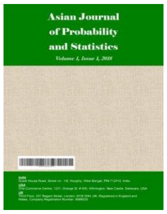

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Unrestricted Vector Autoregressive Modelling of the Interaction among Oil Price, Exchange Rate and Inflation in Nigeria (1981–2017)

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Authors' contributions

This work was carried out in collaboration between both authors. The first draft of the manuscript, the design of the study, statistical analysis, and the interpretation was carried out by the corresponding author GLT while the protocol and management of the literature searches was done by the second author LW. Both authors read and approved the final manuscript.

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Abstract

The interdependence among oil prices, exchange rates and inflation rates, and their response to shocks, was a cause of concern. Unrestricted Vector Autoregression (UVAR) was employed to analyse this interactions as well as to investigate the pattern of causality among the study variable. Annual data spanning from 1981 to 2017 was sourced from the Statistical Bulletin of the Central Bank of Nigeria. Pre-estimation analysis showed that all variables were integrated of order one 1(1), and there no cointegrating relationship. The inverse root of AR characteristic polynomial showed a stable VAR model. All lag length selection criteria chose a lag length of 1. The UVAR estimates and the test of significance particularly the granger causality test indicated significant influence and uni-directional effect from oil price to exchange rates. The Wald statistics, showed significant own shocks, and the impulse response showed that all variables were instantaneously affected by own shocks. Exchange rate was instantaneously affected by oil price; however, it ruled out the response in inflation rate to

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contemporaneous shocks in oil price. The variance decomposition further showed that at least 93.1%, 97.1% and 92.4% of the impulse response in oil price, exchange rate, and inflation rate respectively were from own shocks in the long run. The post estimation analysis showed that the VAR model was multivariate normal, the residual was homoscedastic, and there was no serial autocorrelation. It was recommended that the government should diversify the national income stream and consider policies that will control inflation.

Keywords: Oil price; exchange rate; inflation rate; VAR; impulse response; variance decomposition.

1 Introduction

1.1 Background to the study

Agriculture was the mainstay of the Nigerian economy until the discovery of oil in Nigeria in 1956 and its export in 1958. Since then, crude oil contributes over 80% of the federal revenue hence a major source of income and foreign exchange.

Analysis of the interaction among oil price fluctuation, exchange rates and inflation rates is complicated but obviously necessary as oil price shocks characteristically have real effect on macroeconomic variables particularly the stability indicators of exchange rate and inflation rates.

There are theoretical reasons why an oil price shock should affect macroeconomic variables; firstly, the oil price shock can lead to lower aggregate demand since the price rise redistributes income between the net oil import and export countries since higher costs of production in many cases translated into higher prices for goods and services. Second, the supply side effects relate to the fact that crude oil is considered as a basic input in production process. A rise in the oil price reduces aggregate supply since higher energy prices reduces energy purchase; consequently, the productivity of any given amount of resource reduces, the potential output will also fall.

Several studies have examined the impact of oil price movement and its shocks on the macroeconomic performances of oil exporting and importing countries with clear consensus that oil price affects macroeconomic variables. This study examined the overall interaction among the study variables and among other purposes determined the impulse response of exchange rate and inflation rate to shocks in oil price [1] in [2] defined exchange rate as the price for which the currency of a country can be exchange for another country's currency. Exchange rate is said to depreciate if the amount of domestic currency required to buy foreign currency increases, it is however said to appreciates if the amount of domestic currency required to buy a foreign currency reduces. An appreciation in the real exchange rate may create current account problems because it leads to overvaluation. Overvaluation in the turn makes export relatively expensive and imports artificially cheaper. Exchange rate volatility on the other hand refers to the swings of fluctuations in the deviations from a benchmark or equilibrium exchange rate [3]. Inflation is a persistent rise in general price level of all goods and services over a given period of time. The condition consequently is; if change in price over time is greater than zero ($\frac{\partial p}{\partial t} > 0$).

Vector autoregression (VAR): Vector autoregression(VAR) is linear time-series models, designed to capture the joint dynamics of multiple time series. It is a technique used by macroeconomists to illustrate the joint dynamic behaviour of a collection of variables without requiring strong restrictions as required in the identification of fundamental structural parameters. VAR is an established method of time-series modelling; it has gained so much popularity since its introduction by Sims [4].

VAR is a natural extension of the univariate autoregressive model; it depicts the dynamic behaviours of multivariate time series. The VAR model has proven to be very useful for financial time series, forecasting and describing the dynamic behaviour of economic time series. It often provides superior forecasts to models from univariate time series [5]. Forecasts from VAR models are quite flexible because they can be made conditional on the potential future paths of specified variables in the model.

Although some useful applications of the estimates such as impulse-response functions (IRFs) or variance decompositions do require identifying restrictions, estimating the equations of a VAR does not require strong identification assumptions. Restrictions take the form of an assumption about the dynamic relationship between a pair of variables, for example, that exchange rate affect inflation rate only with a lag, or that exchange rate does not affect inflation rate in the long run.

A VAR system contains a set of m variables, each of which is expressed as a linear function of p lags of itself and of all of the other $m - 1$ variables, including an error term.

1.2 Statement of the problem

Nigeria like other developing countries traditionally experienced macroeconomic instability. Macroeconomic instability conceptually refers to a volatile macroeconomic condition while economic stability refers to absence of excessive fluctuation in key macroeconomic variables.

There have been fluctuations in oil price and consequently its revenue, this results to huge differentials (positive or negative) in oil revenue and consequential effects on other macroeconomic variables including exchange rate and inflation rate. Recently, the global price of crude oil dwindled in the international market; this led to a shock on the foreign exchange rate of the country which affected consumer prices.

Economists often rely on multiple measures to achieve or guide economic growth and stability, this paper analyses the maintenance or distortion in stability arising from the interaction among the identified variables using Variance Autoregressive approach. An import dependent country like Nigeria, consequently requires the understanding of the interaction existing among crude oil price, exchange rates and inflation rates. Thus, the mind blowing questions were; how does exchange rate react to shocks on crude price? How does inflation rate react to shocks on crude price? How does inflation rate react to shocks on exchange rate?

