BANK OF PAPUA NEW GUINEA

Working paper

The Monetary Policy Transmission Mechanism in Papua New Guinea: A Structural Vector Autoregressive (SVAR) Approach

Mark Ofoi[1]

Working Paper BPNGWP 2017#01

October 2017

Bank of Papua New Guinea
Port Moresby
Papua New Guinea

The Working Paper series is intended to provide the results of research undertaken within the Bank to its staff, interested institutions and the general public. It is hoped this would encourage discussion and comments on issues of importance and for policy formulation. Views expressed in this paper are those of the author and do not necessarily reflect those of the Bank of PNG. This paper must be acknowledged for any use of the work and results contained in it.

[1] Mark Ofoi is Senior Analyst, Monetary Policy Unit in Economics Department of the Bank of Papua New Guinea. Email at MOfoi@bankpng.gov.pg

Abstract

This paper examines the monetary policy transmission mechanism in Papua New Guinea (PNG) and its impact on the business cycle using quarterly data from 1980Q1 to 2016Q3. The paper explains the short-run dynamic relationship amongst key macroeconomic variables using a Structural Vector Autoregressive (SVAR) model in an open economy setting. The paper confirms that changes in global economic conditions are a material cause of fluctuations in the business cycle in PNG. In contrast domestic monetary policy shocks play a smaller role in generating business cycle variations in PNG. The paper finds that oil price shocks are more important than commodity price shocks or foreign monetary policy shocks in driving domestic fluctuations. Money supply matter in the transmission of monetary policy, while interest rates contribute modestly to explaining changes in output and inflation in PNG. Monetary policy essentially acts as a stabilizer in limiting the contagion effects of external shocks.

Key words: transmission mechanism, structural vector autoregression, business cycle, price puzzle, impulse response functions, variance decomposition, supply shocks

Table of Contents

1. Introduction

Central Banks use monetary policy to stabilise the economy from large fluctuations in real economic activity and inflation and to sustain economic growth. Most often, interest rates and money aggregates are used to implement this objective, although it can be argued that money aggregates have played a lesser role in recent times (King 2002). Changes in these variables transmit the stance of monetary policy influencing the level of domestic demand and prices. Monetary policy is transmitted through a number of channels. The more traditional channels are the interest rate, credit, exchange rate, asset price and expectations channels (Mishkin 1995). The effectiveness of these channels varies across economies depending on their structural settings and macroeconomic framework. For instance, economies with advanced financial markets have a more effective asset price channel: a drop in interest rates raises the value of firms' assets and collateral and their ability to borrow and raise new capital to finance investment projects. This channel is less important for countries with under-developed financial systems, where firms are less able to borrow from financial institutions or equity markets (Prasad, et al 2009). The exchange rate channel is usually more important for small emerging export dependent economies with flexible exchange rate regimes (Dan 2013).

For the most part, monetary economics focuses mainly on the behaviour of prices, money aggregates, nominal and real interest rates and output (Garlach and Svensson 2000). In this regard, the Vector Autoregressive (VAR) models developed by Sims (1980) have served as a primary tool in much of the empirical analysis of the interrelationships between these variables and for uncovering the impact of monetary phenomena on the real economy and business cycle (Stock and Watson 2001). This paper investigates the monetary policy transmission mechanism in PNG using a Structural Vector Autoregressive (Structural VAR) model, which applies a set of theoretical restrictions to define the relationships amongst key macroeconomic variables of interest, allowing us to recover independent exogenous drivers of cyclical fluctuations. The paper also examines how foreign variables affect the domestic economy. A review of past empirical work shows no prior study of Papua New Guinea using a Structural VAR framework to examine the domestic macroeconomic effects of foreign and domestic monetary policy shocks, and foreign oil and commodity price shocks. The paper confirms that changes in global economic conditions are a material cause of fluctuations in the business cycle in PNG. In contrast, domestic monetary policy shocks play a smaller role in generating business cycle variations in PNG. The paper finds that oil price shocks are more pronounced relative to commodity price shocks and foreign monetary policy shocks in driving domestic fluctuations, which is consistent with the modest response from the non-mineral sector and the low degree of financial integration. Money shocks matter in the transmission of monetary policy, while interest rates contribute modestly to explaining changes in output and inflation in PNG. Monetary policy essentially acts as a stabilising policy variable with respect to the exchange rate, money demand and inflation, in limiting the contagion effects of external supply side shocks.

The approach in this paper is twofold: (1) the paper uses the SVAR model by Kim and Roubini (2000) as a baseline; and (2) it adapts the model by introducing commodity prices and mineral output in the baseline model. Although the KR model is not specifically designed for the PNG economy and is not based on a structural macroeconomic model, it serves as a good starting point given its extensive use in both advanced and emerging economies.

The first part of the paper provides an overview of the monetary policy framework in PNG using stylised facts followed by the literature review in part 3. The fourth part outlines the methodological approach used in the paper, followed by the model estimation and results in part 5, and then the conclusion in part 6.

2. Stylised Facts

The Bank of PNG pursued monetary policy under several operational policy frameworks prior to 2000, varying from targeting credit to money aggregates[2]. In 2000, the Bank was mandated with the objective of price stability. Under the Central Banking Act, the Bank is independently responsible for achieving and maintaining price stability. This involves low and stable inflation that enables conditions for sustained economic growth. The Bank signals its stance of policy through its policy rate while using a reserve money framework. The Bank employs a mix of interest rate and money aggregates as intermediate target variables in its operational conduct. This is done by changing the cost of funds and the availability of liquidity in the economy, by utilising both open market and direct instruments to influence the level of liquidity and interest rates in the banking system. Through these instruments, the Bank targets the level of reserve balances of commercial banks consistent with its stance of policy, which is expected to have a multiplier effect on money aggregates and consequently output and inflation. However, the effectiveness of the reserve money framework is contentious. A working paper on the money multiplier in PNG using monthly data from January 2001 to June 2011 shows no long run co-integrating relationship between reserve money and money aggregates (Ofoi 2013). Excess liquidity in the banking system is a known impediment reflective of swings in fiscal positions and foreign exchange inflows, which are largely exogenous to the central bank. On the other

[2] The estimation methods used in this paper were tested for the different regimes but failed to find significant results.

hand, a paper by Irau (2015) using quarterly data from 1978Q1 to 2010Q4, found a stable money demand function for PNG, meaning that the Central Bank can exert some level of influence on monetary aggregates and the real economy. The paper found a long run co-integrating relationship between real broad money, income, financial innovation[3] and exchange rate using the Engel-Granger method, while interest rates were found to have insignificant effects on money demand. Previous studies also show the traditional interest rate channel to be ineffective in the transmission of monetary policy, while the exchange rate and credit channels were found to be rather credible (David and Nants, 2006; Faal et al, 2008).

3. Literature Review

Seminal work by Christopher Sims in 1980 introduced the VAR model in response to problems with traditional large-scale structural dynamic macroeconometric models, which were difficult to construct, as they required a large number of parameter restrictions to be identifiable. In comparison, VAR models use variables that are considered necessary for specific macroeconomic policy analysis. The large-scale models tried to explain many variables and tried to represent many more contemporaneous relationships, but to model contemporaneous relationships many more restrictions were required. Sims (1980) argued that the restrictions were not well founded and not plausible, i.e. the restrictions might be incorrect and may therefore have bias parameter estimates, ruining the properties of the model. Furthermore, Nelson (1972) showed that the large-scale models did not forecast better than simple autoregressions and so the empirical properties of the large models were not satisfactory. The standard VAR model has a few theoretical restrictions and consequently the number of parameters that needs to be estimated is usually large although the parameter estimates are rarely interpreted. VARs require less restrictive assumptions than other multivariable methods. The VAR models have been widely used in examining monetary policy in many developing and emerging economies. While the literature is relatively small for Pacific Island countries[4] (PICs), VAR models have been used extensively for monetary policy analysis in peer economies in South-East Asia[5] and Sub-Sahara Africa[6]

The Structural VAR (SVAR) model, which is a variant of the VAR model, imposes a set of identification restrictions on variables that are consistent with economic theory. SVARs allow

[3] Irau (2015) defines financial innovation as the ratio of currency in circulation to total deposits placed at commercial banks.
[4] To cite a few, see papers by Yang et al (2012), Peiris and Ding (2012) for PICs and Narayan et al (2012) for Fiji.
[5] To cite a few of them see papers by Allegret et al (2012), Jansen (2003) and Vinayagathasan (2013).
[6]See papers by Bandara (2014), Mengesha and Holmes (2013) Mwabutwa et al (2016) and Suhaibu et al (2017).

for the identification of the parameters of the economic model and the independent, exogenous structural shocks that are the underlying drivers of cyclical fluctuations. These restrictions enable the model results to be interpreted causally[7]. These identification restrictions include both short and long run as well as sign restrictions. SVAR models have been applied to model both open and closed economies. The open economy models have helped solve '*puzzles*' in the behavioural relationship amongst macroeconomic variables that were often paradoxical relative to economic theory, often found in a closed economy models (Eichenbaum and Evans 1995; Cushman and Zha 1997). These include 'price puzzles', where price level increases rather than decreases following tightening shocks to monetary policy 'exchange rate puzzles' where the domestic exchange rate depreciates following a positive interest rate shock and 'liquidity puzzles', where positive money supply shocks are associated with increases in interest rates rather than decreases (Sims 1992); Leeper and Gordon (1992); Grille and Roubini, 1995). These puzzles are usually addressed by including additional variables that neutralise these unexplained or unusual outcomes. International oil and commodity prices are used in the model to account for price puzzles, while long-term interest rates are used to account for exchange rate puzzles (Grilli and Roubini, 1995); Kim and Roubini, 2000). Using the standard framework, the paper follows existing literature to try to avoid or mitigate these *puzzles* that arose in earlier models.

4. Methodological Approach

(i) Background on SVAR Modelling Frameworks

A VAR system is an n equation, n variable model in which each variable is explained by its past values, as well as past values of the $n-1$ other variables. A VAR represents a multivariate time series that involves several variables as well as several equations, having more than one endogenous or dependent variable. Consider a simple bivariate system having variables x and y:

$$x_t = b_{10} - b_{12}y_t + \alpha_{11}x_{t-1} + \alpha_{12}y_{t-1} + \varepsilon_{xt} \quad (1)$$

$$y_t = b_{20} - b_{21}x_t + \alpha_{21}x_{t-1} + \alpha_{22}y_{t-1} + \varepsilon_{yt} \quad (2)$$

Where it is assumed (i) both x_t and y_t are stationary (ii) ε_{xt} and ε_{yt} are white noise disturbances with standard deviation σ_x and σ_y respectively. Both equation (1) and (2)

[7] While OLS is consistent for standard reduced form VARs, the SVAR can also been estimated by other methods depending on the number of restrictions (see Hamilton 1994).

constitute a *first-order* structural VAR given its lag length of one. We transform equation (1) and (2) into a more usable form using matrix algebra:

$$\begin{bmatrix} 1 & b_{12} \\ b_{21} & 1 \end{bmatrix} \begin{bmatrix} x_t \\ y_t \end{bmatrix} = \begin{bmatrix} b_{10} \\ b_{20} \end{bmatrix} + \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} \begin{bmatrix} x_{t-1} \\ y_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{xt} \\ \varepsilon_{yt} \end{bmatrix}$$

and in its more compact form:

$$Bz_t = \Gamma_0 + \Gamma_1 z + \varepsilon_t \qquad (3)$$

Where $B = \begin{bmatrix} 1 & b_{12} \\ b_{21} & 1 \end{bmatrix}$, $z_t = \begin{bmatrix} x_t \\ y_t \end{bmatrix}$, $\Gamma_0 = \begin{bmatrix} b_{10} \\ b_{20} \end{bmatrix}$, $\Gamma_1 z_{t-1} = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} \begin{bmatrix} x_{t-1} \\ y_{t-1} \end{bmatrix}$ and $\varepsilon_t = \begin{bmatrix} \varepsilon_{xt} \\ \varepsilon_{yt} \end{bmatrix}$

Pre-multiplication of equation (3) with the inverse of B matrix (B^{-1}) allows us to obtain the (reduced-form) VAR model in standard form:

$$x_t = A_0 + A_1 x_{t-1} + e_t \qquad (4)$$

Where $A_0 = B^{-1}\Gamma_0$, $A_1 = B^{-1}\Gamma_1$ and $e_t = B^{-1}\varepsilon_t$

