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Estimation of Monetary Response Functions in Zambia

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Abstract:

This study reviewed the responsiveness of monetary policy instruments in Zambia to determine if the central banks behaviour is consistent and predictable. The Zambian monetary policy has consisted of monetary aggregates and policy rate as policy instruments. Responsiveness of the monetary policy was estimated by running two monetary response functions, each based on one of the policy instruments using an SVAR model for the period 2001 to 2018. The results indicate that the policy rate responds positively to inflation gap changes but all responses where insignificant. Money supply also responds insignificantly to the inflation gap and output gap but negatively to exchange rates. Both money supply and interest rates appear to trigger an appropriate response from monetary authorities but this response is insignificant. Therefore, it can be concluded that the Zambian monetary policy may not follow a systematic rule.

JEL classification: E52
Key words: Monetary Policy, Taylor Rule, McCallum Rule

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1. Introduction

Analysis of monetary policy has been of keen interest amongst academics, policy makers and policy implementers. Research of monetary policy instruments, targets and the macroeconomy has provided a lot of understanding of the monetary policy making it more efficient. For instance, various monetary policy instruments have been used over time including monetary aggregates, interest rates and exchange rates among others. In the 1940s it was understood that exchange rates where the most reliable policy instrument until increased international capital flows made it less effective. Most countries then shifted to use of monetary aggregates as policy instrument of the assumption that money supply and inflation had a directly proportional relationship. This, however, has been questioned due to the many other non-policy variables affecting growth of monetary aggregates in an economy and the increasing difficulty in measuring money supply with increasing financial innovation (Bernanke & Mihov, 1998). One of the techniques used to understand central bank behaviour is the monetary response function as it helps establish Central behaviour over a period.

In 1993, John B Taylor coined the Taylor rule which is an interest rate based monetary response function. A monetary response function is a function whose dependent variable is the policy instrument and the explanatory variables, the policy goals. It establishes a rule on how central banks' respond to changes in macroeconomic variables. Thus, the function indicates a systematic and consistent system of the central bank behaviour which helps analyse its responsiveness to its goals (Setlhare, 2004). The use of the Taylor rule addresses the problem of time-inconsistency2 in the implementation of monetary policy. Within the framework of the Taylor rule, the concept of time-inconsistency validates the importance of the rule, additionally, most central banks set monetary policy goals over different time horizons.

Taylor's rule has since been used to measure the responsiveness of monetary policy instruments as it helps determine the reaction of policy instruments to macroeconomic changes. This analysis particularly became common in developed countries after their transition from the monetary aggregates regime to inflation targeting regime. Additionally, monetary response functions help predict central bank behaviour if a rule can be clearly observed. Despite Taylor's rule gaining currency over the years, the use of McCallum's rule did not completely fall out. A few studies have made use of McCallum's rule to explore the responsiveness of monetary policy in developing countries (Rasche & Williams, 2005).
Zambia's monetary policy has been based on several policy instruments. Today, interest rates are the main policy instrument after having used monetary aggregates for over 20 years. The shift to interest rates was made in a bid to address a weakening in the relationship between money supply and inflation. The move was also aimed at anchoring inflation expectations as changes in interest rates are more easily understood by the public. The use of interest rates also allows the Central Bank to influence pricing of commercial bank credit products which were relatively high at the time of the transition (Bank of Zambia, July 2012).

[2] Time inconsistency is a concept developed by Kydland and Prescott (1977) where discretionary monetary policy may lead to bad outcomes (higher inflation instead of output) as it can be exploited. Thus, a rule is preferred as it allows for no exploitation of policy that may want to increase output through expansionary monetary policy.

According to Taylor (1999), interest rates work better in the face of increased volatility in financial markets, which has been a consequence of financial innovation, whereas monetary aggregates are more effective in situations of high/growing inflation levels.

The Zambian economy was characterised by high inflation, averaging around 111% in 1990. The inflation rates were further exacerbated by the removal of price controls, liberalisation of exchange and interest rates, removal of subsidies, as well as seignorage activities pursued in 1992 in response to civil servants demand for increased pay (Simutanya, 1996). This, coupled with calls to make the central bank more independent, necessitated a shift in monetary policy instruments from direct to indirect instruments3 with monetary aggregates being the major policy instrument. During the monetary aggregates' regime, inflation was brought down significantly i.e. 46% in 1995, 30% in 2000 and 6.4% in 2012.