1.3 Objectives of the study

The main objective of the study was to carry out Vector autoregressive modelling of the interaction among oil price, exchange rate and inflation rate. The specific objectives were to

(i) establish the causality of oil price on exchange rate and inflation rate
(ii) determine the impulse response of exchange rate on oil price and inflation rate
(iii) find out the effects of inflation rate on oil price and exchange rate

2 Literature Review

2.1 Conceptual literature

Very few works have identified the interaction existing among oil price, exchange rate and inflation rate hence this study will add to the few existing literature. The study intends to identify both uni and bidirectional relationship existing among the study variables as shown in the conceptual framework in Fig. 1.

2.2 Empirical literature

Tuaneh [2] in his study on Vector Autoregressive Modelling of the Interaction among Macroeconomic Stability Indicators in Nigeria (1981-2016) applied the multivariate time-series modelling approach (VAR) on quarterly data panning the period from 1981 to 2016. The result showed that at least 80% of the impulse response were from own shocks.

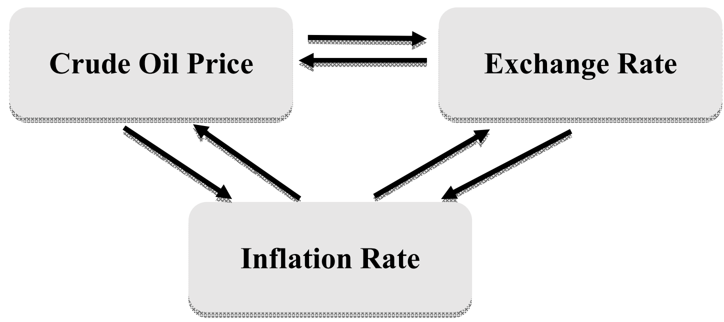

Fig. 1. Conceptual framework on the study variables

Monfared and Akin [6] investigated the relationship between exchange rates and inflation: the case of iran. The study applied Hendry general to specific modelling method and Vector Autoregression (VAR) on annual data for the period 1976-2012. The result showed there is a direct relationship between Exchange rate and inflation.

Apere [7] investigated the relationship between inflation and oil price fluctuations in Nigeria using quarterly data within the period first quarter of 1980 to fourth quarter of 2015 and adopting Vector autoregressive model. The results showed that inflation responded positively to oil price fluctuation.

Garba et al. [5] used VAR to model the structural relationships of exchange rates, of Naira to foreign currencies and concluded that Granger causality has been found useful in determining if a time series can be used in forecasting another, because it goes beyond correlation.

Obioma and Eke [8] carried out an Empirical Analysis of Crude Oil Price, Consumer Price Level and Exchange Rate Interaction in Nigeria: A Vector Autoregressive (VAR) Approach using monthly data (January, 2007-February, 2015). The result showed that all the variables were integrated of order one I (1) and no long-run relationship existed among them. The work also revealed that a shock on crude oil price had a negative impact on exchange rate. More so, variation in exchange rate was substantially caused by crude oil price and a shock on exchange rate had a negative effect on consumer price level.

In the study of Kofi et al. [9], the authors examined both internal and external factors influencing Ghana's inflation and found that in Ghana and the Ivory Coast, there is a significant intra-continental transfer of inflation.

Odili [10] analyzed the impact of real exchange rate volatility and economic growth on export and import in Nigeria using a vector error correction model with time series data from 1971 to 2012. He found that in both the short and long run, there was significant effects of exchange rate volatility and economic growth on international trade in Nigeria.

Aicha and Alaoui [11] investigated the relationship between export, import and economic growth using annual time series data for the Moroccan economy from 1980 to 2013. The cointegration technique was employed to see the long run equilibrium relationship among variables. Granger causality test based on vector error correction model (VECM) was also adopted to see both short and long run causality among the variables. The cointegration results confirm the existence of the long-run relationship among these variables. For the short-run causality, the findings suggest (i) bidirectional causality between economic growth and import, (ii) unidirectional causality that run from export to import, and (iii) no-directional causality between economic growth and export.

Elifand [12] examined the impact of exchange rates on import and export of economically developing countries for the period of 1985-2012. The study applies the panel cointegrationmethod. Annual data obtained from the World Bank were used in the empirical analysis and the result showed that there was cointegrating relationship between effective exchange rates and export-import of emerging countries in the long run.

Niyimbanira [13] used the Johansen-Juselius co-integration technique to investigate the relationship between oil price and inflation in South Africa. The study tested the long run relationship between oil prices and inflation. The results revealed a co-integrating relationship between oil prices and inflation in South Africa. The study also revealed a unidirectional causality running form the oil prices to inflation.

Mohsen [14] analysed the effects of change in exchange rates on the export, import, product prices and others macroeconomic variables in Iran during the period of 1960 to 2012. The method which was used in this study was based on cointegration method and vector autoregressive method (VAR). In the study long-term and short-term relationships between variables were determined according to Impulse response functions. The result revealed that there were no effects from exchange rate on macro-economic variables.

Chou [15] applied a nonlinear error-correction model on monthly data from January 1981 to May 2011 and. The results revealed that the oil price has long-term pass-through effects on the producer price in Taiwan.

Oyovwi [16] studied the effect of exchange rate volatility on economic growth in Nigeria on the basis of annual data from 1970 to 2009. His empirical analysis began with testing for stationarity of the variables by applying the Augmented Dickey-Fuller (ADF). This was followed by co-integration test of the model. The unit root test results showed that all variables except exchange rate volatility were integrated at order one, that is I(1) while exchange rate volatility is integrated at order zero that is I(0). Also, co-integration analysis indicated that variables are co-integrated. The study basically employed the Generalised Autoregressive Conditional Heteroscedasticity (GARCH) technique to generate exchange rate volatility; his findings further showed that in the short run, economic growth had positively responsive to exchange rate volatility while in the long run, a negative relationship existed between the two variables.

Mpofu [17] studied money supply, interest rate, exchange rate and oil price influence on inflation in South Africa. He used the ordinary least squares regression on monthly data from January, 1999 through September, 2010. The findings from the study showed that interest rates and oil price had a significant negative relationship with inflation the long run.

Nwosu [18] studied the impact of fuel price on inflation. He employed the variance Autoregression on quarterly data spanning from the period 1995 to 2008, to assess the relative effects of fuel price on inflation. The result showed a positive relationship between fuel price and inflation.

Enders [19] joined other proponents of VAR to suggest that in the forecasts of economic indicators, VAR models should be used as all variables in the models are endogenous, therefore, not a single variable may be removed when explanations for the behaviour of other variables are offered.