For notational purposes, we can define a_{i0} as element i of the vector A_0, a_{ij} as the element in row i and column j of the matrix A_1, and e_{it} as the element i of the vector e_t. Using this notation we can rewrite equation (4) in the equivalent form:

$$x_t = a_{10} \mp a_{11} y_{t-1} + a_{12} x_{t-1} + e_{1t} \qquad (5)$$

$$y_t = a_{20} \mp a_{21} y_{t-1} + a_{22} x_{t-1} + e_{2t} \qquad (6)$$

The VAR system of equations (1) and (2) is called the structural VAR or the primitive system, which we have transformed to a standard VAR system. Hence, a multivariate generalisation would take the form:

$$z_t = A_0 + A_1 z_{t-1} + A_2 z_{t-2} + \dots\dots\dots\dots\dots\dots\dots A_p z_{t-p} + e_{it} \qquad (7)$$

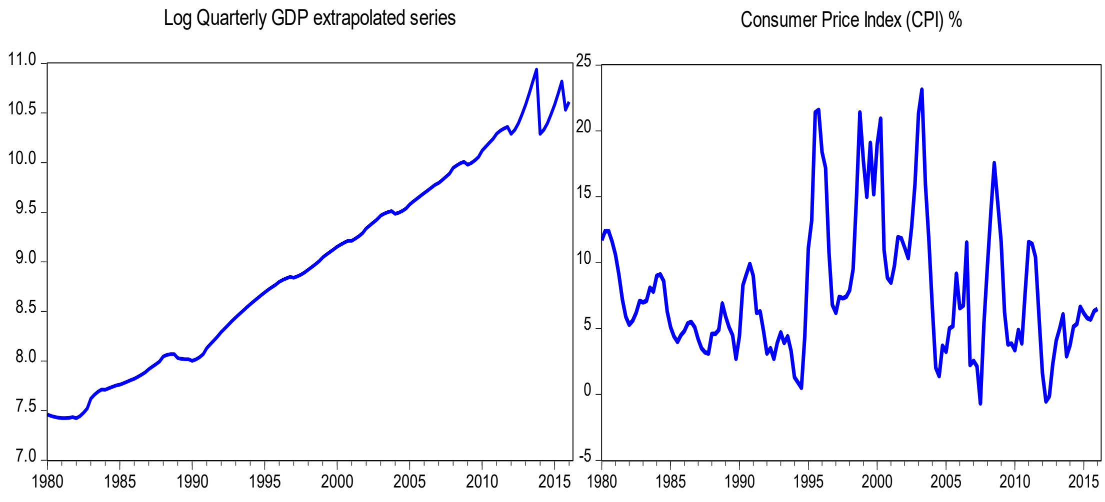
Where x_t = an $(n \times 1)$ vector containing each of the n variables included in the VAR with A_0 = an $(\mathrm{n} \times 1)$ vector of intercept terms A_i = an $(\mathrm{n} \times \mathrm{n})$ matrix of coefficients, *i=1,2,…,p*, and e_t = an $(\mathrm{n} \times 1)$ vector of error terms.

Since ε_{xt} and ε_{yt} are white noise processes, it follows that e_t is a stationary process with a zero mean and constant variances $var(e_{it}) = \sigma_i^2$ and is individually serially uncorrelated. With the variance/covariance matrix of the e_{it} shocks as Σ with all elements as time independent where $\Sigma = \mathrm{E}\,[e_t e_t']$. To identify the structural model from the estimated VAR (equation 7) it is necessary to impose $(n^2 - n)/2$ restrictions on the structural model to exactly identify parameters of the structural model. In the model below the restrictions imposed are based on some economic theory. If more (where some k > (n^2-n)/2) restrictions are imposed, the model will be over-identified and it is possible to test the statistical validity of the restrictions.

(ii) The Base Model for this paper Full sample period 1980q1-2016q3

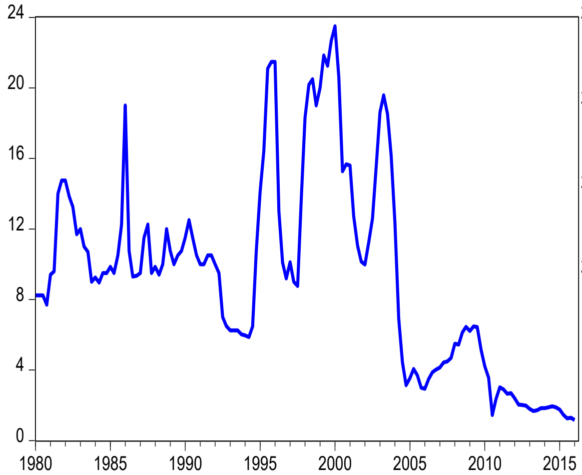
(a) Data and Variables of Interest

In the baseline model, the approach by Kim and Roubini (2000) is adopted, having the same variables and identification restrictions in explaining the relationship among non-policy and policy variables. The model uses seven variables, of which two are foreign. The domestic variables comprise real Gross Domestic Product (GDP) as a measure of output, domestic prices using the Consumer Price Index (CPI) data, a short term interest rate, broad money supply (M3) and the nominal US$ per kina exchange rate. The foreign block is made up of international oil prices (an index) and the US federal funds rate. Domestic data are sourced from the Bank of PNG's quarterly economic bulletins while external data are sourced from the IMF. Data are in logarithm of levels except the CPI, which is the annual percent change, and the interest rate variables, which are left untransformed, and are in quarterly series for a full sample period beginning 1980Q1 to 2016Q3. Output has been interpolated[8] into quarterly intervals using annual figures, given the lack of quarterly GDP data (see respective graphs below).

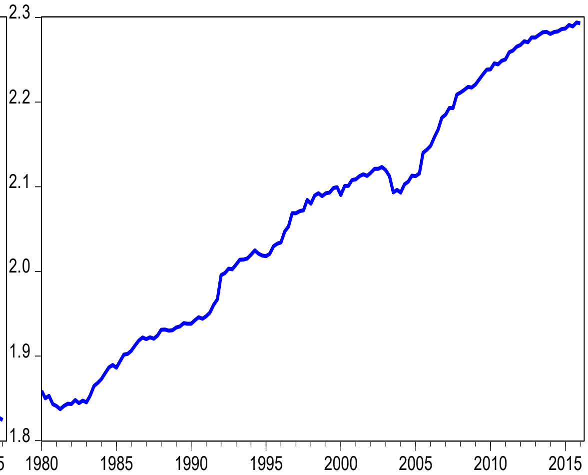


[8] Converting low (annual) to high frequency (quarterly) data using quadratic averages in Eviews.

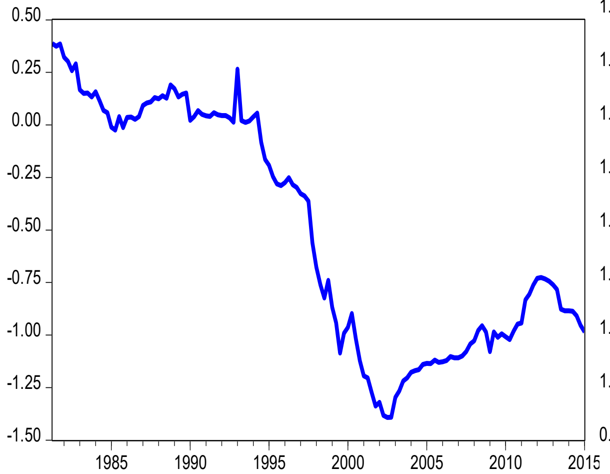
interest_ rate



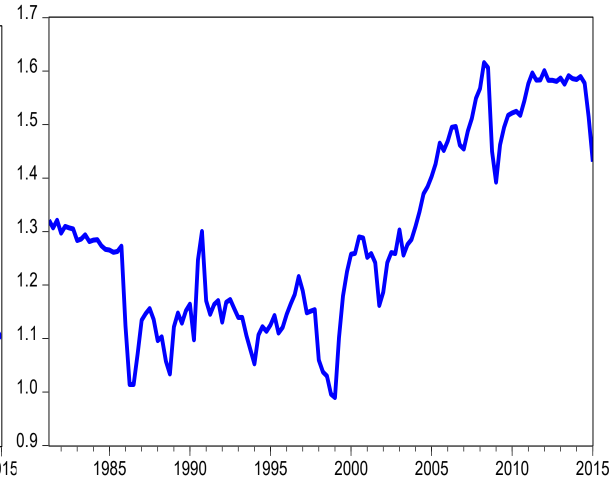
Log money_supply



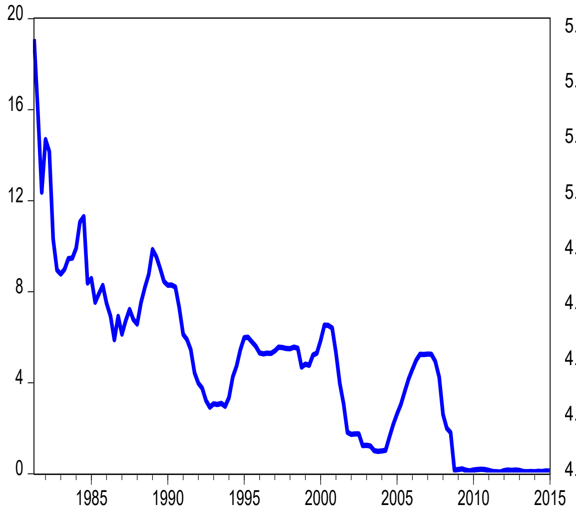
Log Nominal USD/kina exchange rate



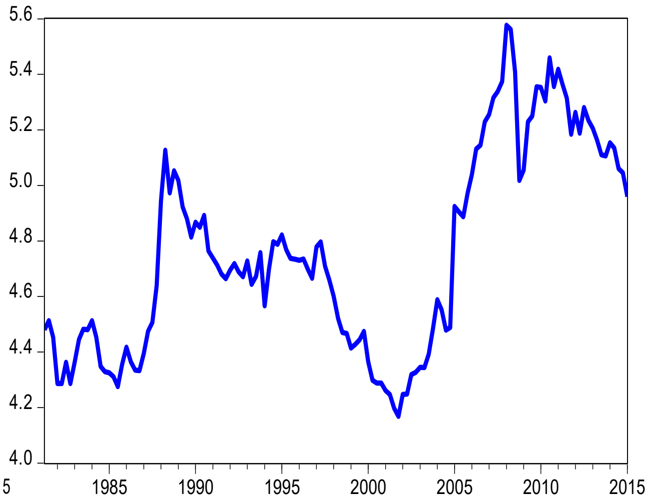
Log Oil_prices



foreign_monetary pol



Log World commodity Price Index



(b) Reduced form VAR specification

The reduced form of the VAR model takes the following specifications:

$$\begin{bmatrix} GDP_t \\ CPI_t \\ IR_t \\ MD_t \\ ER_t \\ OP_t \\ FMP_t \end{bmatrix} = \begin{bmatrix} \alpha_{GDP} \\ \alpha_{CPI} \\ \alpha_{IR} \\ \alpha_{MD} \\ \alpha_{ER} \\ \alpha_{OP} \\ \alpha_{FMP} \end{bmatrix} + \begin{bmatrix} \beta_{GDP} \\ 0 \\ 0 \\ \beta_{MD} \\ \beta_{ER} \\ \beta_{OP} \\ 0 \end{bmatrix} t + \Phi_1 \begin{bmatrix} GDP_{t-1} \\ CPI_{t-1} \\ IR_{t-1} \\ MD_{t-1} \\ ER_{t-1} \\ OP_{t-1} \\ FMP_{t-1} \end{bmatrix} + \Phi_2 \begin{bmatrix} GDP_{t-2} \\ CPI_{t-2} \\ IR_{t-2} \\ MD_{t-2} \\ ER_{t-2} \\ OP_{t-2} \\ FMP_{t-2} \end{bmatrix} + \begin{bmatrix} \varepsilon_{GDP} \\ \varepsilon_{CPI} \\ \varepsilon_{IR} \\ \varepsilon_{MD} \\ \varepsilon_{ER} \\ \varepsilon_{OP} \\ \varepsilon_{FMP} \end{bmatrix} \quad (1)$$