In April 2012, there was a shift from the use of monetary aggregates as policy instrument to interest rates. Following the shift, inflation rates remained fairly stable and within the central bank target range of 6-8% with the exception of 2015 when inflation shot up from 7.7% in September to 14.3% in October. This rise in inflation was on account of a sharp decline in world copper prices, a major export for Zambia. This resulted in the depreciation of domestic currency and thus an increase in prices due to the country's large import dependency (Ministry of National Planning, 2017). In response to the high inflation, the central bank raised the policy rate to a high of 15.5% from 12.5% at the beginning of the last quarter. This led to inflation declining back to single digits by end of 2016 (BOZ, 2017).

The advantages of interest rates instruments are clear and thus the reason for most countries adopting them over monetary aggregates. Most developed countries have successfully used these and developing countries are effectively implementing these in their monetary policy. Other researchers however have observed that developing countries may not be able to rip all the benefits of interest rate instruments due to the weak transmission mechanism, the high exchange rate to price pass through effects and financial innovation (Sánchez-Fung, 2002), effects that are quiet significant in Zambia.

Various studies on the appropriate policy instruments in Zambia have been done using several approaches. Studies as far back as Ng'andwe (1980) and Pamu (2005) found monetary aggregates and inflation to have no relationship recommending interest rates with Hangoma (2010) showing that treasury bills and inflation have a significant relationship though the transmission was not smooth. However, Chileshe and Zgambo (2014), who estimated the money demand function and the monetary policy transmission mechanisms, observed that a strong inverse relationship exists between monetary aggregates and inflation. They also found that the interest rate channel in the transmission mechanism had no significant effect on output or inflation and thus recommended continued use of money aggregates in monetary policy. The findings were consistent with Chileshe et al (2014). This study uses monetary response rules with various instruments to try and explain monetary policy, an approach that has not been commonly used so far in the Zambian context.

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[3] Examples of direct instruments include cash reserves and credit allocations while indirect instruments include OMOs and repurchasement agreements.

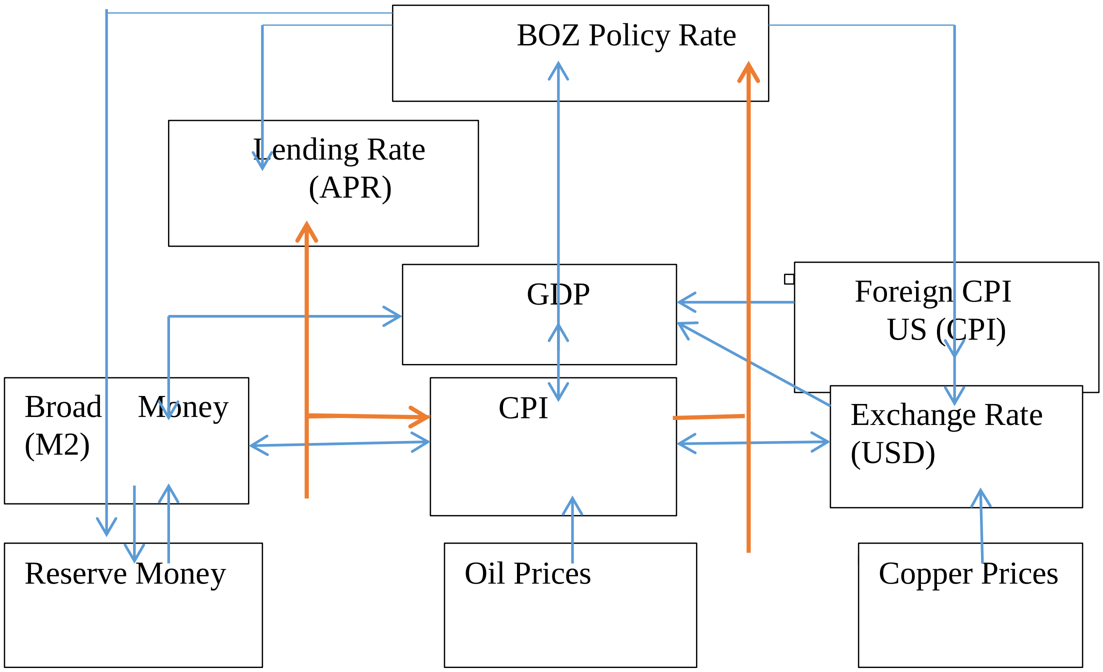
2. Monetary Policy Framework in Zambia

The mandate of the Central Bank is to formulate and implement monetary and supervisory policies that achieve and maintain price stability and promote financial stability. The primary objective of the Bank of Zambia's (BoZ) monetary policy is price stability. The price level is to be kept low and stable to promote investment and consequently economic growth. The inflation rate is targeted to be maintained in a range of 6% - 8% in the medium term.