3 Materials and Methods

3.1 Test for Stationarity

Time series data are often non stationary, however, the assumption of stationarity of the regressors and the regressand are crucial for the adoption of the Least Squares estimators [20] in [21]. Tuaneh and Essi [21] noted that the Stationarity of a series can strongly influence its behaviour, consequently, the use of non-stationary data can lead to spurious regression. Time series data on all variables included in the model are required to be stationary in order to carry out joint significant test on the lags of the variables. Gujarati [22] explained that the various methods often used to test for stationarity; Augumented Dicky Fuller, the Philip

Peron test, and the graphical method (the correlogram). The study however adopted the; Augmented Dickey Fuller Unit Root Test.

Augmented Dickey-Fuller (ADF) unit root test was employed to determine the order of integration of the series (i.e. to investigate the stationary status of each variable). The test is the *t*-statistic on the parameters. The following unit root tests regression equations are used for the first difference of the variables;

$$\Delta OP_t = \tau_{11} + \tau_{12} \sum_{t-1}^{k} p_i \, \Delta OP + \mu_{t1} \quad (1)$$

$$\Delta EXR_t = \tau_{21} + \tau_{22} \sum_{t=1}^{k} p_i \, \Delta EXR_{t-1} + \mu_{t2} \quad (2)$$

$$\Delta IFR_t = \tau_{31} + \tau_{32} \sum_{t=1}^{k} p_i \, \Delta IFR_{t-1} + \mu_{t3} \quad (3)$$

Where: Δ is the difference operator

OP = Oil Price, EXR = Exchange Rates, IFR = Inflation Rates.

U_t = random terms, t = time, ρ_i= coefficient of the preceding observation, ($_{t-1}$) is the immediate prior observation, k is the number of lags, while τ_{11}– $\tau_{32}$are the parameters to be determined.

The inherent null hypothesis is that each series has a unit root 1(0), if 'τ' is found to be more negative and statistically significant. We compare the *t*-statistic value of the parameter, with the critical value tabulated in (MacKinnon, 1991), We reject the null and conclude that the series do not have a unit root at levels.

3.2 Co-integration Test

it is necessary to determine if there is a long run cointegrating relationship, since only variables that are of the same order of integration may constitute a potential cointegrating relationship,oncethe unit roots of the study variables have been examined, and the order of integration ascertained, we continue to determine the presence of cointegrating relationship.

Regression analysis on time series variablesareoften gives spurious results; it is consequently necessary to find out if the series are cointegratedTime series variables may be individually non-stationary, but their linear combination can be stationary. This means subjecting these time series individually to unit root analysis and finding out if both are I (1) – non-stationary. Cointegration suggests that there is long-run or equilibrium relationship between them. To test whether the linear combination of non-stationary series has a long-run equilibrium relationship, the study adopts the Johansen procedure. The number of significant cointegrating vectors in nonstationary time series is tested using the maximum likelihood based statistics. The stationary linear combination is called the cointegrating equation and interpreted as a long run relationship among the variables.

3.3 Models specification

$$Y_t = \varphi + \sum_{i=1}^{p} \varphi_i Y_{t-i} + \varepsilon_t \quad (4)$$

Where; Y_t for t = 1,2,……, T is an M X 1 vector containing observation on a m time series variables Y_t = (Y_{t1}, Y_{t2}, …. , Y_{tn}), φ_i are full rank mxm matrix of coefficients, and i = 1, 2, 3,… , p, ϵ_t = (U_{t1}, U_{t2}, … , U_{nt}) is a M X 1 Vector of unobservable i.i.d. zero mean error term.

The reduced form of the unrestricted VAR model is a an approximation for the dynamic process of any vector of time series. This study assumed a simple UVAR model of oil price, Exchange rate, and Inflation.
Adapting equation (4) in the following VAR model form:

$$U\ (VAR) = (OP, EXR, INFL) \quad (5)$$

Presenting the contemporaneous coefficient and the lagged endogenous variables as the exogenous variables, the VAR, may be written as:

$$OP_t = \Gamma_{11(i)}OP_{t-i} + \Gamma_{12(i)}EXR_{t-i} + \Gamma_{13(i)}IFR_{t-i} + K_1 + \epsilon_{1t} \quad (6)$$

$$EXR_t = \Gamma_{21(i)}OP_{t-i} + \Gamma_{22(i)}EXR_{t-i} + \Gamma_{23(i)}IFR_{t-i} + K_2 + \epsilon_{2t} \quad (7)$$

$$IFR_t = \Gamma_{31(i)}OP_{t-i} + \Gamma_{32(i)}EXR_{t-i} + \Gamma_{33(i)}IFR_{t-i} + K_3 + \epsilon_{3t} \quad (8)$$

A basic feature of the equation is that no current time variables appear on the right-hand side of any of the equations. This makes it plausible, though not always certain, that the repressors are weakly exogenous.However, equations (6) – (8) are estimated if the variables are stationary at levels, in which case any shock to the stationary variables are temporary. If the variables are nonstationary and not cointegrated, then they have to be transformed into stationary variables by differencing, if the variables are stationary after first difference and co-integrated then VAR can be transformed to Vector Error Correction Model.

3.4 Vector autoregressive lag length selection criteria

The VAR lag length is selected using some model selection criteria. The general approach is to fit VAR models with orders p= 0, 1, 2,...,, P_{max} and choose the value of p which minimizes the model selection criteria [23]. Understanding that choosing too few lags could lead to systematic variation in the residuals whereas, too many lags come with the penalty of fewer degrees of freedom. The optimum or appropriate lag length for the VAR model was concluded based on the VAR lag order selection results in Table 1. All criteria; the sequential modified LR test, Final prediction errorcriterion(FPE), Akaike information criterion (AIC), Schwarz Information Criteria (SC), and the Hannan-Quinn information criterion(HQ) selected lag 1, the researcher consequently concluded that the fit is good at lag 1