Where $\Phi_1$and Φ_2 are 7 X 7 parameter matrices. The non-zero parametersβ_{GDP}, β_{MD} etc. essentially remove the time trend from the VAR variables that trend over time, in theory and empirically as evidenced in the graphs above. Hence, it is reasonable to assume that the VAR is stationary around a deterministic time trend in the appropriate variables. The paper estimates the reduced form by first linearly detrending the GDP,MD, ER and OP variables, i.e., by using the residuals obtained from the regression of each of the variables on a time trend and constant.:

$$GDP_t = \alpha_{GDP} + \beta_{GDP} * t + \overline{GDP_t} \quad (2)$$

$$MD_t = \alpha_{MD} + \beta_{MD} * t + \overline{MD}_t \quad (3)$$

$$ER_t = \alpha_{ER} + \beta_{ER} * t + \overline{ER}_t \quad (4)$$

$$OP_t = \alpha_{OP} + \beta_{OP} * t + \overline{OP}_t \quad (5)$$

Where $\overline{GDP_t}$, $\overline{MD}_t$, $\overline{ER}_t$, $\overline{OP}_t$ denotes the regression residuals for the respective variables. While the remaining variables are demeaned using a regression of each of those variables on a constant:

$$CPI_t = \alpha_{CPI} + \overline{CPI_t} \quad (6)$$

$$IR_t = \alpha_{IR} + \overline{IR_t} \quad (7)$$

$$FMP_t = \alpha_{FMP} + \overline{FMP_t} \quad (8)$$

Finally, the reduced form VAR to be estimated is as follows:

$$\begin{bmatrix} \overline{GDP}_t \\ \overline{CPI}_t \\ \overline{IR}_t \\ \overline{MD}_t \\ \overline{ER}_t \\ \overline{OP}_t \\ \overline{FMP}_t \end{bmatrix} = +\Phi_1 \begin{bmatrix} GDP_{t-1} \\ CPI_{t-1} \\ IR_{t-1} \\ MD_{t-1} \\ ER_{t-1} \\ OP_{t-1} \\ FMP_{t-1} \end{bmatrix} + \Phi_2 \begin{bmatrix} GDP_{t-2} \\ CPI_{t-2} \\ IR_{t-2} \\ MD_{t-2} \\ ER_{t-2} \\ OP_{t-2} \\ FMP_{t-2} \end{bmatrix} + \begin{bmatrix} \varepsilon_{GDP} \\ \varepsilon_{CPI} \\ \varepsilon_{IR} \\ \varepsilon_{MD} \\ \varepsilon_{ER} \\ \varepsilon_{OP} \\ \varepsilon_{FMP} \end{bmatrix} \tag{9}$$

Note that this VAR has a constant of zero. Hence, the estimates of each constant parameter are close to zero and insignificant. Once the model is estimated, as a result of the detrending exercise, we obtain a stable model as indicated by the inverse roots characteristics polynomial. It is also worth noting that commodity prices and non-mineral output are also detrended similar to oil prices and total output in the robustness test the model.

(c) Identification Scheme: Non-recursive Approach

Data in this VAR system are estimated in levels, as the paper is particularly interested in the structural dynamics, individual stationarity is not considered necessary (Sims 1980). However, because the variables are detrended (and demeaned), this makes the VAR system stable. There are 33 zero restrictions so the system is over identified ($\frac{n^2-n}{2} = \frac{7^2-7}{2} = 21$ for an exactly identified system) with 12 degrees of freedom since there are 12 over-identifying restrictions (33-21=12). The log likelihood-ratio test will determine if the restrictions are rejected or not.

KR identification scheme – Non-recursive approach

$$\begin{bmatrix} e^{GDP} \\ e^{CPI} \\ e^{IR} \\ e^{MD} \\ e^{ER} \\ e^{OP} \\ e^{FMP} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & a_{16} & 0 \\ a_{21} & 1 & 0 & 0 & 0 & a_{26} & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & a_{36} & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} & a_{57} \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & a_{76} & 1 \end{bmatrix} \begin{bmatrix} \varepsilon^{GDP} \\ \varepsilon^{CPI} \\ \varepsilon^{MS} \\ \varepsilon^{MD} \\ \varepsilon^{ER} \\ \varepsilon^{OP} \\ \varepsilon^{FMP} \end{bmatrix}$$

Where e_{GDP} , e_{CPI} , e_{IR} , e_{MD} , e_{ER} , e_{OP} and e_{FMP} are the structural disturbances – output shocks, domestic price shocks, money supply shocks, money demand shocks, exchange rate shocks, oil price shocks and foreign monetary policy shocks respectively and ε_{GDP} , ε_{CPI} , ε_{IR} , ε_{MD} , ε_{ER} , ε_{OP} and ε_{FMP} are reduced form residuals that describe the unanticipated movements of each regressor, respectively.

The underlying assumptions for the contemporaneous restrictions in the KR model are based on the G-7 economies experience. For the domestic block:

- The first equation in the system represents the goods market equilibrium of the domestic economy. The assumption here is that money, interest rates, the exchange rate, and foreign inflation do not affect output and prices contemporaneously, they are assumed to have lagged effects. Oil prices are assumed to affect the real sector contemporaneously, since oil is an essential input in the domestic economy.
- The second equation represents prices where output and oil prices affect the real sector contemporaneously. Money, domestic interest rates exchange rate and the US interest rate do not affect prices contemporaneously; they are assumed to have effects only with a lag.
- The third equation which is the interest rate is assumed to be the monetary authority's reaction function. It is assumed to be contemporaneously affected by output, prices and the interest rates. The contemporaneous inclusion of prices and output gives a form of reaction function similar to a Taylor rule. The international oil price is allowed to enter contemporaneously into the monetary authority's reaction function, to control for the negative supply shocks and inflationary pressures.
- The fourth equation is the money demand function, which also represents the money market equilibrium along with the third equation. The demand for money responds contemporaneously to income, prices and interest rates, while all other variables only affect money with a lag.
- The fifth equation, which is the exchange rate, represents the financial market equilibrium. It is assumed that the nominal exchange rate is contemporaneously affected by all the variables in the system of equation. Furthermore, through this equation, foreign variables are allowed to influence domestic variables implicitly.

For the foreign block:

- The sixth equation in the system represents oil price shocks. An exogenous shock that arise from the world economy, domestic variables do not affect world oil price.
- The seventh equation represents foreign monetary policy proxied by the US federal funds rate. Domestic variables do not affect foreign monetary policy decisions while oil prices are allowed to impact it contemporaneously.

There needs to be enough restrictions to ensure identification. More restrictions can be included and tested statistically, but too many restrictions can lead to failures in the convergence process. Conditional on the identification scheme, one can predict what will happen to output growth and inflation when the central bank tightens monetary policy.

(d) Model Diagnostics and Specification

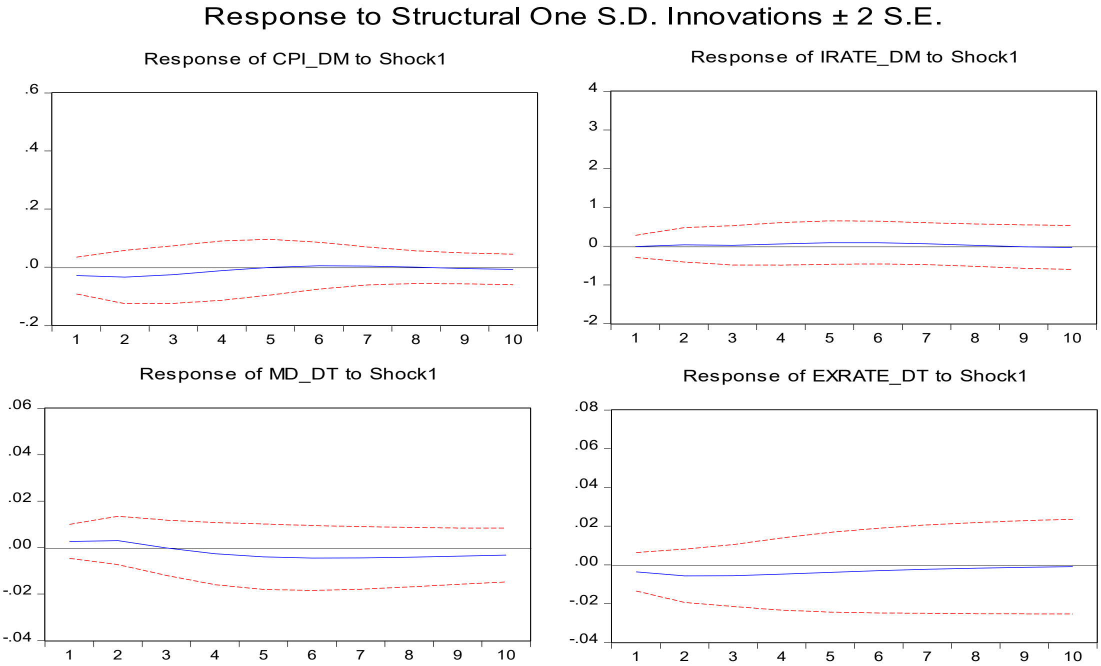
For the model specifications, a series of diagnostic tests are undertaken to identify the appropriate fit. Lag length selection criteria are used to determine the number of lags to include in the model. The lag length selected by Schwartz (SIC) and Hannan Quinn (HQ) Information Criterion is 1 lag, the Akaike Information Criterion (AIC) shows 14 lags while the Log likelihood Ratio (LR) and Final Prediction Error (FPE) select 2 lags (Appendix 1.a). We start with the minimum number of lags according to the LR and FPE which is 2 lags. We then test for autocorrelation and non-normality in the residuals. In order for the VAR to be correctly specified, residuals need to be white noise.(The correlogram charts show the autocorrelation process of the residuals within the $\pm$ 2 standard error bounds, as well as no signs of seasonality in the data). The residual tests using residual graphs show the residuals are generally white noise, albeit exhibiting a few structural breaks (Appendix 1.b). For VAR systems, it is important to establish stationarity as this has implications on the systems response to shocks, which should gradually die down over the forecast horizon. For this model, the detrending of the variable included in the VAR system corrects for stability in the model without having to take the non-stationarity variables at first difference (Appendix 1.d). The over identification restrictions set for the model are tested and are not-rejected using the results from the log likelihood ratio test (Appendix 1.e), which suggests that the orthogonalisation in the system are fine and the impulse response functions are reasonably estimated.

5. Model estimation and results

(e) Impulse Response Functions

Impulse response functions are an important output generated by VAR models. The impulse response functions show how the variables in the system respond to shocks. They show the dynamic interactions between the endogenous variables in the VAR (*p*) process, conditional on different orthogonal innovations. For SVARs the impulse responses depict the responses to the “identified” structural shocks, where the effects of the structural shocks u_t can be investigated. The impulse response functions are usually computed to show the response of the model to a one standard deviation shock to the structural innovations. The impulse response functions trace the effect of a shock to one endogenous variable onto the other variables in the VAR. For this model, the shock propagations numbering 1 to 7, reflect the ordering in which the variables enter the reduced form, starting with output for shock 1 followed by domestic price (shock 2), interest rate (shock 3), money supply (shock 4), exchange rate (shock 5), oil price (shock 6) and foreign monetary policy (shock 7), respectively. The abbreviations DM and DT indicate demeaned and detrended variables.

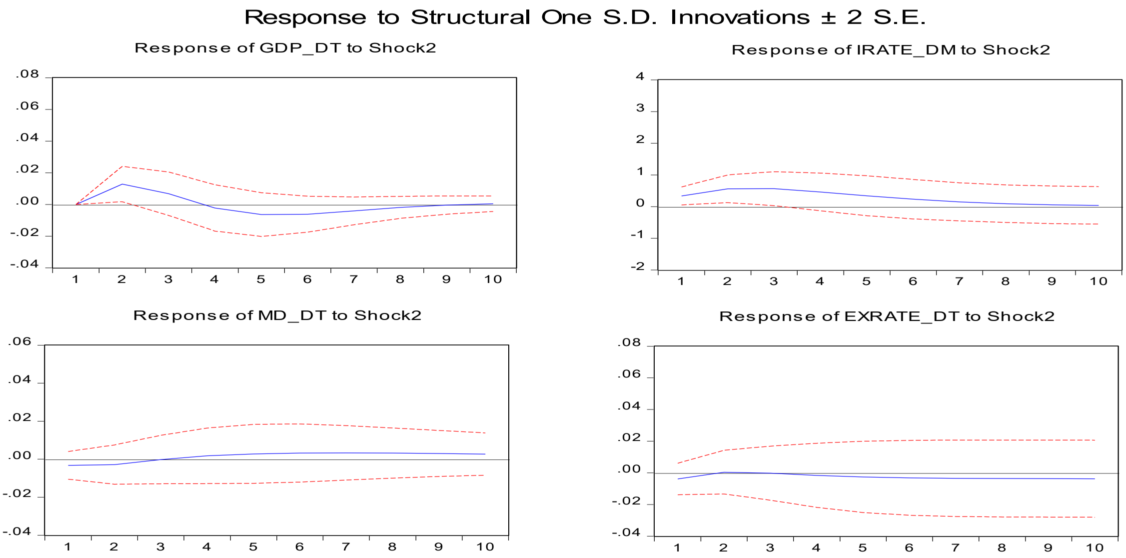
Figure 1: Response to output (GDP) shocks



Source: Author's calculations

The results in Figure 1 as indicated by all four panels of the impulse response functions, show domestic variables to be generally unresponsive to output shocks and are statistically insignificant. This is as expected for most small open and emerging economies, where growth in output is usually generated exogenously (Ma´ckowiak 2007). However, given data caveats, the results for output need to be interpreted with some caution, as quarterly estimates for the model were derived through interpolation give the lack of proxies for output with longer series of quarterly estimates.