As stated above, the Bank of Zambia uses the policy rate as an instrument for anchoring price level. The policy rate is determined by the Monetary Policy Committee (MPC) which sits quarterly to revise the rate depending on long-term goals and the prevailing economic environment. The policy rate determines the fluctuations of the overnight interbank rate, which is usually in the interval of ±2% of the interbank rate corresponding to the policy rate, unless circumstances require otherwise. The MPC thus set the rate and the central bank maintains the overnight interbank rate within the acceptable range through Open Market Operations (OMOs). If the interbank rate is too high, the central bank can carry out an open market purchase to increase liquidity and therefore reduce the interbank rate. This interbank rate thus affects market interest rates, thereby leading to a contraction in aggregate demand and a reduction in inflation (Bank of Zambia, 2016).

In summary, the policy rate is the primary instrument, the interbank rate the operating target, and inflation the policy goal. The policy rate also affects other variables like money supply, thus indirectly influencing inflation. Exchange rates are also influenced by policy rates since the change in interest rates will cause an increase or decrease in demand of domestic currency so that the currency appreciates or depreciates respectively. Thus, assuming substitutability between domestic and foreign capital assets, a change in interest rates will affect exchange rates. This consequently affects price of traded goods, and therefore affecting inflation rates. The impact of policy rate through to inflation rate can be shown on the Zambian Quarterly Model (ZQM) below reflecting the monetary policy transmission mechanism (ibid).

Figure 1: Zambia Quarterly Model



Source: Bank of Zambia (www.boz.zm)

The highlighted arrows show the major monetary policy transmission mechanisms. From the model above, it can be seen that copper price affects inflation through the exchange rate channel whereas oil prices directly affect inflation as oil is vital for production of most goods and services. As an import dependent economy, changes in either copper or oil prices affect the macroeconomic variables, thus triggering a response from monetary authorities.

3. Literature Review

Several studies have been carried out on monetary response functions in both developed and developing countries. Rather than cross-section studies, most focus on country specific monetary reaction functions to help understand monetary policy for each country better. This study focusses on the McCallum (1988) rule which is a nominal feedback rule based on a monetary base rule and Taylor (1993) linear feedback rule based on interest rates' rule.
Cross-section studies like that of Hashmi et.al (2011) consisting of Pakistan, Korea, Philippines and Japan used OLS to estimate the McCallum response functions. Exchange rates were also included amongst other variables and were observed to be insignificant in the short run. In this study, foreign capital inflows were also included and were observed to be generally insignificant in the short run. However, the monetary policy appears to be adequately responsive to all variables in the long run (Hashmi, Xu, Khan, Bashir, & Ghazanfar, 2011). Another panel study by Mehrotra & Sanchez-Fung (2009) estimated

Taylor's, McCallum and the hybrid rules in 20 emerging nations. The McCallum rule also included the lagged monetary base and exchange rates estimated using GMM. The results showed that most countries have expected signs except exchange rates which were observed to be insignificant for traditional models. The study concludes inflation targeting economies in emerging economies were better characterised by hybrid Taylor-McCallum rule (Mehrotra & Sánchez-Fung, 2009).

In developed countries, monetary response functions have been estimated for various reasons. A study in the United States (US) by Clarida, Gali and Gertler in 2000 estimated the effectiveness of monetary policy in the pre-Volcker4 era and the Volcker era. The study compared the standard error of inflation gap and output gap in the 2 periods. The study concluded that the response to inflation gaps has been more systematic in the Volcker era and thus monetary policy can be said to be more effective. Additionally, the study noted that the monetary policy in the Volcker era was forward looking as instruments responded not only to inflation but also inflation expectations. Similarly, Boivin and Giannoni (2006) estimated effectiveness of monetary policy in the US overtime (before and after 1980) using monetary response functions among others. Using a reduced- form VAR, the results show that monetary policy is now more responsive to inflation expectations making it more effective. However, Pancrazi and Vukotic (2015), also used Taylor's rule to determine if the policy instruments used in the US before the 1990s during the Volcker era is still as effective almost 30 years later using DSGE. The results showed that the monetary policy rule is no longer as effective as it was previously in reacting to inflation changes.