Table 1. VAR lag order selection results

Included observations: 40						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	-571.8093	NA	6.09e+08	28.74047	28.86713	28.78626
1	-524.6400	84.90472	90456712*	26.83200*	27.33866*	27.01519*
2	-518.9708	9.354150	1.08e+08	26.99854	27.88520	27.31913
3	-515.9710	4.499778	1.49e+08	27.29855	28.56521	27.75653
4	-508.8884	9.561446	1.70e+08	27.39442	29.04108	27.98980
5	-501.2057	9.219300	1.95e+08	27.46028	29.48694	28.19306
6	-497.0688	4.343753	2.77e+08	27.70344	30.11009	28.57361
7	-489.3134	6.979795	3.46e+08	27.76567	30.55232	28.77324
8	-466.4787	17.12604*	2.20e+08	27.07394	30.24059	28.21890

** indicates lag order selected by the criterion*

The lag length selection criteria indicated two lags, hence the model above is written as

$$OP_t = \Gamma 11OP_{t-1} + \Gamma 12OP_{t-1} + \Gamma 13IFR_{t-1} + K_1 + \varepsilon_{1t} \quad (9)$$

$$EXR_t = \Gamma 21OP_{t-1} + \Gamma 22EXR_{t-1} + \Gamma 23IFR_{t-1} + K_2 + \varepsilon_{2t} \quad (10)$$

$$IFR_t = \Gamma 31OP_{t-1} + \Gamma 32EXR_{t-1} + \Gamma 33IFR_{t-1} + K_3 + \varepsilon_{3t} \quad (11)$$

This can be written in matrix form as

$$\begin{bmatrix} OP_t \\ EXR_t \\ IFR_t \end{bmatrix} = \begin{bmatrix} \Gamma_{10} \\ \Gamma_{20} \\ \Gamma_{30} \end{bmatrix} + \begin{bmatrix} \Gamma_{11}\Gamma_{12}\,\Gamma_{13} \\ \Gamma_{21}\Gamma_{22}\Gamma_{23} \\ \Gamma_{31}\Gamma_{32}\Gamma_{33} \end{bmatrix} \begin{bmatrix} OP_t \\ EXR_t \\ IFR_t \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{bmatrix} \quad (12)$$

The researcher used Eviews 10 in the statistical data analysis which requires a different model specification, for the purpose of analysis in the Eviews, the model is specified as:

VAR Model Specification (Eviews):

OP = C(1,1)*OP(-1) + C(1,2)*EXR(-1) + C(1,3)*IFR(-1) + C(1,4) (13)

EXR = C(2,1)*OP(-1) + C(2,2)*EXR(-1) + C(2,3)*IFR(-1) + C(2,4) (14)

IFR = C(3,1)*OP(-1) + C(3,2)*EXR(-1) + C(3,3)*IFR(-1) + C(3,4) (15)

The system of equation above can also be presented in Eviewsfor ease of analysis, explanation and understanding as:

OP = C(1)*OP(-1) + C(2)*EXR(-1) + C(3)*IFR(-1) + C(4) (16)

EXR = C(5)*OP(-1) + C(6)*EXR(-1) + C(7)*IFR(-1) + C(8) (17)

IFR = C(9)*OP(-1) + C(10)*EXR(-1) + C(11)*IFR(-1) + C(12) (18)

This is an indication that 12 parameters would be estimated. The square of the number of variables multiplied by the number of lags plus the number of variables given as $[(k^2)L + k]$ where K number of endogenous variables, L = lag length hence number of estimated parameter is $[(3^2)1 + 3] = 12$

4 Results

4.1 Time plots

The time plots shown in figure 2 are indications that all variables showed fluctuations within the period of the study, no variable followed a steady trend.

4.2 Diagnostic test results

4.2.1 Unit root test result

The study variables are time series in nature which are often non stationary, consequently, the Johansen technique cannot be applied unless it is established that the variables concerned are stationary. Data on each series were tested for stationarity so as to avoid the problem of spurious regression [23]. For this study, the Augmented Dickey-Fuller (ADF) test was used to test the null hypothesis of a unit root. The null hypothesis of a unit root is rejected in favour of the stationary alternative in each case if the test statistic is more negative than the critical value. A rejection of the null hypothesis means that the series do not have a unit root.

Table 2 presents results of the unit root tests, p-values are in brackets. The results showed that at levels, all variables had unit root (p-values > 0.05), however, all variables do not have unit root at levels(t-values more negative than the test statistics at 99% confidence, more so p-values are less than 0.05 level of significance at both intercept, and Constant & trend, consequently the null hypothesis of unit roots were rejected. Conclusively, Oil Price Exchange rates, and Inflation Rates were stationary at order 1(1).