Figure 2: Response to domestic price shocks

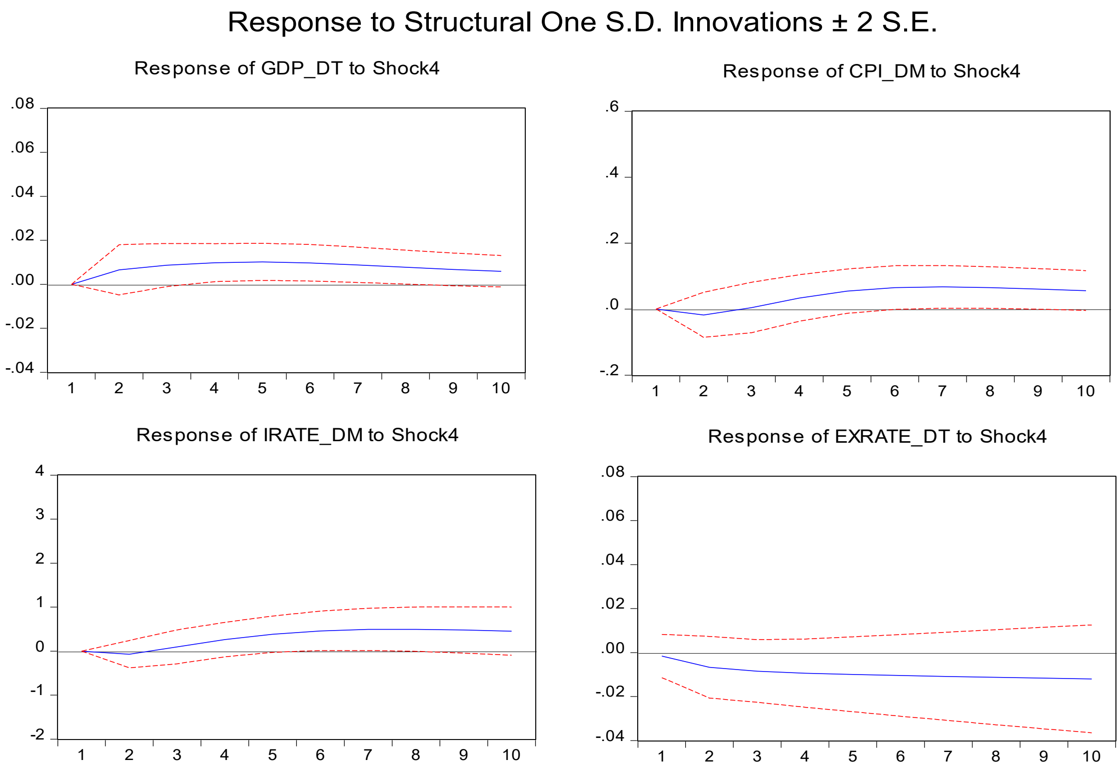


Source: Author's calculations

With respect to positive domestic price shocks, the expansion of output is short-lived, rising over the first three quarters by less than 0.02 percent and then contracting after the next three quarters as shown in the top left panel of Figure 2. As a policy response, the central bank tightens monetary policy by a sustained rise in interest rates peaking at 0.5 percent over the first 4 quarters indicated in the top right panel. The bottom left panel shows that the demand for money is generally unresponsive to prices and interest rate hikes over the same period. The exchange rate is also insensitive to domestic price shocks, which is a reflection of PNG's trade external balance, and its position as a price taker in the international market.(bottom right panel). The impulse responses to price shocks are generally consistent with economic theory, with respect to the monetary policy reaction function featuring a statistically significant response to price changes. This could imply that monetary policy is capable of keeping the macroeconomic effects of price shocks in check. However, it is plausible that aggregate demand shocks pass through the system with relatively little effect other than raising prices somewhat.

For money demand shocks (Figure 3), output expands (top left panel) over much of the forecast horizon, peaking after 4 quarters at 0.01 percent and is statistically significant, while prices increase (top right panel) after a 3 quarter lag by 0.5 percent. The exchange rate depreciates in response to money demand shocks as shown in the bottom right panel. The response from output is expected, as demand for money fuels domestic demand, while the initial price drop may suggest an adjustment before output reaches full capacity, fuelling inflation. The bottom left panel shows that monetary policy is tightened after a three quarters lag by the same magnitude in response to increase in inflation, while the exchange rate comes under pressure from higher money and domestic demand and consequently imports, though the effect is estimated imprecisely.

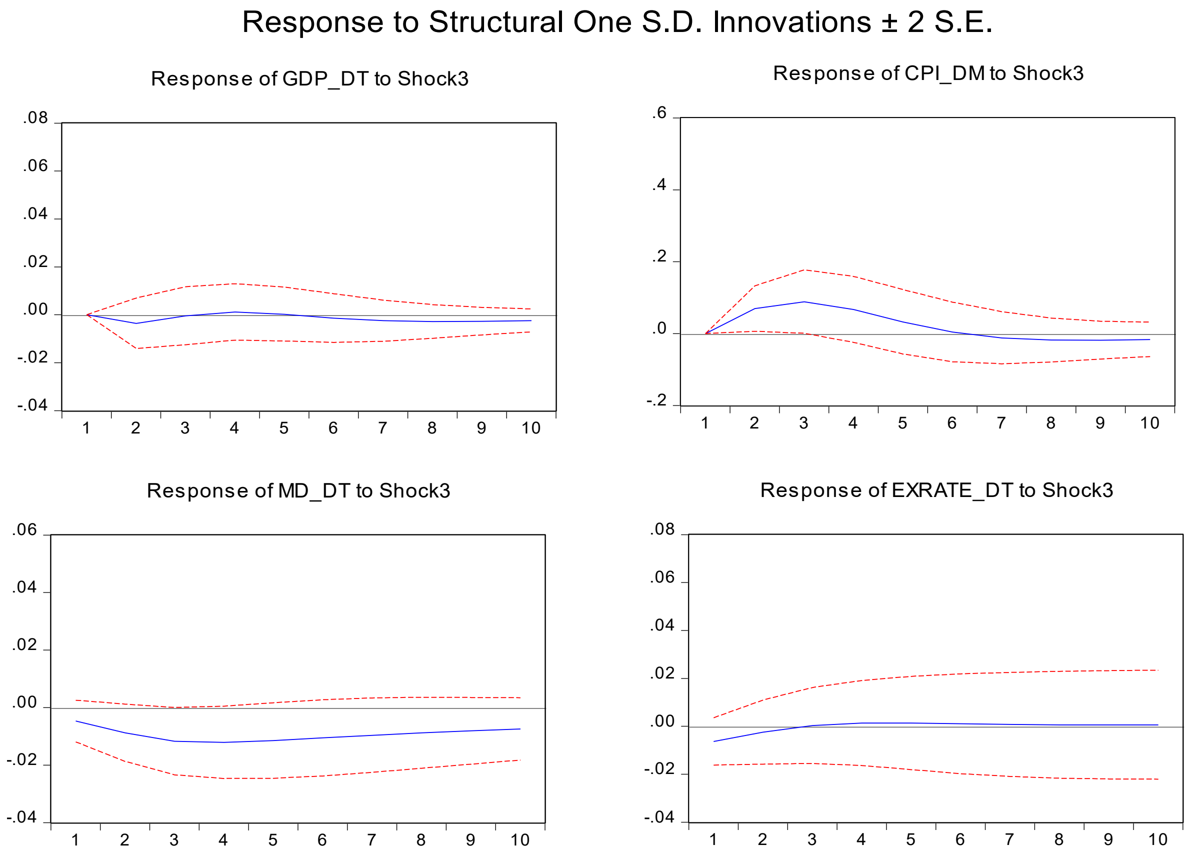
Figure 3: Response to money demand shocks



Source: Author's calculations

Figure 4 illustrates the response of the economy to a discretionary monetary policy shock (shock 3). Output is unresponsive to a positive (contractionary) monetary policy shock as shown in the top left panel; a rise in the interest rate has little effect on domestic demand, while a price increase (top right panel) suggests a “price puzzle” in our results. Prices increase initially by over 0.1 percent over 3 quarters then fall thereafter, while demand for money contracts (bottom left panel) falling by around 0.01 percent over 4 quarters, as the opportunity cost of holding money increases given higher interest rates. Interestingly, the monetary policy shock does not trigger an appreciation in the exchange rate, with nominal exchange rate remaining sluggish over the forecast horizon (bottom right panel). Overall, for the monetary policy reaction function, there is no discernible effect on output and a very pronounced “price puzzle”. In general, domestic variables are insensitive to interest rate shocks, which suggest a lack of transmission to the real economy.

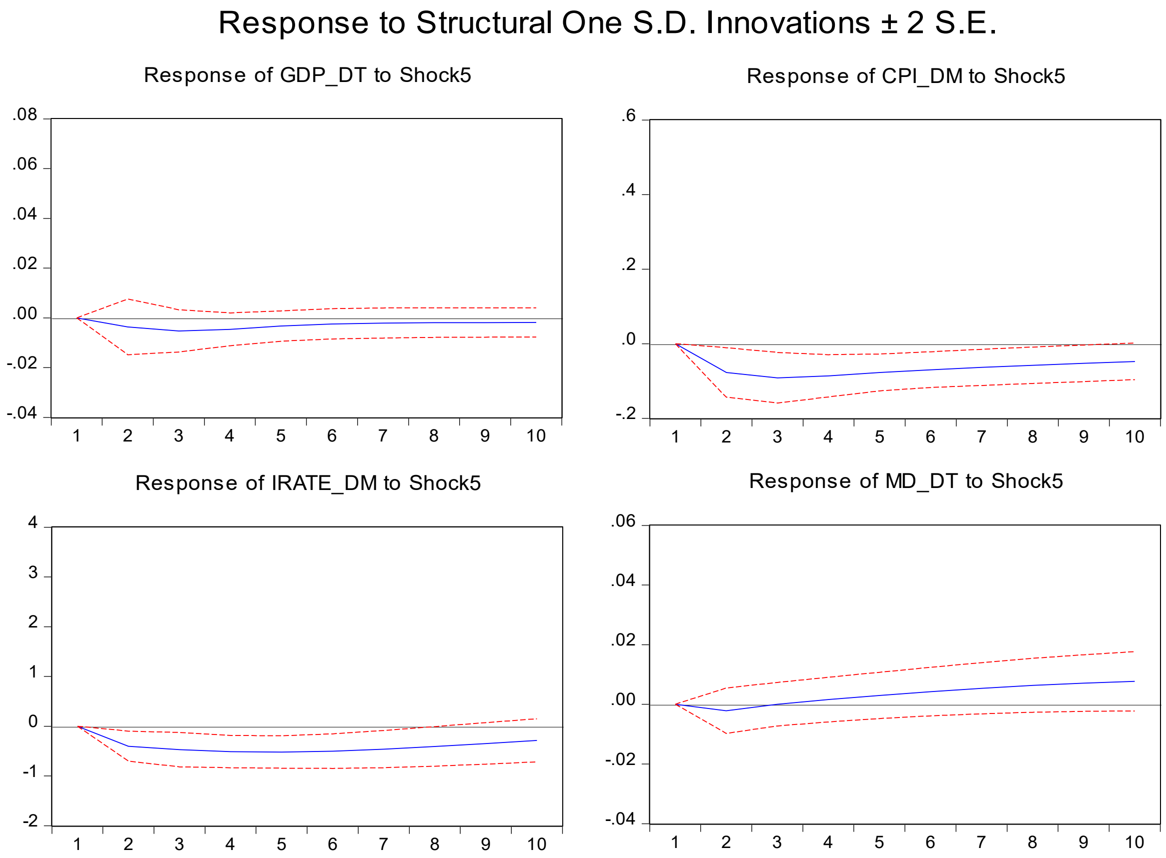
Figure 4: Response to positive monetary policy shocks



Source: Author's calculations

With respect to exchange rate shock (shock 5) depicted in Figure 5, output (top right panel) contracts slightly to an appreciation given the worsening of the tradable sector from a stronger kina. Domestic prices decline by 0.1 percent after 2 quarters from the pass-through of the appreciation and is statistically significant over the forecast horizon, while money demand (bottom right panel) increases given a substantial decrease in interest rate (top right panel) from easing monetary policy in response to the fall in prices and a stronger kina exchange rate. The statistically significant responses of prices and the interest rate reaffirms the importance of the exchange rate pass-through to inflation and the subsequent effect on monetary policy, echoing previous studies on the significance of the exchange rate channel and the pass-through to inflation in PNG (David and Nants (2006); Faal et al (2008); Sampson et al. (2006).