In developing countries, there are several studies employing Taylor's rule to estimate response functions. In Nigeria, Iklaga (2009), Agu (2011), and Kelikume et. al (2016) employed Taylor's rule to estimate response functions. Agu (2011) extends the model by including credit to private sector and exchange rates. The study found that only inflation, output gap and private credit significantly affect the interest rate and like Iklagi (2009) concluded that the Central Bank follows some rule that was biased towards inflation stabilization. Other studies in developing countries i.e. Setlhare (2004); Rotich, Kathanje and Maana (2007); Inoue and Hamori (2009) in Botswana, Kenya and India respectively include exchange rate in the model and found it to be statistically significant.

To incorporate both monetary aggregates and policy rate, Rotich, Kathanje and Maana (2007) estimated response functions, one using Taylor's rule and the other using McCallum's rule. The estimation procedure used was GMM and the results were observed to be against expectation when exchange rates were left out but were consistent when exchange rates are included. The study concluded that inflation was adequately addressed by both instruments with exchange rates playing a key role.

In the Zambian context, only three significant studies are available on the appropriate monetary policy instrument. One study, Mwenda (1999), compared the pre-liberalization and post-liberalisation monetary policy instruments which are direct and indirect instruments, respectively. The study revealed that indirect instruments where more

[4] Volcker was the Federal Reserve Chairman during the period 1979 to 1987

effective than the direct ones in controlling inflation based on the success recorded in bringing down and stabilizing inflation.

A more recent study on the measure of effectiveness of monetary policy was done by Chileshe and Zgambo (2014), focussing on the monetary aggregates regime. The results indicated the continued importance of monetary aggregates in monetary policy. Similar results were obtained by Chileshe et.al (2014) who concluded that there had been, up until 2014, a strong link between monetary aggregates, inflation and output whilst interest rates link remained weak. These studies attempted to better capture the role of interest rates as policy instruments.

4. Methodology.

4.1. Theoretical Model

Several monetary response functions have been coined in the last two decades. Prominent amongst these are Taylor's rule and McCallum's rule. These rules both advocate for a rule guided rather than discretionary guided monetary policy based on the time-inconsistency critic. However, both rules are applied with some flexibility depending on the nature of the economies in which they are estimated as observed in the previous chapter. These rules, along with other more recent policy rules like the Hybrid Taylor-McCallum rule and the Hybrid McCallum-Hall-Mankiw rule, incorporate some discretion in their monetary response rule. Taylor's rule extends further by allowing for other variables such as stock prices, exchange rates, fiscal deficit, employment, and private credit (Patra and Kapur, 2012).

The general formulation of Taylor's rule is given below

$$i_t = f(\Delta\pi_t, \Delta y_t) \qquad (1.1.1)$$

Where;

i_t = central bank interest rate

$\Delta\pi_t$ = inflation gap (actual inflation- target inflation)

Δy_t = output gap (actual output - target output)

This rule has a linear specification as shown below

$$i_t = \pi_{t-1} + \bar{r} + \alpha(\pi_t - \pi^T) + \beta(Y_t - Y^T) \qquad (1.1.2)$$

Where;

π_{t-1} = average inflation rate over the previous quarter

$\bar{r}$ = neutral interest rate

π^T = target inflation

Y^T = potential output

Generally, the nominal interest rate is the real interest plus inflation in that period. Thus, the first two terms correspond to interest rate in the previous period. This term is added for interest rate smoothing so that Taylor's rule can be specified as

$$i_t = i_{t-1} + \alpha(\pi_t - \pi^T) + \beta(Y_t - Y^T) \quad (1.1.3)$$

According to Taylor (1993), the coefficients α and β are expected to be positive. This implies when actual inflation exceeds the targeted inflation, the interest rate is increased. Therefore, when inflation rate shoots above its target, it is responded to by the central bank contractionary monetary policy. Similarly, an increase in actual output over the targeted will result in increase in interest rate. This is because when the output exceeds the targeted output then a contractionary monetary policy will be required to reduce output and bring it towards the target output.