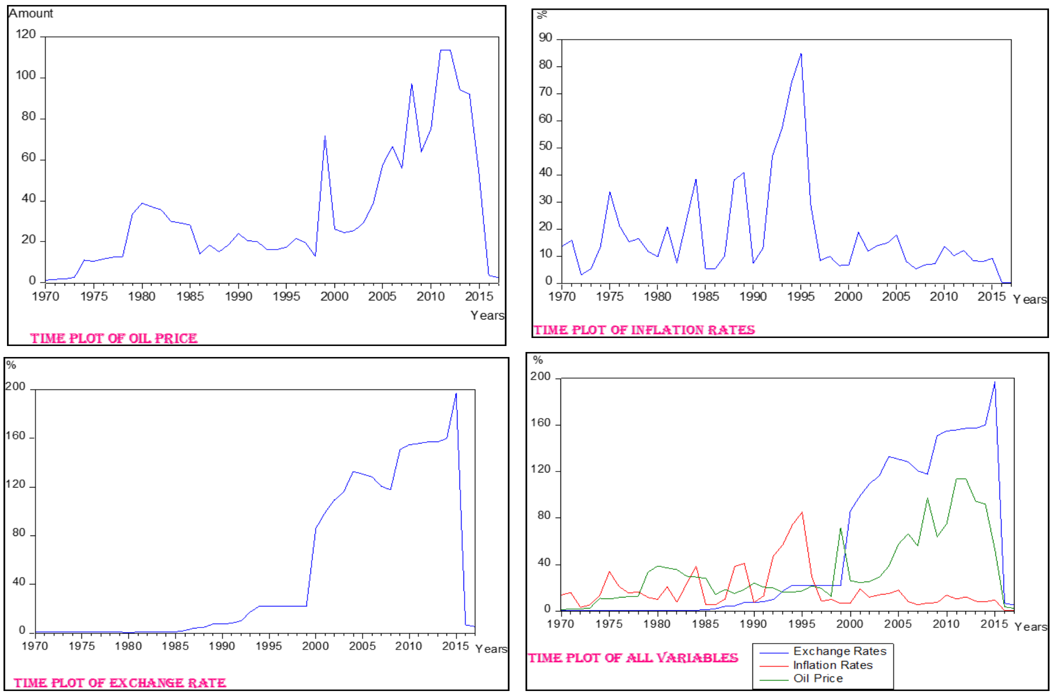

Fig. 2. Time plots on all variables

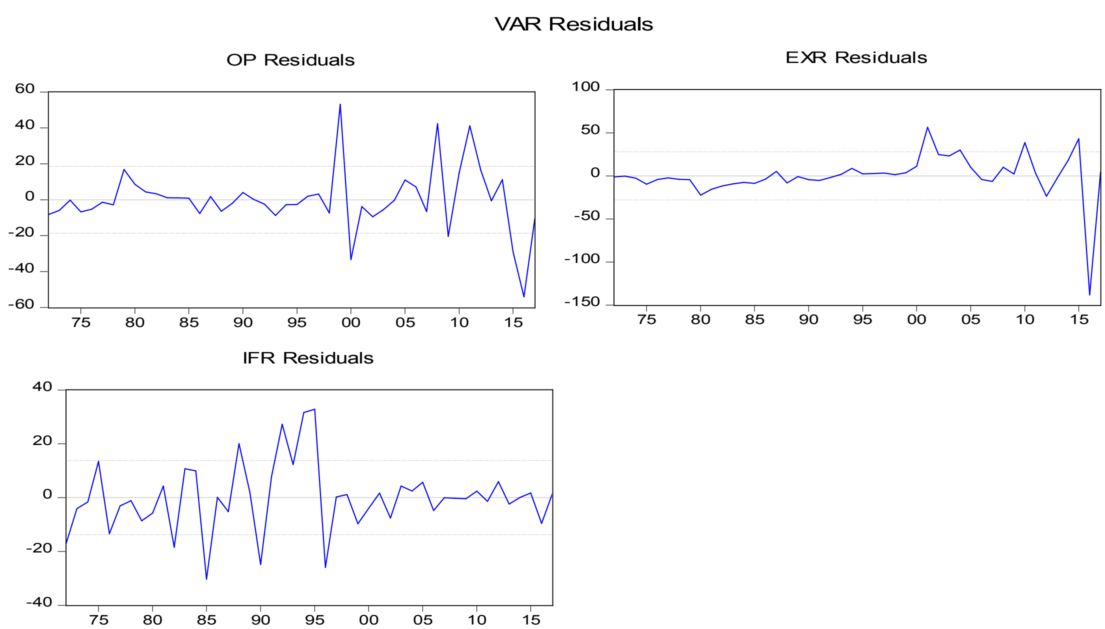

Fig. 3. Residual plots at levels on all variables

Table 2. Augmented dickey-fuller unit root test result

Variables	Levels		1st difference		Order of integration
	Constant	Constant, linear trend	Constant	Constant, linear trend	
Oil Price (OP)	-2.198(0.21)	-2.146(0.51)	-7.667 (0.000)	-7.745 (0.000)	1(1)
Exchange Rate (EXR_t)	-1.673(0.44)	-1.816(0.681)	-7.510 (0.000)	-7.548 (0.000)	1(1)
Inflation Rate (IFR_t)	-2.198(0.210)	-2.146(0.504)	-7.666 (0.000)	-7.745 (0.000)	1(1)

Critical values for test statistics:	***%level***	***Constant***	***Constant, linear trend***
	1% level	-3.5777	-4.1657
	5% level	-2.9251	-3.5085
	10%level	-2.6006	-3.1842

Table 3. JohansenCo-integration Test Result

Hypothesized		Trace	0.05		Max-Eigen	0.05	
No. of CE(s)	**Eigenvalue**	**Statistic**	**Critical value**	**Prob.****	**Statistic**	**Critical value**	**Prob.****
None	0.279459	26.08259	29.79707	0.1263	15.07662	21.13162	0.2836
At most 1	0.175512	11.00597	15.49471	0.2111	8.877651	14.26460	0.2965
At most 2	0.045214	2.128323	3.841466	0.1446	2.128323	3.841466	0.1446

Max-eigen value test and Trace test indicates no co-integration at the 0.05 level

4.2.2 Co-integration test result

Studies have shown that the long run combination of stationary processes can be non stationary. Cointegration exists if two variables have a long run or equilibrium, relationship between them. This study employs the Johansen maximum likelihood approach to test for co-integration. Though trace statistic is said to be more robust to both skewness and excess kurtosis in residuals than the maximum-eigen value test, the Johansen maximum likelihood approach is said to be more preferable to the other methods due to its properties the researcher consequently used both maximum-eigen test and the trace statistics.

Table 3 showed the results of the λ_{trace} and λ_{max} statistics respectively. Max-eigenvalue test and Trace test indicates no co-integration at the 0.05 level.

4.3 VAR analysis result of the contemporaneous coefficients

$$OP_t = 0.662OP_{t-1} + 0.087EXR_{t-1} + 0.007IFR_{t-1} + 7.166 \quad (19)$$

$$EXR_t = 0.640OP_{t-1} + 0.650EXR_{t-1} - 0.009IFR_{t-1} - 4.269 \quad (20)$$

$$IFR_t = 0.010OP_{t-1} - 0.033EXR_{t-1} + 0.619IFR_{t-1} + 8.781 \quad (21)$$

The estimated model (substituted coefficients) above is a representation of the detail VAR model estimation output. The estimates of the coefficients of multiple determinations (R^2) of the models were respectively 0.666, 0.818, and 0.437 respectively indicating that the dependent variables were largely explained by the independent variables. The VAR estimates indicate that exchange rates, inflation rates, and interest rates, were positively and significantly affected by their own first lags. The Wald statistics in the system analysis showed that previous lags of each variable were jointly significant in affecting itself. The VAR result above satisfy the stability condition as no root lied outside the unit root circle as shown in graph of the inverse roots of a characteristic polynomial in Fig. 4 below. More so, the table 4 showed that the modulus were less than one but greater than zero