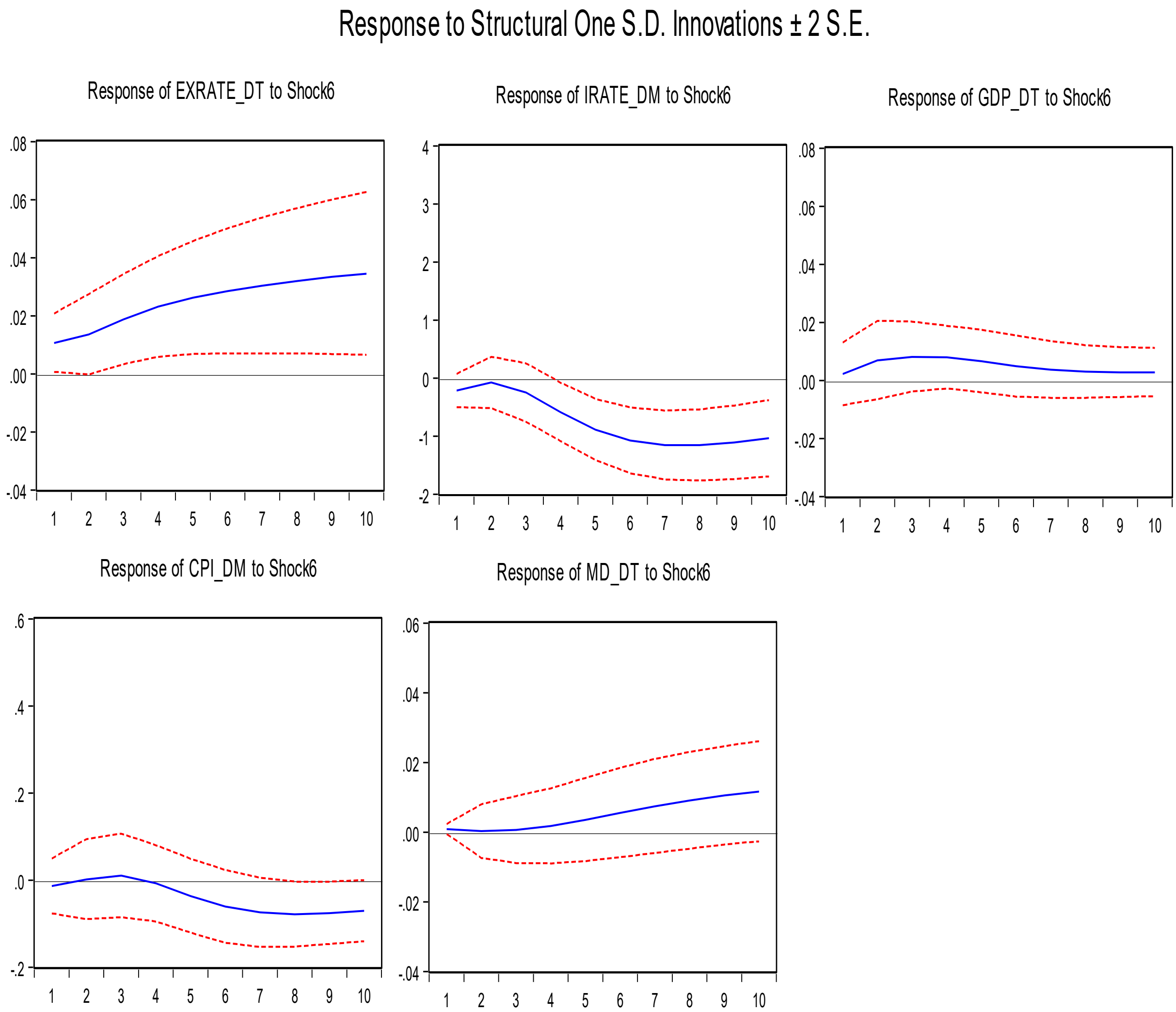
Figure 5: Response to positive nominal exchange rate shocks



Source: Author's calculations

When examining the variables response to oil price shocks (shock 6) in Figure 6the exchange rate (top left panel) appreciation is statistically significant over the forecast horizon, with a pass-through to a fall in prices after a 4 quarter lag shown in the bottom left panel. The monetary policy (top middle panel) is eased over the forecast period in response to fall in prices with a substantial drop in the interest rate of over 1 percent. The expansion in output (top right panel) reflects the significant spill-over effects of the oil industry on aggregate demand, credit boom and the real economy. While the initial impact of oil price shocks on increase in domestic inflation is expected, it falls over the forecast period, offset by a stronger appreciation in the nominal exchange rate and its pass-through to inflation. The bottom right panel of Figure 6 shows that the transactions demand for money increases in response to oil price shocks over the forecast horizon, given the increase in output and fall in interest rates. The results show that most domestic variables respond significantly to oil price shocks.

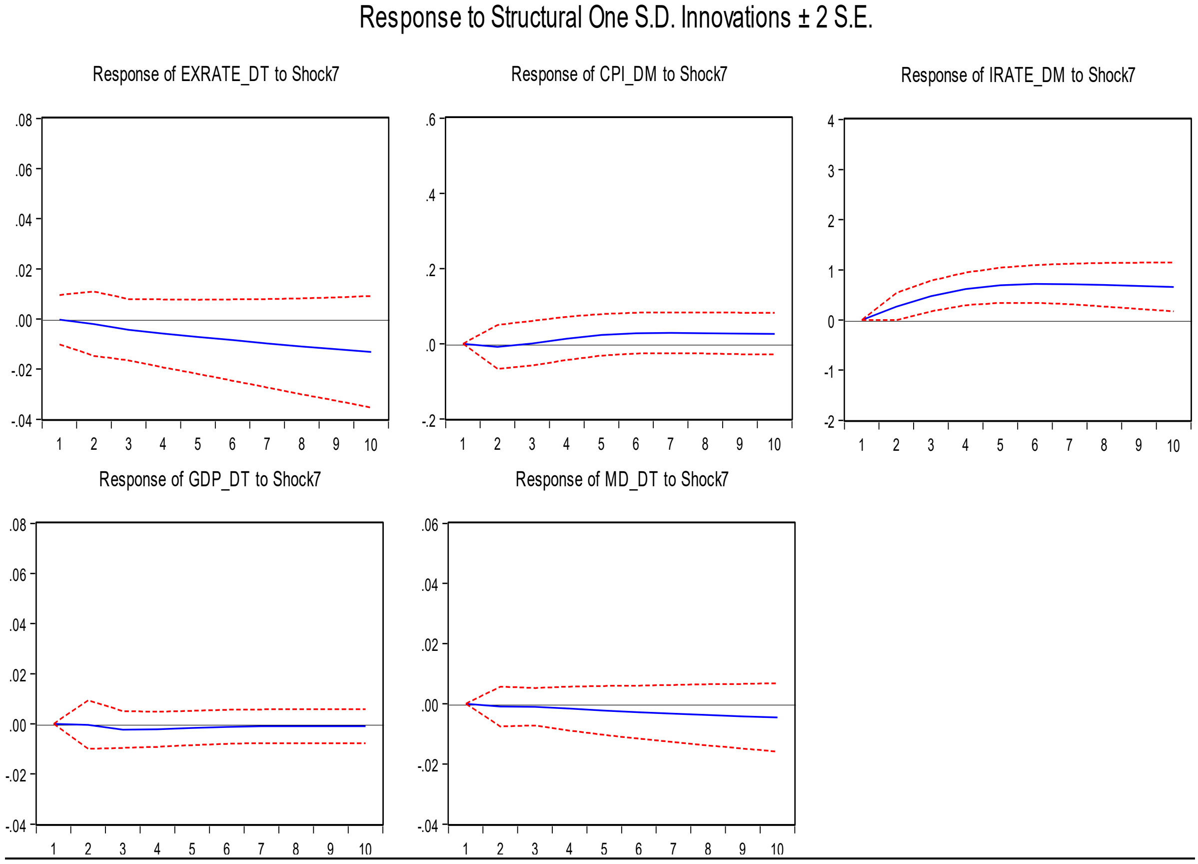
Figure 6: Response to positive oil price shocks



Source: Author's calculations

In Figure 7the kina exchange (top left panel) depreciates in response to a foreign monetary policy shock: a higher foreign interest results in a stronger US dollar. In part, this could reflect the use of the US dollar as the currency of intervention at the central bank. Domestic prices increase somewhat (top middle panel) given a weaker kina while domestic monetary policy tightens in response to the price increase as indicated in the top right panel. Output however, is insensitive to foreign interest rates (bottom left panel). In the bottom right panel, demand for money eases slightly in response to higher prices and increase in domestic interest rates. The exchange rate appears to be somewhat sensitive to foreign interest rates, so some degree of capital market integration is suggested which triggers some monetary policy tightening to stabilize the exchange rate. The depreciation passes through to prices and domestic interest rates, but overall the effect is modest as domestic variables response to foreign monetary policy shocks is insignificant. This is further confirmed by the results from the variance decomposition analysis in the preceding section.

Figure 7: Response to positive foreign monetary policy shocks



Source: Author's calculations

(f) Forecast Error Variance Decomposition

The Forecast Error Variance Decomposition (FEVD) tells us the proportion of the movements in the variables that can be attributed to each independent exogenous shock versus shocks to the other variables. The FEVD is the percentage of the variance of the error made in forecasting a variable due to a specific shock at a given horizon. The FEVD separates the variation in an endogenous variable into the contributions explained by the component shocks in the VAR. That is, the variance decomposition provides information about the relative importance of each random shock in affecting the variables in the system. In this analysis, the forecast horizon of ten quarters, i.e., 2.5 years was chosen on the basis of the dominant transmission channel which is the exchange rate, which has a pass-through to inflation of between four to six quarters (Sampson et al 2006). Hence, there should be sufficient lags for the shocks to wear off.

Table 1: Variance decomposition of output

Variance Decomposition of GDP_DT: Perio...	S.E.	Shock1	Shock2	Shock3	Shock4	Shock5	Shock6	Shock7
1	0.063026	99.87607	0.000000	0.000000	0.000000	0.000000	0.123929	0.000000
2	0.078513	95.34302	2.682079	0.209107	0.697711	0.218351	0.847488	0.002242
3	0.083399	92.68870	3.032380	0.188109	1.711050	0.598569	1.701139	0.080050
4	0.085499	90.41826	2.953316	0.197714	2.938629	0.863999	2.482350	0.145728
5	0.086959	88.07121	3.398649	0.191930	4.205786	0.982474	2.970483	0.179469
6	0.088006	86.20425	3.814257	0.212097	5.329126	1.038074	3.207060	0.195140
7	0.088711	84.91195	3.965779	0.286978	6.229894	1.077319	3.322558	0.205527
8	0.089198	84.00684	3.968182	0.384334	6.912317	1.114700	3.398288	0.215337
9	0.089564	83.32519	3.937792	0.471886	7.419843	1.151925	3.467801	0.225567
10	0.089858	82.78046	3.914034	0.540467	7.800693	1.187270	3.541228	0.235844

Table 1 shows that at the 10 quarter horizon, 7.8 percent of the variation in output is explained by money demand (shock4), 3.5 percent is from oil price (shock6), while 1.2 percent of the variation is explained by exchange rate (shock5). While past output explains current and future output growth, money demand also contributes to explaining changes in output in the longer horizon. This is not surprising as a majority of PNG's rural population is still highly dependent on cash money-balances, with interest rates (shock 3) contributing little to explaining changes in output.