The second monetary policy rule, McCallum's rule specified monetary base as the monetary policy instrument. In this proportional rule, there is feedback from changes in the nominal income growth rate onto the monetary base. The model is generalised as

$$b_t = f(\Delta x) \quad (1.1.4)$$

Where

b_t = monetary base

Δx = nominal income growth rate gap (actual nominal income growth rate - target nominal income growth rate)

The function is specified as the linear function shown below

$$\Delta b_t = \Delta x^* - \Delta v_t + \varphi(\Delta x^* - \Delta x_{t-1}) \quad (1.1.5)$$

Where

Δb_t = change in the log of the monetary base

Δx^* = target growth rate for nominal GDP

Δx_t = change in the log of nominal GDP

Δv_t = average growth of base velocity over the previous 16 quarters or 4 years

Change in nominal GDP is generally considered change in price level plus change in real income. The average growth of base velocity was introduced as it represents a long-lasting trend unlike average growth in velocity. Based on Fishers equation, the nominal growth rate less average growth of base velocity is expected to be the growth in monetary base. Thus, the first two variables reflect long lasting changes that may affect monetary base. This term is however not considered vital and can thus be left out (Patra & Kapur, 2012). McCallum's rule can then be simplified to

$$\Delta b_t = \Delta b_{t-1} + \alpha[(\Delta p + \Delta y) - (\Delta p + \Delta y)^*] \qquad (1.1.6)$$

Where;

Δp = change in price level

Δy = change in income

Simplified as;

$$\Delta b_t = \Delta b_{t-1} + \gamma(\Delta p - \Delta p^*) + \beta(\Delta y - \Delta y^*) \qquad (1.1.7)$$

Where $\alpha = \gamma + \beta$

The coefficients $\gamma$and β are expected to be negative. This is because an increase in inflation over its target will be responded to by a decrease in monetary base, a contractionary monetary policy response. An increase in output over its target will also require a contractionary monetary policy action to bring output down to its target, thus a decrease in the monetary base is required.

4.2. Model Specification

Since Zambia has had two major policy instruments in the last 20 years, two response functions are estimated, one based on Taylor's rule and the other on McCallum's rule as done by Rotich et.al (2007). According to Patra and Kapur (2012) exchange rate smoothing is vital in these rules for emerging economies since the Central Bank has to intervene frequently as small economies are more often exposed to exchange rate volatility. Therefore, exchange rates are added to both response functions as done by Graber and Hertz (2000).

To estimate response functions, Taylor (1993), suggested a complete structural model would make it easy to quantify the effects of monetary policy since it will incorporate exogenous effects of aggregate supply and demand. However, Rudebusch (1998) advocated for the VAR model in studying monetary policy as it can identify the effects of a policy without a complete structural model. The SVAR approach is used to estimate the response functions as it not only allows for endogeneity but also allows for more realistic assumptions to be imposed on the model during identification. Relative to a reduced form VAR, an SVAR will allow for contemporaneous correlations where theory or empirical evidence may be used to put restrictions. Imposing appropriate restrictions will ensure reliable impulse response functions.

The SVAR framework is as shown below;

$$SX_t = A_0 + \sum_{i=1}^{p} A_i X_{t-i} + \gamma_i d_i + V_T \qquad (1.2.1)$$

Where X_t denotes a vector of endogenous variables

Thus, $X_t = (i, Y, \pi, Ex)'$ for the Taylor rule based model and
$X_t = (Ms, Y, \pi, Ex)'$ for the McCallum based rule.

The variables are defined as

V_T is a vector of disturbance terms with mean of zero and constant variance.

A is matrix of lagged coefficients

d_i is a vector of dummy variables where d_i=1 when t=2012 to 2017 (representing period on interest rates as policy instrument) and 0 otherwise.

S is an n*n matrix of coefficients showing the contemporaneous interactions between the variables in X to isolate purely exogenous shocks.

i = Policy rate

Y = Output gap

π = Inflation gap

Ex = Exchange rate

Ms = Money Supply

As stated by Taylor (1993), $Y_t = 100(y - y^*)/y^*$, where y^* is obtained from output trend. If y is regressed against time, the estimated y represents potential y = y*. The time dummy is included to take care of any structural breaks particularly with interest rates.