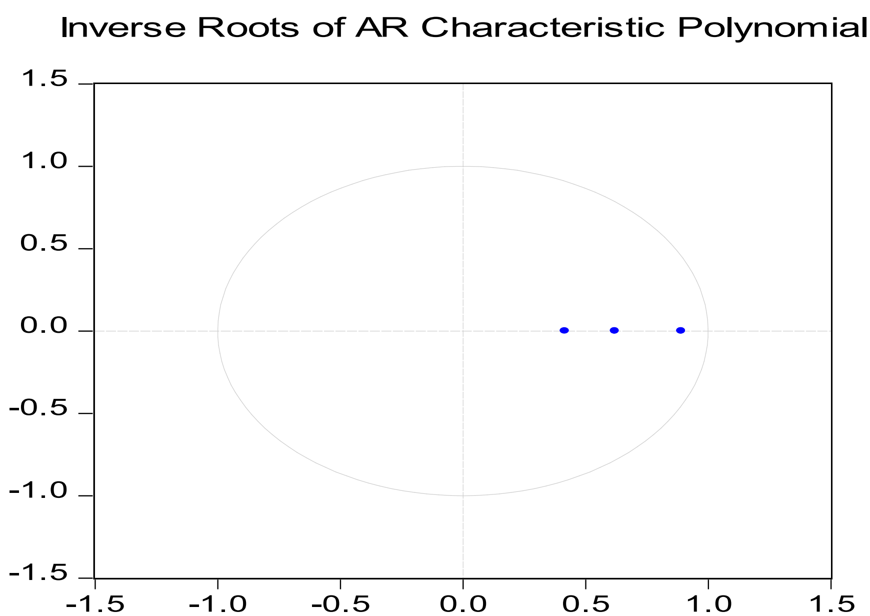

Fig. 4. Inverse roots of a characteristic polynomial

Table 4. Roots of characteristic polynomial (Endogenous variables: OP, EXR, and IFR. exogenous variables: C)

Root	Modulus
0.892776	0.892776
0.622443	0.622443
0.417626	0.417626
No root lies outside the unit circle.	
VAR satisfies the stability condition.	

4.4 Granger causality

The granger causality test conducted and the summary result presented in table 5 below showed most particularly that each variable significantly affected itself. It also showed that oil price granger caused exchange rates (Chi-square =8.354, PV = 0.003< 0,05).

Table 5. Granger causality (Block Exogeneity Wald and system Wald) test result (Test statistics is chi-square and P-values in bracket)

Dependent	Independent variables			
Variables	**OP**	**EXR**	**IF**	**All**
Crude Oil Price Op		1.782 (0.181)	0.002 (0.959)	1.785 (0.409)
Exchange Rate (EXR_t)	8.354 (0.003)*		0.001 (0.967)	8.481 (0.014)
Inflation Rate (IFR_t)	0.009 (0.923)	0.430(0.511)		1.271 (0.529)

(Bold values are t-values indicating own effects)

The post analysis diagnostic test carried out as shown in the summary result of post analysis diagnostic test in table below shows that the residual is multivariate normal, no serial correlation and homoschedastic residual.

Table Post analysis diagnostic test

S/n	Diagnostic test	Test statistics	Calculated value (Prop. value)	Conclusion
1	Normality	JarqueBera	1.1104(0.5739)	Residuals is multivariate normal
2	Serial correlation	Edgeworth expansion corrected likelihood ratio statistic (F-Rao stat)	1.137(0,344)*	No serial autocorrelation
3	Var Lag Exclusion	Chi-square	266.8(0.000)	Lag order is accurate
4	Var Residual Heteroschedasticity	Chi-square	188.8 (0.073)	Homoschedastic

4.6 Impulse response

The zero values right from the start at lag zero for the contemporaneous response to shocks are impose by the Cholesky decomposition by the particular ordering. The first row of figure 5 represent response of oil price to shocks on all other variables, the second row represent variations in exchange rates to shocks on all other variables, while the third row represent changes in inflation rates to shocks on all other variables.

4.6.1 Impulse response of oil price

The first row of Fig. 5 above shows the response of oil price to shocks in oil price, exchange rates and inflation rates. The zero values right from the start at lag zero ruled out to have an immediate effect.

Consequently, oil price had an immediate and positive response to shocks in oil price, it however did not have an immediate nor positive response to shocks in exchange rate and inflation rates, the response to inflation rates was not immediate nor subsequently.

4.6.2 Impulse response of exchange rates

The second row of Fig. 5 above shows the response of exchange rate to shocks to in all studied variables. Exchange rate had an immediate and positive response to own shocks and shocks on oil price, it however did not have an immediate response to shocks in inflation rates. The response to inflation rates was not immediate nor subsequently.

4.6.3 Impulse response of inflation rates

Row 3 of Fig. 5 shows the response of inflation rates to shocks to all variables of the study. Inflation rates had an immediate and positive response to own shocks; it however did not have an immediate response to shocks in other variables of the study. This agrees with the findings of Tuaneh [2]. The response to oil price and exchange rates were not immediate nor subsequently.