Table 2: Variance decomposition of prices

Variance Decomposition of CPI_DM: Perio...	S.E.	Shock1	Shock2	Shock3	Shock4	Shock5	Shock6	Shock7
1	0.370535	0.617868	99.24336	0.000000	0.000000	0.000000	0.138775	0.000000
2	0.532741	0.719226	95.27633	1.683842	0.109032	2.114934	0.068020	0.028616
3	0.598462	0.759065	91.49984	3.520335	0.092526	4.023116	0.082220	0.022901
4	0.621832	0.740970	88.65222	4.413605	0.373527	5.658944	0.092089	0.068641
5	0.633400	0.714216	86.10500	4.512928	1.095380	6.952665	0.422422	0.197386
6	0.644307	0.695156	83.29586	4.365222	2.073679	7.895763	1.301122	0.373203
7	0.655992	0.673651	80.36540	4.245616	3.058358	8.560569	2.546424	0.549985
8	0.667278	0.651085	77.67423	4.178252	3.913595	9.034520	3.841155	0.707164
9	0.677246	0.636948	75.40971	4.131738	4.610015	9.379946	4.987307	0.844336
10	0.685651	0.635089	73.57983	4.090476	5.165176	9.634366	5.927653	0.967411

In the forecast error of domestic prices (table 2), 9.6 percent of the variation in price is due to exchange rates (shock 3) after 10 quarters, 5.9 percent is due oil price shocks, 5.1 percent is due to money demand shocks, while interest rate shocks (shock 3) explains around 4.0 percent of the variation. Much of the changes in domestic prices are explained by external shocks which feed-through to the exchange rate and money demand.

Table 3: Variance decomposition of interest rates

Variance Decomposition of IRATE_DM:

Perio...	S.E.	Shock1	Shock2	Shock3	Shock4	Shock5	Shock6	Shock7
1	1.682278	0.002638	3.971294	94.38792	0.000000	0.000000	1.638146	0.000000
2	2.583378	0.017963	6.412529	89.23087	0.077979	2.438111	0.790257	1.032289
3	3.070700	0.017061	7.911548	83.46829	0.152657	4.096375	1.234586	3.119485
4	3.388643	0.042893	8.332882	75.35014	0.713553	5.652195	4.041145	5.867195
5	3.677016	0.098262	7.917547	65.72330	1.692831	6.810732	9.262615	8.494715
6	3.969895	0.136686	7.131061	56.67723	2.785573	7.449832	15.28493	10.53470
7	4.253332	0.140340	6.333392	49.39332	3.765696	7.675965	20.69415	11.99714
8	4.509993	0.127392	5.672378	43.93476	4.557216	7.648841	24.98339	13.07602
9	4.731840	0.116440	5.165994	39.93120	5.165922	7.488399	28.19454	13.93750
10	4.918419	0.113709	4.787177	36.98774	5.623083	7.268475	30.53923	14.68058

In the forecast error of the interest rate in PNG (table 3), over 30.5 percent in the variation is explained by oil price (shock 6) after 10 quarters, 14 percent is due to foreign interest rates (shock 7) after 10 quarters, while over 7 percent of the variation is due to exchange rates (shock 5) after ten quarters. Output (shock 1) and prices (shock 2) account for 0.1 percent and 8.3 percent, respectively after 4 quarters. Monetary policy responds more to external and exchange rate shocks than to domestic shocks, given that these variables contribute the most to explaining much of the variation in prices.

Table 4: Variance decomposition of money demand

Variance Decomposition of MD_DT:

Perio...	S.E.	Shock1	Shock2	Shock3	Shock4	Shock5	Shock6	Shock7
1	0.042817	0.389436	0.577324	1.207721	97.79127	0.000000	0.034245	0.000000
2	0.059981	0.456174	0.519144	2.776179	96.07645	0.128317	0.019306	0.024432
3	0.071844	0.318229	0.362748	4.590498	94.58146	0.089443	0.021932	0.035695
4	0.080477	0.359812	0.336687	5.935447	93.12418	0.110037	0.063345	0.070491
5	0.086965	0.514876	0.390276	6.823210	91.71325	0.211309	0.218620	0.128463
6	0.092018	0.695983	0.470405	7.404156	90.25823	0.403306	0.558719	0.209196
7	0.096099	0.853708	0.549802	7.791893	88.69684	0.684337	1.112227	0.311189
8	0.099506	0.970056	0.616477	8.052648	87.01103	1.043874	1.872133	0.433786
9	0.102440	1.045051	0.666049	8.222421	85.20999	1.466319	2.813545	0.576627
10	0.105035	1.086187	0.698175	8.321596	83.31552	1.934397	3.904927	0.739200

In the forecast for demand for money in PNG (table 4), over 3.9 percent in the variations is due to oil price (shock 6) in after 10 quarters quarter, while output (shock 1) and the exchange rate (shock 5) account for around 1.0 percent and 1.9 percent respectively, after 10 quarters. Interest rates contribute to explaining over 8 percent in the variation of holdings of real money balances.

Table 3: Variance decomposition of nominal exchange rate

Variance Decomposition of EXRATE_DT:

Perio...	S.E.	Shock1	Shock2	Shock3	Shock4	Shock5	Shock6	Shock7
1	0.058974	0.374067	0.440073	1.163360	0.078496	94.67380	3.266602	0.003603
2	0.080990	0.695707	0.235951	0.709675	0.738089	93.02444	4.531935	0.064204
3	0.098823	0.784515	0.159063	0.477627	1.228557	90.45188	6.660170	0.238185
4	0.114524	0.759105	0.138180	0.369105	1.585108	87.68002	9.032168	0.436317
5	0.128761	0.691125	0.151177	0.302640	1.849557	85.05807	11.28984	0.657592
6	0.141812	0.614211	0.175423	0.254602	2.064890	82.63897	13.35113	0.900773
7	0.153885	0.543181	0.199575	0.218492	2.253061	80.38084	15.23758	1.167267
8	0.165140	0.482304	0.220820	0.191022	2.424358	78.24184	16.98428	1.455379
9	0.175689	0.431463	0.239310	0.169841	2.583067	76.20100	18.61373	1.761583
10	0.185610	0.389246	0.255501	0.153308	2.731037	74.25280	20.13633	2.081773

In the forecast error of the nominal kina exchange rate (table 5), oil price (shock6) account for over 20 percent of the variations in the exchange rate after 10 quarters, money demand (shock 4) explains 2.7 percent, output accounts for 0.7 percent, while much of the variation is explained by the external oil price shocks (shock 6) which explains over 20.0 percent of the variation after 10 quarters. While the nominal exchange rate shock explains much of the changes in the monetary policy reaction function on one hand, the monetary policy shock on the other hand is insignificant in explaining variations in the exchange rate.

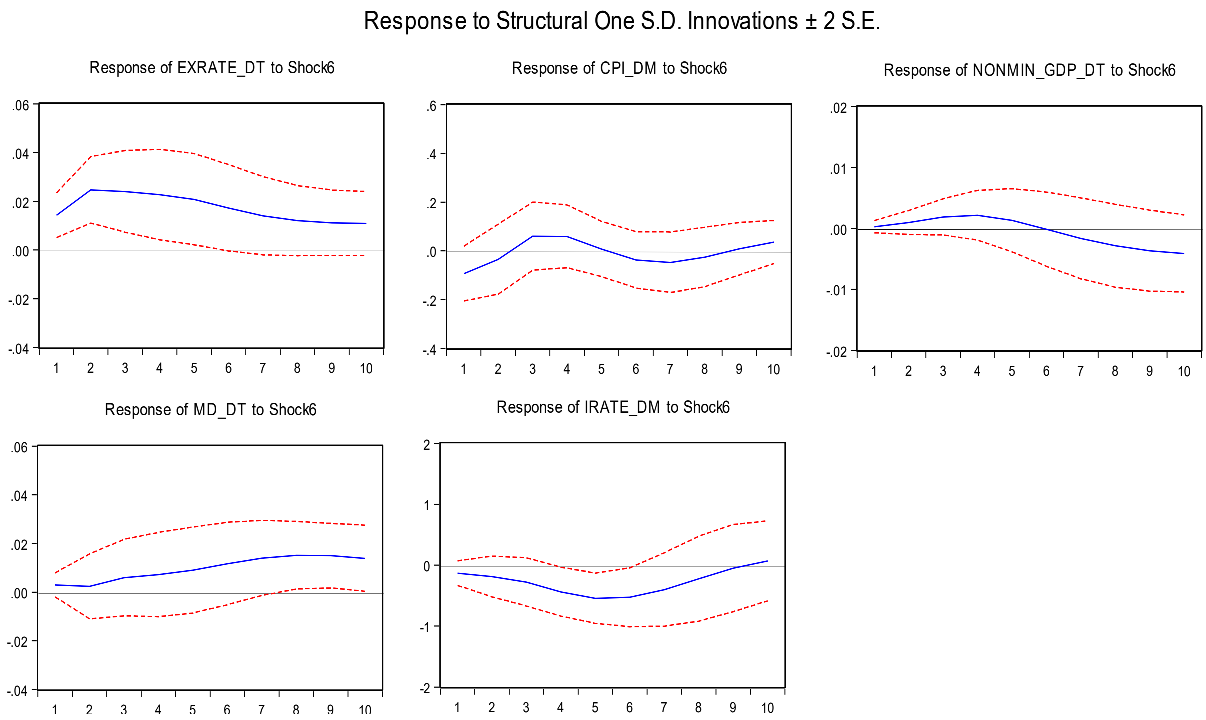
(iii) Robust Model: International commodity prices and non-mineral output: Sub-sample period 2000q1 – 2015q4

The robustness of the model is tested using subsample period 2000q1 - 2015q4, with the KR model extended to include international commodity prices in place of oil prices, while using non-mineral output, given the importance of the commodity exports and non-mineral sector of the economy with respect to the conduct of monetary policy: It is implicitly assumed that monetary policy decisions impacts the non-mineral sector more than mineral sector – i.e., the non-mineral sector rely more on the domestic banking system for funding while the mineral sector is largely based on foreign direct investment. The reference period of year 2000 is significant as this marked the start of the price stability mandate for the monetary policy regime under the central banking Act 2000, which the Bank adopted and has pursued since. The contemporaneous restrictions are consistent with the KR model, while allowing for similar assumptions for commodity prices to that of oil price shocks. The response of domestic variables to positive commodity price shocks is first examined, followed by an analysis using non-mineral output. Note that in the model specification and selection process, the reduced form of the model is also tested for stability for the sample period with favourable results including the robust model.

(a) International commodity price shocks

Based on the analysis of the impulse response functions, the response of the nominal exchange rate to international commodity prices shocks is strong and statistically significant as (top left panel) in Figure 8*.* Similar to oil price shocks, some pass-through to prices is observed, although statistically not significant as indicated in the top middle panel: There is an initial increase in price after 4 quarters, but then eases thereafter. The impact on non-mineral output although indicating signs of some expansion, is also not significant (top right panel), which could reflect the relative size of the non-mineral sector and its lack of response to improvements in international commodity prices. The demand for money (bottom left) expands, while the central bank eases monetary policy (bottom right) given subdued prices stemming largely from the significant exchange rate appreciation.

Figure 8: Response to positive commodity price shocks



Source: Author's calculations

Table 4: Variance decomposition of non-mineral output

Variance Decomposition of NONMIN_GDP_DT:

Perio...	S.E.	Shock1	Shock2	Shock3	Shock4	Shock5	Shock6	Shock7
1	0.003716	99.47029	0.000000	0.000000	0.000000	0.000000	0.529705	0.000000
2	0.007069	94.34405	0.101620	2.072556	0.031077	0.005971	1.962387	1.482338
3	0.010893	81.26999	1.186431	9.588709	1.332872	0.403356	3.810733	2.407913
4	0.015322	68.44801	2.005213	18.81973	3.050535	1.081842	3.924974	2.669702
5	0.019989	59.88292	2.169450	26.73796	4.346586	1.626133	2.746251	2.490696
6	0.024463	54.77955	1.938895	32.23199	5.243875	1.837884	1.837202	2.130602
7	0.028396	51.85715	1.569474	35.47245	5.902499	1.754838	1.700543	1.743043
8	0.031641	50.12090	1.265803	37.05474	6.436518	1.522952	2.179479	1.419616
9	0.034221	48.90428	1.123692	37.54221	6.895232	1.303122	3.001979	1.229494
10	0.036247	47.82219	1.121432	37.37328	7.292084	1.214782	3.972361	1.203865

The FEVD results of non-mineral output and prices with respect to international commodity prices shocks are then examined: since the two are important variables in the business cycle and monetary policy reaction function. Commodity price shocks (shock 6) contribute around 4.0 percent in the variation in non-mineral output after 10 quarters (Table 6). On the other hand, commodity prices shocks (shock 6) account for around 5.0 percent of the variation in prices in the first quarter (Table 7). This indicates that international commodity prices have more of an immediate effect on prices than on output.

