.19127]
DVOL(-2)	-11.05936	15.19764	0.939039	-5.64E+11	0.067711
	(10.6089)	(3.79576)	(0.77224)	(8.1E+12)	(0.08074)
	[-1.04246]	[4.00385]	[1.21599]	[-0.06927]	[0.83868]
DVOL(-3)	10.51010	-3.366610	-1.009549	-4.42E+12	0.183177
	(10.6286)	(3.80281)	(0.77367)	(8.2E+12)	(0.08089)
	[0.98885]	[-0.88530]	[-1.30488]	[-0.54230]	[2.26464]
C	-0.280719	-0.868997	-0.682792	2.11E+12	0.013405
	(3.20396)	(1.14635)	(0.23322)	(2.5E+12)	(0.02438)
	[-0.08762]	[-0.75806]	[-2.92765]	[0.85749]	[0.54976]
R-squared	0.149859	0.949839	0.935525	0.062875	0.218568
Adj. R-squared	0.072103	0.945251	0.929628	-0.022838	0.147095
Sum sq. resids	455.6197	58.32572	2.414171	2.68E+26	0.026387
S.E. equation	1.666784	0.596359	0.121328	1.28E+12	0.012685
F-statistic	1.927286	207.0301	158.6420	0.733551	3.058069
Log likelihood	-338.9921	-153.9867	132.6352	-5264.950	539.0953
Akaike AIC	3.944357	1.888741	-1.295946	58.67723	-5.812170
Schwarz SC	4.228175	2.172560	-1.012128	58.96104	-5.528352
Mean dependent	-1.866612	0.533430	-8.946606	1.24E+11	0.018315
S.D. dependent	1.730332	2.548702	0.457365	1.26E+12	0.013735
Determinant resid covariance (dof adj.)		2.69E+18			
Determinant resid covariance		1.69E+18			
Log likelihood		-5054.429			
Akaike information criterion		57.04921			
Schwarz criterion		58.46830			

Impulse Response Function

Impulse response Function

Response to Cholesky One S.D. Innovations ± 2 S.E.



Variance Decomposition

Variance Decomposition of RGDP:

Table 1

Period	S.E.	RGDP	DIR	DEI	OREC	DVOL
1	1.666784	100.0000	0.000000	0.000000	0.000000	0.000000
2	1.729002	93.07297	0.007915	0.794569	5.659198	0.465352
3	1.752154	90.63127	0.849794	1.017576	6.144416	1.356948
4	1.776418	88.81424	1.394717	1.035339	6.451902	2.303804
5	1.778955	88.56108	1.410729	1.041893	6.435335	2.550962
6	1.780330	88.43798	1.479972	1.040887	6.442036	2.599126
7	1.782614	88.32050	1.562051	1.048291	6.474787	2.594371
8	1.783982	88.23852	1.650260	1.055316	6.465036	2.590869

9	1.785814	88.11202	1.754157	1.070396	6.465141	2.598285
10	1.787416	87.98220	1.858277	1.097534	6.455357	2.606635
Variance Decomposition of DIR:						
Table 2						
Peri od	S.E.	RGDP	DIR	DEI	OREC	DVOL
1	0.596359	13.53331	86.46669	0.000000	0.000000	0.000000
2	1.115302	21.15255	78.40191	0.346711	0.053344	0.045483
3	1.569941	24.90428	73.00810	0.635084	0.106751	1.345783
4	1.950618	25.40336	70.22528	1.036354	0.280058	3.054948
5	2.261761	24.51521	68.98683	1.393669	0.576940	4.527353
6	2.513467	23.58167	67.95606	1.643065	0.759428	6.059780
7	2.710455	22.79606	67.05589	1.759524	0.884473	7.504053
8	2.859783	22.12021	66.37115	1.764344	0.998800	8.745497
9	2.969097	21.54626	65.92793	1.705564	1.079988	9.740254
10	3.046954	21.09286	65.66266	1.628555	1.129912	10.48601
Variance Decomposition of DEI: Table 3						
Peri od	S.E.	RGDP	DIR	DEI	OREC	DVOL
1	0.121328	3.773317	0.825209	95.40147	0.000000	0.000000
2	0.203401	6.196542	3.664567	84.85028	0.288157	5.000459
3	0.269423	5.120935	5.757379	77.62327	0.187326	11.31109
4	0.317971	3.758516	6.725098	75.98169	0.434920	13.09978
5	0.357765	3.390385	7.346648	74.66831	0.648178	13.94648
6	0.390468	3.192183	8.269066	73.32654	0.654150	14.55806
7	0.417271	3.111689	9.408321	71.72922	0.690395	15.06037
8	0.438963	3.187998	10.56420	70.25810	0.721633	15.26808
9	0.456406	3.361723	11.65924	68.98391	0.726000	15.26912
10	0.470456	3.542235	12.70067	67.87852	0.713447	15.16514
Variance Decomposition of OREC:						
Table 4						
Peri od	S.E.	RGDP	DIR	DEI	OREC	DVOL
1	1.28E+12	9.920561	1.602984	0.000884	88.47557	0.000000
2	1.30E+12	10.11858	2.201692	0.857420	85.64974	1.172570
3	1.31E+12	11.00272	2.187283	0.847180	84.70383	1.258980
4	1.32E+12	11.64829	2.205410	0.837719	83.83781	1.470778
5	1.32E+12	11.69931	2.320434	0.841467	83.64493	1.493858
6	1.32E+12	11.68628	2.430170	0.857253	83.53362	1.492672
7	1.32E+12	11.68146	2.478107	0.889542	83.45325	1.497637
8	1.32E+12	11.70280	2.496186	0.910954	83.37136	1.518705
9	1.32E+12	11.70612	2.509308	0.938416	83.31653	1.529634
10	1.32E+12	11.70367	2.523738	0.958946	83.27116	1.542492

Variance Decomposition of DVOL:						
Table 5						
Period	S.E.	RGDP	DIR	DEI	OREC	DVOL
1	0.012685	0.466108	2.974187	0.025946	0.268815	96.26494
2	0.013151	1.675802	2.766939	3.294572	0.279249	91.98344
3	0.013380	1.618922	2.959751	3.621217	0.387093	91.41302
4	0.013905	1.864571	2.808607	3.660128	0.952123	90.71457
5	0.014015	1.867218	2.827748	3.770073	0.965836	90.56913
6	0.014093	1.890154	2.823355	3.760959	1.041639	90.48389
7	0.014136	1.959313	2.809983	3.749910	1.057527	90.42327
8	0.014160	2.009330	2.841007	3.741946	1.054304	90.35341
9	0.014177	2.075395	2.920140	3.763802	1.052028	90.18863
10	0.014199	2.173648	3.025893	3.822476	1.052664	89.92532
Cholesky Ordering: RGDP DIR DEI OREC DVOL						