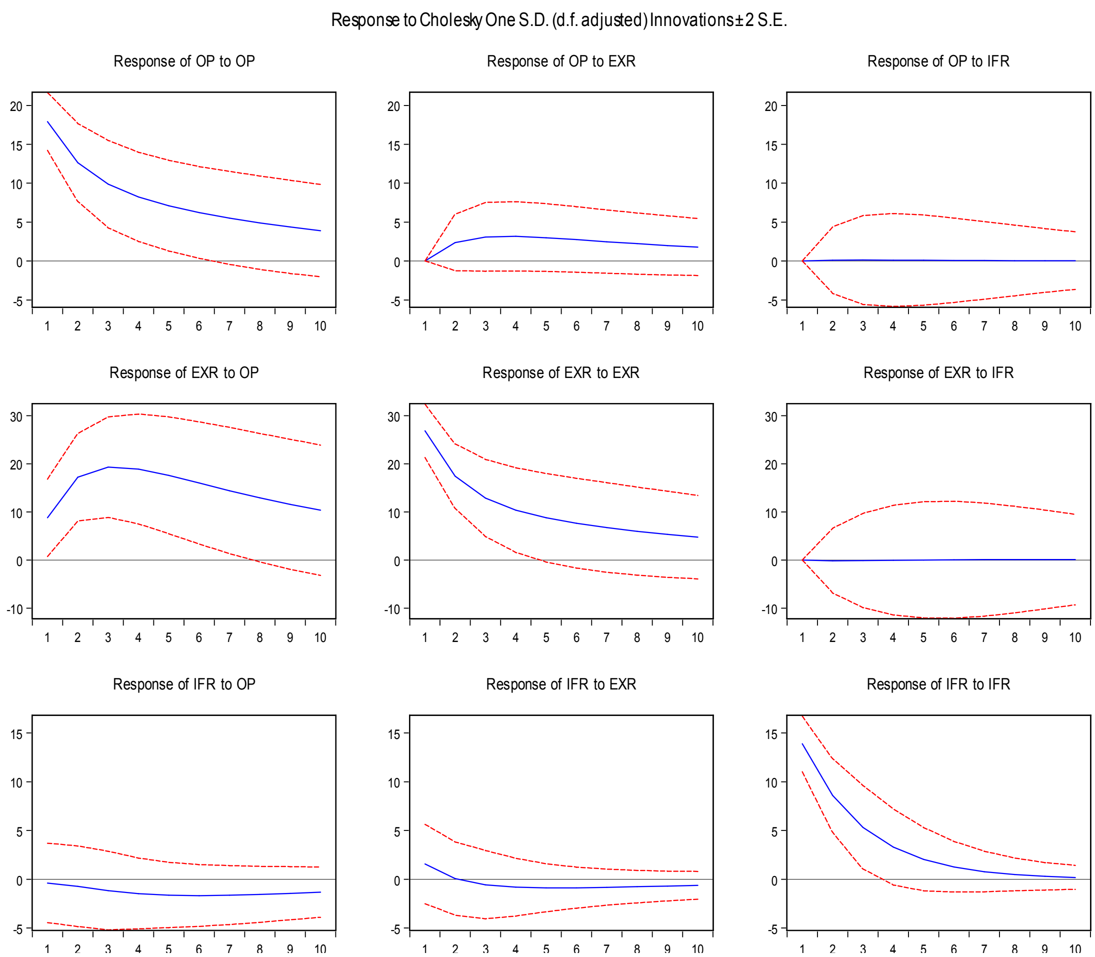

Fig. 5. Impulse response graphs

4.7 Variance decomposition

4.7.1 Variance decomposition of oil price

The first section of table 6 shows that in the short run, the response of oil price due to own shock is 97.4%. The table also showed that a shock in exchange rate and inflation rates respectively cause 2.5%, and 0.004% fluctuations in oil price. In the long run however, the response of exchange rate due to own shock is 93.1%. The fluctuations in oil price due to impulse in exchange rate and inflation rates are 6.7%, and 0.008% respectively.

4.7.2 Variance decomposition of exchange rates

The responses of exchange rates in the short run due to own shock as indicated in the second segment of table 6 is 66.4%. The shock in oil price and inflation rates respectively caused 38.5%, and 0.001% fluctuations in exchange rates. In the long run however, the response of exchange rate due to own shock is 97.1%. The fluctuations in exchange rate due to impulse in oil price and inflation rates are 0.7% and 1.57% respectively.

4.7.3 Variance decomposition of inflation rates

The responses of inflation rates in the short run due to own shock as indicated in the third section of table 6 shows is 92.4%. The shock in oil price and exchange rates respectively can cause 0.66% and 0.92% fluctuations in inflation rates. In the long run however, the response of inflation rate due to own shock is 92.4%. The fluctuations in inflation rates due to impulse in oil price and exchange rates are 5.4% and 2.1% respectively.

Table 6. Variance decomposition result

Period	S.E.	OP	EXR	IFR
Variance decomposition of OP:				
3	24.37122	97.44575	2.549509	0.004737
		(5.09577)	(4.40443)	(2.64449)
10	29.74346	93.19585	6.795992	0.008163
		(12.5581)	(10.2756)	(7.30001)
Variance decomposition of EXR:				
3	43.97954	38.50404	61.49446	0.001501
		(15.4609)	(15.4895)	(2.41446)
10	7.506602	0.794994	97.15740	1.570381
		(17.7529)	(17.2708)	(7.36002)
Variance decomposition of IFR:				
3	17.32332	0.667441	0.920052	98.41251
		(4.54419)	(4.61556)	(6.29385)
10	18.40413	5.485435	2.106306	92.40826
		(11.0032)	(7.20912)	(13.4092)

5 Conclusion

The results based on data for the period 1981 to 2017 showed that the previous lags of oil price, exchange rates, and inflation rates, significantly caused own shocks, however, fluctuations due to other study variables were minimal as shown by the impulse response and variance decomposition analyses. Worthy of note is that; the study ruled out the response of inflation rate to contemporaneous shocks in oil price and exchange rate, it also rule out the fluctuation of exchange rate to contemporaneous impulse in inflation rate. The test of significance particularly the granger causality test indicated significant influence and uni-directional effect from oil price to exchange rates.

6 Recommendation

Own shocks were found to be major and significant determinants of impulse response, it is consequently recommended that economic modelling should consider models which allow the inclusion of the lags of the response variable among the determinants, particularly for multivariate models. Diversification of the national economy is also recommended. There is also the need for policies which will stabilise inflation rate since it did not respond to shocks in oil price nor exchange rate

Competing Interests

Authors have declared that no competing interests exist.

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APPENDIX

Vector Autoregression Estimates
Date: 01/09/19 Time: 16:14
Sample (adjusted): 1971 2017
Included observations: 47 after adjustments
Standard errors in ( )& t-statistics in [ ]

	OP	EXR	IFR
OP(-1)	0.662815	0.640122	-0.010496
	(0.14060)	(0.22146)	(0.10969)
	[4.71410]	[2.89042]	[-0.09569]
EXR(-1)	0.087562	0.650687	-0.033554
	(0.06559)	(0.10330)	(0.05116)
	[1.33508]	[6.29876]	[-0.65581]
IFR(-1)	0.007835	-0.009780	0.619342
	(0.15418)	(0.24286)	(0.12028)
	[0.05082]	[-0.04027]	[5.14913]
C	7.166439	-4.269779	8.781957
	(5.44352)	(8.57410)	(4.24657)
	[1.31651]	[-0.49799]	[2.06801]
R-squared	0.666490	0.818960	0.436529
Adj. R-squared	0.643222	0.806329	0.397217
Sum sq. resids	13812.91	34269.07	8406.226
S.E. equation	17.92290	28.23039	13.98190
F-statistic	28.64388	64.83875	11.10423
Log likelihood	-200.2456	-221.5986	-188.5747
Akaike AIC	8.691301	9.599941	8.194670
Schwarz SC	8.848761	9.757400	8.352130
Mean dependent	34.79574	50.79660	18.11149
S.D. dependent	30.00607	64.14823	18.00884
Determinant resid covariance (dof adj.)		44606263	
Determinant resid covariance		34159195	
Log likelihood		-607.7141	
Akaike information criterion		26.37081	
Schwarz criterion		26.84319	
Number of coefficients		12	