Table 5: Variance decomposition of domestic prices

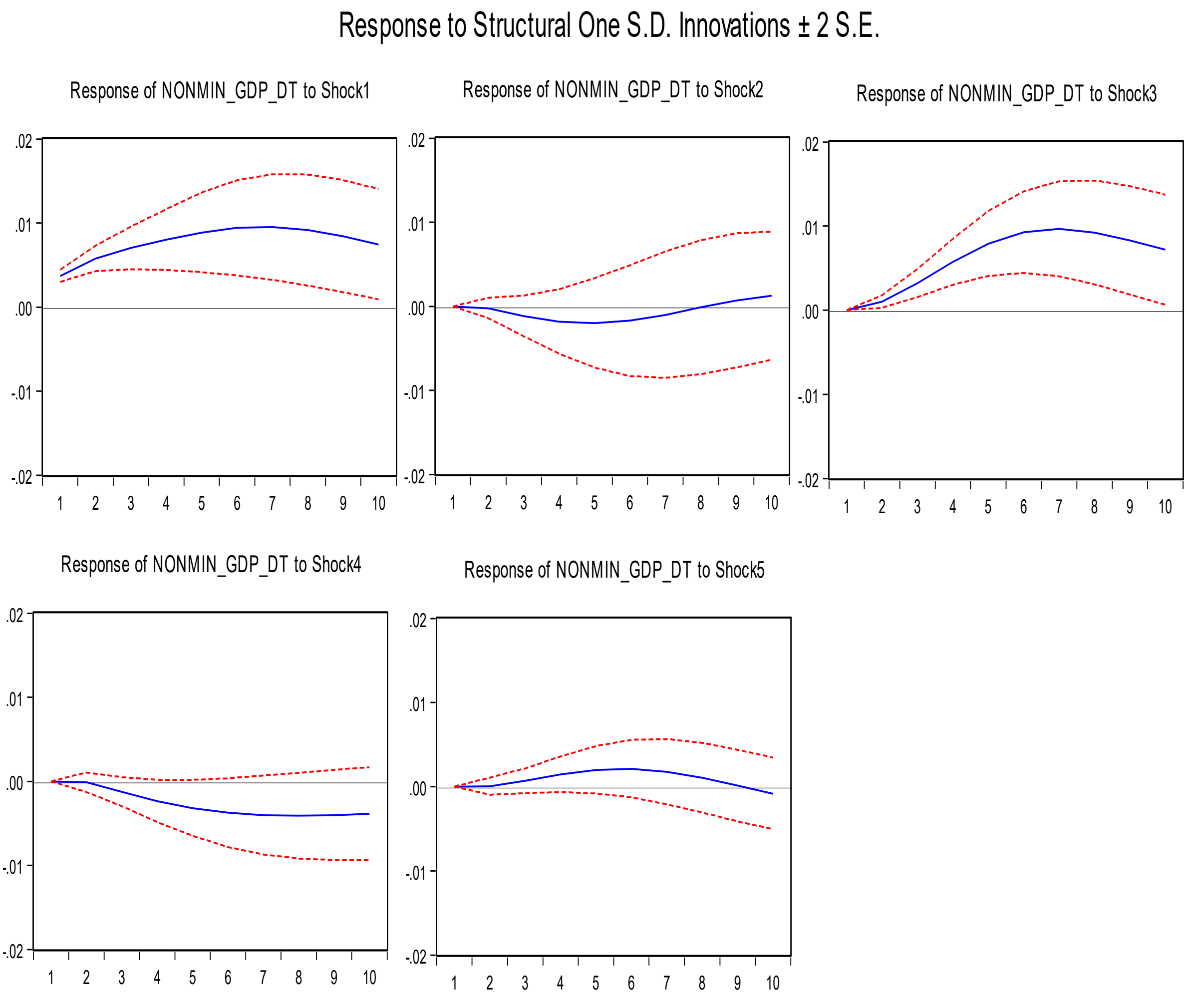
Variance Decomposition of CPI_DM:

Perio...	S.E.	Shock1	Shock2	Shock3	Shock4	Shock5	Shock6	Shock7
1	0.413464	1.480225	93.43860	0.000000	0.000000	0.000000	5.081173	0.000000
2	0.509529	5.032006	88.21616	0.764447	0.067970	0.414537	3.808259	1.696621
3	0.540366	4.605414	86.07397	0.691419	0.090397	1.584033	4.624881	2.329890
4	0.557393	5.856348	81.36347	1.113201	0.145372	2.945480	5.474116	3.102012
5	0.585125	9.662650	74.30683	3.081891	0.432866	3.984575	4.982706	3.548486
6	0.624215	13.35503	66.56953	6.549411	0.946947	4.415751	4.733310	3.430014
7	0.658758	15.44900	60.63345	10.13510	1.410618	4.485184	4.764676	3.121975
8	0.678364	16.28918	57.42896	12.59027	1.669301	4.426185	4.637538	2.958567
9	0.685535	16.49005	56.25351	13.56177	1.740532	4.353469	4.555722	3.044941
10	0.688382	16.42137	55.78991	13.59662	1.730240	4.339170	4.783238	3.339457

(b) Non-mineral output analysis

In the analysis using non-mineral output, we examine the results from the impulse response functions to see if non-mineral output responds to any of the shocks from the variables in the model, with the shocks separated into domestic and external, to determine which influences the non-mineral sector the most. When examining the impact of domestic shocks on non-mineral output (Figure 9), non-mineral output contracts in response to both domestic inflation (top middle panel–shock 2) and money demand shocks (bottom left panel–shock 4): Hence, these suggest that a general rise in cost of goods and services and subsequently factors of production and the availability of excess funds discourages non-mineral production. While in contrast, non-mineral output expands in response to interest rates (top right panel–shock 3) and nominal exchange rate shocks (bottom left panel–shock 5). All other domestic variables, with the exception of monetary policy shocks (shock 3) are not significant and trigger modest responses from non-mineral output.

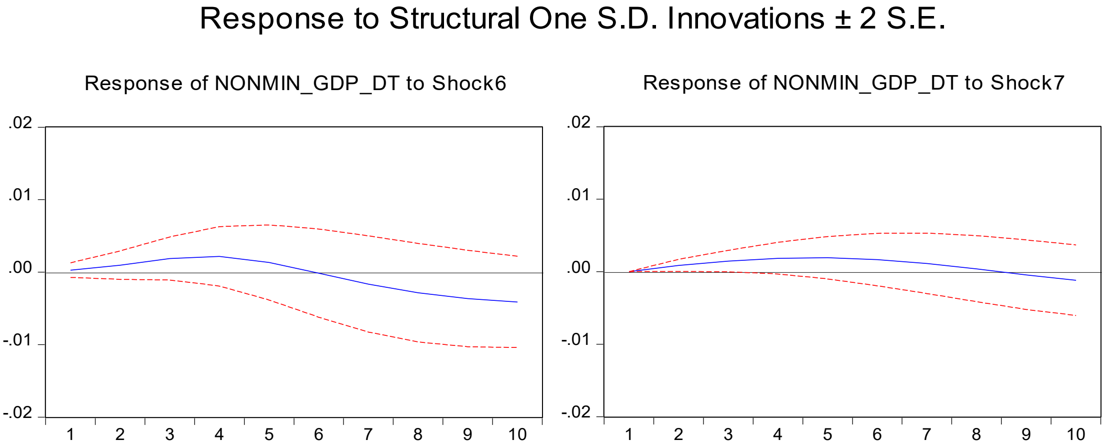
Figure 9: Response of non-mineral output to domestic shocks



Source: Author's calculations

When examining the impact of external shocks on non-mineral output as represented in the two panels in Figure 10, the results with respect to external price shocks, is consistent with a priori expectations in that international commodity price induces an expansion in non-mineral output (left panel–shock 6) while on the other hand, counterintuitively, foreign interest rate shocks (right panel-shock 7) also cause an expansion in non-mineral output: international commodity prices and foreign monetary policy shocks both induce a positive response from the non-mineral sector, although both are statistically not significant.

Figure 10: Response of non-mineral output to external shocks



Source: Author's calculations

6. Conclusion

Results from the paper confirm the vulnerability of the PNG economy as a small open economy to external shocks: fluctuations in the business cycle are subject to conditions in the global economy. In essence, the central bank's monetary policy reaction function is fundamentally driven by external supply side factors that drive inflation. Oil price shocks are more pronounced compared to commodity prices or foreign monetary policy shocks, which are limited to the exchange rate and inflation. This reflects the inherent dependence of the PNG economy on the oil and gas sector for revenue streams, with the contribution to output expansion reflecting a large spill over effect on aggregate demand. In contrast, while non-mineral output response to commodity price shocks is positive the effect is modest, which suggests that the production of non-mineral commodities in PNG is less sensitive to improvements in international commodity prices. This also suggests that any response from the non-mineral sector may be less evident, given its relatively smaller size and contribution to exports and subsequently total output. Foreign monetary policy shocks are insignificant, given the size and structure of PNG's financial sector, which is less developed and not fully integrated. The exchange rate pass-through to inflation and the real sector remains significant reemphasising the importance of the exchange rate channel. When posing the policy question on the importance of money supply and interest rates on the economy, money shocks matter while interest rate shocks have little significance on the real sector and business cycle variations in PNG. This explains the Central Bank's policy response to changes in money demand. However, the transmission from money to inflation and output is unclear in this model; albeit weak for output which can be further investigated through the credit channel.

With respect to monetary policy shock on inflation, a 'price puzzle' is observed where a rise in interest rates causes an increase in prices. While the demand for money contracts in response to rise in interest rate given the increase in opportunity cost of holding money balances, with the nominal exchange rate relatively unresponsive, despite higher interest rates. However, the FEVD results indicate that interest rates contribute modestly in explaining changes in the demand for real money balances. While the monetary policy response to price changes is appropriate, it contributes little to explaining variations in prices and exchange rate compared to external shocks. In general, interest rate innovations or unanticipated monetary policy shocks contribute modestly to explaining changes in domestic variables. These findings are generally consistent with earlier papers showing a weak interest rate channel in the transmission of monetary policy.

Because money shocks matter for monetary policy in PNG, an important policy consideration for the Bank is that it can be adjusted to strengthen the interest rate channel. Overall, an appropriate policy mix is required to complement monetary policy to assist in aggregate demand management. Hence, the policy mix of monetary and fiscal is worth investigating using a SVAR model, in a similar open economy context. While monetary policy may not affect output directly, it essentially acts as a stabilising policy variable with respect to the exchange rate, money demand and inflation in limiting the contagion effects of external supply side shocks.