As the model (1.2.1) appears, it cannot be estimated as the unknown parameters exceed the number of equations available. To ensure the model is exactly identified, the model is pre-multiplied by the inverse of the S matrix as shown below;

$$S^{-1}SX_t = S^{-1}\,A_0 + \sum_{i=1}^{p} S^{-1}A_iX_{t-i} + \gamma_i S^{-1}d_i + S^{-1}V_T \qquad (1.2.2)$$

Which can be simplified as

$$X_t = Z_0 + \sum_{i=1}^{p} Z_iX_{t-i} + \delta_i d_i + \varepsilon_T \qquad (1.2.3)$$

Where $Z_0 = S^{-1}\,A_0$;

$Z_i = S^{-1}A_i$;

$\delta_i = \gamma_i S^{-1}d_i$;

$\varepsilon_T = S^{-1}V_T$

Using the model above, restrictions can be imposed on the S matrix to ensure exact identification. These restrictions will be based on economic theory providing a structural model as opposed to using the Choleski decomposition which makes assumptions that are hard to justify (Roger, Smith, & Morissey, 2017). Additionally, Christiano et al. (2006) argued that short-run SVARs perform remarkably well when used to construct impulse response functions. A non-recursive approach is adopted as it is argued to better represent Central Bank behaviour. This is because the policy instruments are assumed to have contemporaneous effects on the macroeconomic variables as opposed to recursive models which may only correlate the instruments to lags of macroeconomic variables (Raghavan, Silvapulle, & Athanasopoulos, 2012).

The relationship between the VAR residuals and the orthogonal structural shocks can be represented by the lower triangular matrix in equation 1.2.5.

$$\begin{bmatrix} v_{1t} \\ v_{2t} \\ v_{3t} \\ v_{4t} \end{bmatrix} = \begin{bmatrix} S_{11} & 0 & 0 & 0 \\ S_{21} & S_{22} & 0 & 0 \\ S_{31} & S_{32} & S_{33} & 0 \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix} \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \end{bmatrix} \qquad (1.2.4)$$

This matrix S essentially represents the restrictions to be imposed on the model where some variables will have contemporaneous effects and others will not. Since there are 4 endogenous variables, there will be 4 restrictions as done by Sims (1992).

From this SVAR (p) model 1.2.3 the desired system of equations is obtained. The ordering of the variables is also of importance in the SVAR framework. The ordering of the endogenous variables requires the first variables be the one with the least contemporaneous potential impact on all the other variables. The order will be based on increasing impact on the remaining variables as done by Hsing (2004) beginning with exchange rates, inflation gap, output gap and the policy instruments.

Output gap is ordered first in this as it is considered exogenous in this model. This is because output is determined mostly by supply-side factors which are considered external factors in the model and are generally respond slowly to monetary changes. Exchange rates are then ordered as exchange rates are known to be determined by supply and demand forces which are both domestic and foreign factors. Output is said affect supply of foreign currency leading to an appreciation/depreciation of domestic currency. Consequently, inflation is ordered thirdly as it responds directly to exchange rate changes particularly in small open economies. For Zambia, being highly import dependent entails an increased pass-through effect from exchange rates to domestic price level. The policy instruments are then ordered as they are responsive to changes in inflation or/and output.

Based on the SVAR modelled above, the Taylor-rule based equation and McCallum-rule based equations were drawn out as shown;

$$\begin{bmatrix} Y_t \\ \pi_t \\ Ex_t \\ i_t \end{bmatrix} = \begin{bmatrix} Z_{01} \\ Z_{02} \\ Z_{03} \\ Z_{04} \end{bmatrix} + Z_{1i} \begin{bmatrix} Y_{t-1} \\ \pi_{t-1} \\ Ex_{t-1} \\ i_{t-1} \end{bmatrix} + \cdots + Z_{pi} \begin{bmatrix} Y_{t-p} \\ \pi_{t-p} \\ Ex_{t-p} \\ i_{t-p} \end{bmatrix} + \delta_i \begin{bmatrix} d_{1i} \\ d_{2i} \\ d_{3i} \\ d_{4i} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \end{bmatrix} \quad (1.2.5)$$

$$\begin{bmatrix} Y_t \\ \pi_t \\ Ex_t \\ Ms_t \end{bmatrix} = \begin{bmatrix} Z_{01} \\ Z_{02} \\ Z_{03} \\ Z_{04} \end{bmatrix} + Z_{1i} \begin{bmatrix} Y_{t-1} \\ \pi_{t-1} \\ Ex_{t-1} \\ Ms_{t-1} \end{bmatrix} + \cdots + Z_{Pi} \begin{bmatrix} Y_{t-p} \\ \pi_{t-p} \\ Ex_{t-p} \\ Ms_{t-p} \end{bmatrix} + \delta_i \begin{bmatrix} d_{1i} \\ d_{2i} \\ d_{3i} \\ d_{4i} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \end{bmatrix} \quad (1.2.6)$$