Variance decomposition of OP:				
Period	**S.E.**	**OP**	**EXR**	**IFR**
1	17.92290	100.0000	0.000000	0.000000
2	22.06198	98.85188	1.145686	0.002433
3	24.37122	97.44575	2.549509	0.004737
4	25.91820	96.24199	3.751769	0.006238
5	27.03967	95.31294	4.679952	0.007110
6	27.88426	94.61798	5.374417	0.007598
7	28.53327	94.10040	5.891733	0.007869
8	29.03779	93.71264	6.279337	0.008022
9	29.43278	93.41951	6.572383	0.008110
10	29.74346	93.19585	6.795992	0.008163
Variance decomposition of EXR:				
Period	**S.E.**	**OP**	**EXR**	**IFR**
1	28.23039	9.680285	90.31971	0.000000
2	37.37328	26.68361	73.31507	0.001321

3	43.97954	38.50404	61.49446	0.001501
4	48.97066	45.93062	54.06811	0.001269
5	52.76268	50.65716	49.34173	0.001105
6	55.66008	53.77614	46.22276	0.001096
7	57.88916	55.91108	44.08772	0.001195
8	59.61560	57.41930	42.57936	0.001347
9	60.96053	58.51250	41.48599	0.001512
10	62.01329	59.32125	40.67708	0.001667
Variance decomposition of IFR:				
Period	**S.E.**	**OP**	**EXR**	**IFR**
1	13.98190	0.075432	1.244342	98.68023
2	16.43217	0.246958	0.902514	98.85053
3	17.32332	0.667441	0.920052	98.41251
4	17.71530	1.323811	1.092259	97.58393
5	17.92923	2.117489	1.310788	96.57172
6	18.07271	2.940668	1.524443	95.53489
7	18.18241	3.716860	1.713052	94.57009
8	18.27119	4.405989	1.871555	93.72246
9	18.34417	4.994741	2.001395	93.00386
10	18.40413	5.485435	2.106306	92.40826
Cholesky Ordering: OP EXR IFR				
Variance decomposition of OP:				
Period	**S.E.**	**OP**	**EXR**	**IFR**
1	17.92290	100.0000	0.000000	0.000000
		(0.00000)	(0.00000)	(0.00000)
2	22.06198	98.85188	1.145686	0.002433
		(2.87494)	(2.59076)	(1.34541)
3	24.37122	97.44575	2.549509	0.004737
		(5.09577)	(4.40443)	(2.64449)
4	25.91820	96.24199	3.751769	0.006238
		(6.97686)	(5.92486)	(3.70109)
5	27.03967	95.31294	4.679952	0.007110
		(8.48280)	(7.13668)	(4.56564)
6	27.88426	94.61798	5.374417	0.007598
		(9.66468)	(8.07208)	(5.28155)
7	28.53327	94.10040	5.891733	0.007869
		(10.6002)	(8.79997)	(5.88547)
8	29.03779	93.71264	6.279337	0.008022
		(11.3611)	(9.38332)	(6.40821)
9	29.43278	93.41951	6.572383	0.008110
		(12.0016)	(9.86596)	(6.87419)
10	29.74346	93.19585	6.795992	0.008163
		(12.5581)	(10.2756)	(7.30001)
Variance decomposition of EXR:				
Period	**S.E.**	**OP**	**EXR**	**IFR**
1	28.23039	9.680285	90.31971	0.000000
		(8.36966)	(8.36966)	(0.00000)
2	37.37328	26.68361	73.31507	0.001321
		(12.9999)	(13.0271)	(1.12555)
3	43.97954	38.50404	61.49446	0.001501
		(15.4609)	(15.4895)	(2.41446)
4	48.97066	45.93062	54.06811	0.001269
		(16.5103)	(16.4648)	(3.57758)
5	52.76268	50.65716	49.34173	0.001105

		(17.0147)	(16.8515)	(4.55609)
6	55.66008	53.77614	46.22276	0.001096
		(17.3055)	(17.0221)	(5.36002)
7	57.88916	55.91108	44.08772	0.001195
		(17.4954)	(17.1144)	(6.01791)
8	59.61560	57.41930	42.57936	0.001347
		(17.6236)	(17.1774)	(6.55658)
9	60.96053	58.51250	41.48599	0.001512
		(17.7061)	(17.2277)	(6.99765)
10	62.01329	59.32125	40.67708	0.001667
		(17.7529)	(17.2708)	(7.36002)
Variance decomposition of IFR:				
Period	**S.E.**	**OP**	**EXR**	**IFR**
1	13.98190	0.075432	1.244342	98.68023
		(2.90316)	(3.84271)	(4.87824)
2	16.43217	0.246958	0.902514	98.85053
		(3.36730)	(3.87611)	(5.01218)
3	17.32332	0.667441	0.920052	98.41251
		(4.54419)	(4.61556)	(6.29385)
4	17.71530	1.323811	1.092259	97.58393
		(5.74718)	(5.36668)	(7.64264)
5	17.92923	2.117489	1.310788	96.57172
		(6.89512)	(5.91885)	(8.88924)
6	18.07271	2.940668	1.524443	95.53489
		(7.92712)	(6.30343)	(10.0054)
7	18.18241	3.716860	1.713052	94.57009
		(8.82436)	(6.58936)	(10.9928)
8	18.27119	4.405989	1.871555	93.72246
		(9.61205)	(6.82209)	(11.8710)
9	18.34417	4.994741	2.001395	93.00386
		(10.3289)	(7.02487)	(12.6684)
10	18.40413	5.485435	2.106306	92.40826
		(11.0032)	(7.20912)	(13.4092)

Cholesky Ordering: OP EXR IFR
Standard Errors: Monte Carlo (100 repetitions)

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