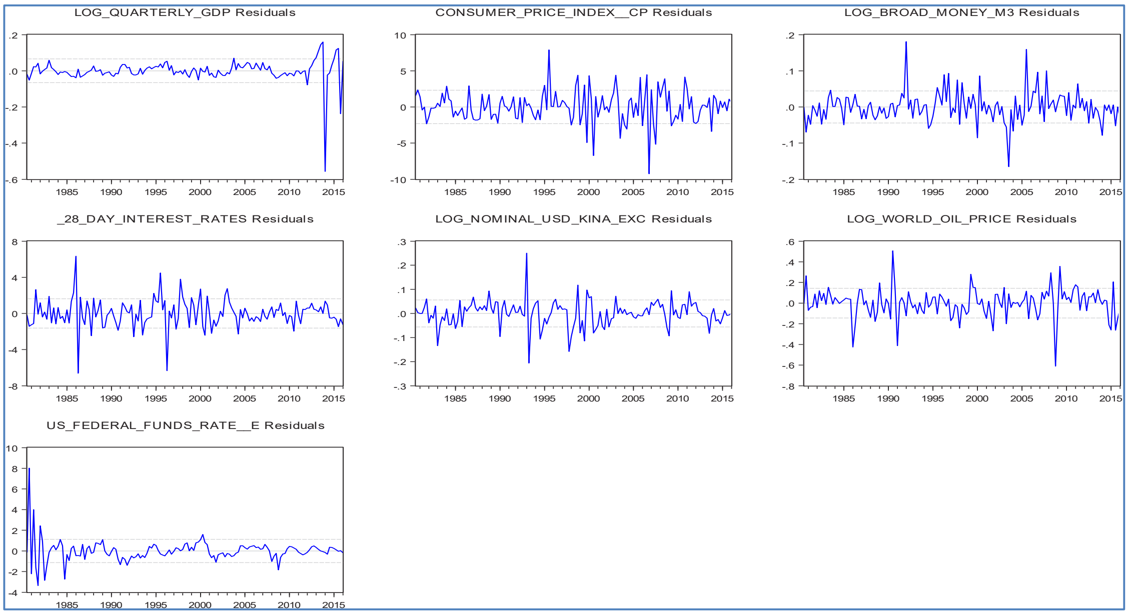
APPENDIX 1.a: Lag length selection criteria

VAR Lag Order Selection Criteria
Endogenous variables: LOG QUARTERLY GDP CONSUMER PRICE INDEX CP LOG BROAD M...
Exogenous variables: C
Date: 01/27/17 Time: 17:15
Sample: 1980Q1 2016Q2
Included observations: 131

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1121.318	NA	0.071439	17.22623	17.37987	17.28866
1	6.676946	2118.220	5.01e-09	0.753024	1.982116*	1.252459*
2	66.57830	106.0848*	4.27e-09*	0.586591	2.891138	1.523032
3	96.96171	50.56171	5.76e-09	0.870814	4.250817	2.244260
4	126.6516	46.23461	7.97e-09	1.165625	5.621083	2.976077
5	158.2647	45.85111	1.09e-08	1.431073	6.961987	3.678531
6	205.3179	63.21649	1.21e-08	1.460796	8.067165	4.145259
7	239.9712	42.85377	1.68e-08	1.679828	9.361653	4.801297
8	271.8182	35.97974	2.54e-08	1.941707	10.69899	5.500182
9	321.6661	50.98949	3.07e-08	1.928762	11.76150	5.924242
10	385.7865	58.73625	3.20e-08	1.697916	12.60611	6.130401
11	439.7740	43.68456	4.24e-08	1.621770	13.60542	6.491262
12	493.1114	37.45832	6.38e-08	1.555551	14.61465	6.862048
13	578.2097	50.66922	6.91e-08	1.004432	15.13899	6.747934
14	676.9129	48.22142	7.59e-08	0.245604*	15.45562	6.426112

* 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

APPENDIX 1.b: Residual test for white noise



APPENDIX 1.c: Serial correlation LM test

VAR Residual Serial Correlation LM Te...
Null Hypothesis: no serial correlation at...
Date: 01/27/17 Time: 15:38
Sample: 1980Q1 2016Q2
Included observations: 143

Lags	LM-Stat	Prob
1	56.89960	0.2046
2	50.23525	0.4243
3	41.25767	0.7761
4	67.44196	0.0413
5	54.39822	0.2765
6	28.45901	0.9917
7	42.25481	0.7412
8	44.49103	0.6563
9	39.62030	0.8282
10	35.78133	0.9207
11	43.14730	0.7083
12	20.00722	0.9999

Probs from chi-square with 49 df.

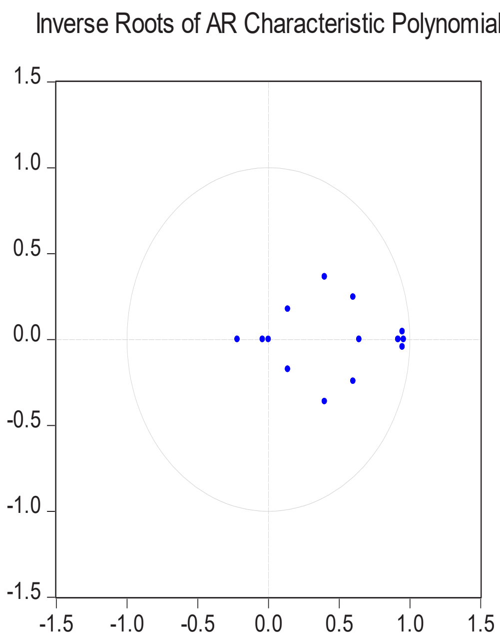
Date: 01/27/17 Time: 15:50
Sample (adjusted): 1980Q4 2016Q1
Included observations: 142 after adjustments
Trend assumption: Linear deterministic trend
Series: LOG_QUARTERLY_GDP CONSUMER_PRICE_INDEX__CP LOG_BROAD_MONEY_M3 _28_DAY_INTEREST_RATES LOG...
Lags interval (in first differences): 1 to 2

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.330977	164.1568	125.6154	0.0000
At most 1 *	0.263720	107.0818	95.75366	0.0066
At most 2	0.210548	63.60932	69.81889	0.1415
At most 3	0.114625	30.03828	47.85613	0.7170
At most 4	0.051857	12.75069	29.79707	0.9026
At most 5	0.035830	5.189227	15.49471	0.7884
At most 6	5.61E-05	0.007969	3.841466	0.9284

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

APPENDIX 1.d: VAR stability condition check



Roots of Characteristic Polynomial
Endogenous variables: GDP_RESID CPI_RESID IR_...
Exogenous variables: C
Lag specification: 1 2
Date: 01/09/20 Time: 16:16

Root	Modulus
0.958788	0.958788
0.949178 - 0.044919i	0.950240
0.949178 + 0.044919i	0.950240
0.919121	0.919121
0.601279 - 0.244507i	0.649091
0.601279 + 0.244507i	0.649091
0.643396	0.643396
0.400006 - 0.362798i	0.540025
0.400006 + 0.362798i	0.540025
0.139043 - 0.174408i	0.223050
0.139043 + 0.174408i	0.223050
-0.217478	0.217478
-0.038313	0.038313
0.002011	0.002011

No root lies outside the unit circle.
VAR satisfies the stability condition.

APPENDIX 1.e: Log Likelihood test for over identifying restrictions

Log likelihood	154.6517			
LR test for over-identification:				
Chi-square(5)	2.898624		Probability	0.7156

Estimated A matrix:						
1.000000	0.000000	0.000000	0.000000	0.000000	-0.015081	0.000000
0.462408	1.000000	0.000000	0.000000	0.000000	0.086851	0.000000
-0.282793	-0.908206	1.000000	0.000000	0.000000	1.382604	0.000000
-0.039160	0.006199	0.002879	1.000000	0.000000	0.000000	0.000000
0.059537	0.007306	0.004004	0.039023	1.000000	-0.067433	0.000309
0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000	-1.358201	1.000000
Estimated B matrix:						
0.062987	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.369130	0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	1.634391	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.042342	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.057382	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000	0.147118	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.146785

References

Allegret J, Couharde C and Guillaumin C (2012), “The Impact of External Shocks in East Asia: Lessons from a Structural VAR Model with Block Exogeneity”, International Economics Vol. 132, pp. 35-89.

Bandara A (2014), “How Effective Are Countercyclical Policy Tools in Mitigating the Impact of Financial and Economic Crises in Africa?”, Journal of Policy Modeling Vol. 36, No. 5.

Cushman D O and Zha T (1997), “Identifying Monetary Policy in a Small Open Economy Under Flexible Exchange Rates”, Journal of Monetary Economics, Vol. 39, No. 3, pp. 433-448.

David S and Nants A (2006), “Monetary Policy Transmission Mechanisms in Papua New Guinea” Bank of Papua New Guinea working paper Series 2006/01, pp.3-24.

Eichenbaum M and Evans C L (1995), “Some Empirical Evidence on the Effects of Shocks to Monetary policy on Exchange Rates”, Quarterly Journal of Economics, Vol. 110, No. 4, pp. 975-1010.

Garlach, S and. Svensson Lars E. O (2000). “Money and Inflation in the Euro Area: A case for Monetary Indicators?’ National Bureau of Economic Research, Working paper 8025 Cambridge M.A, pp.3-18

Grilli, V. and Roubini, N. (1995). “Liquidity and Exchange Rates: Puzzling Evidence from the G-7 Countries”, Working Paper, Yale University

Dan, H. (2013). “The Exchange Rate Channel and Its Role within the Monetary Policy Transmission Mechanism”. Studia Universitatis Babes-Bolyai.Studia Europaea, Vol. 58, No.3, pp. 133-148.

International Monetary Fund (2008), “The Monetary Transmission Mechanism in Papua New Guinea’. Papua New Guinea: Selected Issues and Statistical Appendix”, IMF Country report No. 08/93.

Irau T. (2015), “Demand for money in Papua New Guinea”, Bank of Papua New Guinea working paper Series 2015/01, pp. 5-17.

Jansen, W. J (2003). “What do capital inflows do? Dissecting the transmission mechanism for Thailand,1980–1996”, Journal of Macroeconomics, Vol. 25, pp. 457–480.

Kim, S. and Roubini, N. (2000), “Exchange Rate Anomalies in the Industrial Countries: A Solution with a Structural VAR Approach,” Journal of Monetary Economics, Vol. 45, No. 3, pp.561-586.

King, M. A. (2002). “No Money, No Inflation? The Role of Money in the Economy.” Bank of England Quarterly Bulletin, Summer 2002, pp.162-77.

Leeper, E. M and Gordon, D. B (1995). ‘In search of the liquidity effect’ Journal of Monetary Economics, Vol. 29, No. 3, pp. 341-369.

Ma´ckowiak, B. (2007). "External shocks, U.S. monetary policy and macroeconomic fluctuations in emerging markets." Journal of Monetary Economics, Vol. 54, No. 8, pp. 2512–2520.

Mengesha, L. G and Holmes, M. J (2013). "Monetary policy and its Transmission Mechanisms in Eritrea" Journal of Policy Modeling, Vol. 35, pp. 766–780.

Mishkin, F. S (1995). "Symposium on the Monetary Transmission Mechanism" The journal of Economic Perspectives, Vol. 9, No.4, pp. 3–10.

Mwabutwa C N, Viegi. U N and Bittencourt M (2016), "Evolution of Monetary Policy Transmission Mechanism in Malawi: A TVP-VAR Approach", Journal of Economic Development, Vol. 41, No.1, pp. 35-52.

Nayaran P K, Nayaran S, Mishran S, and Smyth R. (2012), "An Analysis of Fiji's Monetary Policy Transmission", Studies in Economics and Finance, Vol. 29, No. 10, pp.52-70

Nelson C R (1972), "The Prediction Performance of the F.R.B.-M.I.T.-Penn Model of the U.S. Economy," American Economic Review, Vol. 62, pp. 902-917.

Ofoi M (2013), "Studies on the Economy of Papua New Guinea: The Money Multiplier in Papua New Guinea" Bank of Papua New Guinea working paper Series 2013/02, pp.42-53

Peiris S J and Ding D (2012), "Global commodity prices, monetary transmission, and exchange rate pass-through in the Pacific Islands" IMF Working Paper Series. WP/12/176 pp.03-13.

Prasad E S, Hammond G and Kanbur R. (2009), "Monetary Policy Challenges for Emerging Market Economies", Brookings Global Economy and Development Working Paper (36).

Stock J H and Watson W M (2001), "Vector Autoregressions," Journal of Monetary Economics, Vol. 44, pp. 293-335.

Suhaibu I, Harvey S K and Amidu M (2017). "The Impact of Monetary Policy on Stock Market Performance: Evidence from Twelve (12) African Countries" Research in International Business and Finance, Volume 42.

Sampson T, Yabom J, Nindim W and Marambini J, (2006) "Exchange Rate Pass-Through in Papua New Guinea" Bank of Papua New Guinea working paper Series 2006/02

Sims, C. A, (1980). "Macroeconomics and Reality", Econometrica, Vol. 48, pp. 1-48.

Vinayagathasan T. (2013). "Monetary Policy and the Real Economy: A Structural VAR Approach for Sri Lanka" National Graduate Institute for Policy Studies 7-22-1 Tokyo, Japan

Yang Y, Davies M, Wang S, Dunn J and Wu Y. (2012), "Monetary Policy Transmission and Macroeconomic Policy Coordination in Pacific Island Countries" Asia Pacific Economic Literature, Vol. 13, No. 33, pp. 46-68.