The system of equations will then give an equation similar to Taylors' equation (1.1.3) from system 1.2.6

$$i_t = Z_{04} + \sum_{j=1}^{p} Z_{1i} Y_{t-j} + \sum_{j=1}^{p} Z_{2i} \pi_{t-j} + \sum_{j=1}^{p} Z_{3i} Ex_{t-j} + \sum_{j=1}^{p} Z_{4i} i_{t-j} + \gamma_i d_i \quad (1.2.7)$$

Similarly, the second VAR (1.2.3) is run to obtain the McCallum response functions (11.6) for monetary aggregates from system 1.2.7;

$$Ms_t = Z_{04} + \sum_{j=1}^{p} Z_{1i} Y_{t-j} + \sum_{j=1}^{p} Z_{2i} \pi_{t-j} + \sum_{j=1}^{p} Z_{3i} Ex_{t-j} + \sum_{j=1}^{p} Z_{4i} Ms_{t-j} + \gamma_i d_i \quad (1.2.8)$$

Impulse response functions were used to determine the response of policy rates when a shock in the output and inflation gap is introduced to the system in (1.2.6). Similarly, the response of monetary aggregates to a shock in the output and inflation gap is obtained from the impulse response functions for (1.2.7).

4.3. Choice and Measurement of Variables

Quarterly data from 2001 to 2018 obtained from the BoZ, Ministry of Finance (MoF) and Central Statistical Office (CSO) is used for analysis of both the Taylor- based rule and the McCallum based rule. There is no quarterly data available for GDP for the period 2001 to 2010, hence the Index of Industrial Production (IIP) was used to proxy a quarterly GDP series as done by Chileshe and Zgambo (2014). Output gap is measured by the difference between the actual output and potential output where potential output was proxied by estimating a trend series using the Hodrick-Prescott Filter as done by McCallum (2000). Thus, a positive output gap represents an excess of demand over the potential output.

The inflation gap is computed by obtaining the difference between actual inflation and target inflation. Since only annual targets for inflation are available, the inflation gap in any given year depended only on the actual inflation in each quarter. End quarter values were used as the main interest was to determine how far the actual value is from the target. The other variables are taken as given by the central bank. Money supply is measured as M2 and entered in logarithmic form for scaling purposes whilst exchange rate is measured as the domestic price of a US dollar, as US dollar is the most commonly traded foreign currency in Zambia.

5. Analysis
5.1. Unit Root Tests

To avoid obtaining spurious results, a phenomenon common in time series data, unit root tests were carried out. The Augmented Dickey Fuller (ADF) is usually considered when testing time series for unit root. Other stronger tests like the Phillips-Perron (PP) and Kwiatkowski-Philip-Schmidt-Shin (KPSS) are also preferable. However, none of these tests consider the probability of a structural break in their functional form. Thus, to incorporate possible structural breaks, breakpoint unit root tests as suggested by Clementine-Montanes-Reyes (1998) were used. This approach allows for either an additive outlier or an innovative outlier. The study used an innovative outlier as this is considered superior due to its allowance of a dual change in the mean of the time series as opposed to a sudden change (Muchai and Muchai, 2016). The breakpoint unit root results are summarized in the table below.

Table 1: Breakpoint Unit Root Test

Variable Name	*Break point*	*P-values*		*Summary*
		Levels	First difference	
Policy Rate[5]	2004Q4	0.0173	-	I(0)
Money Supply	2015Q4	0.0132	-	I(0)
Inflation Gap	2015Q2	0.0459	-	I(0)
Output Gap	2010Q1	< 0.01	-	I(0)
Exchange rates	2015Q2	< 0.01	-	I(0)

The results above indicate that all the variables are stationary at levels. This implies running the model in its level form will not give spurious regression. It could also be noted that the breakpoint for most variables was 2015, when the country experienced falling copper prices. Cointegration tests were not run as the study did not focus on the long-run relationship of the variables.

5.2. Empirical Results and Discussion

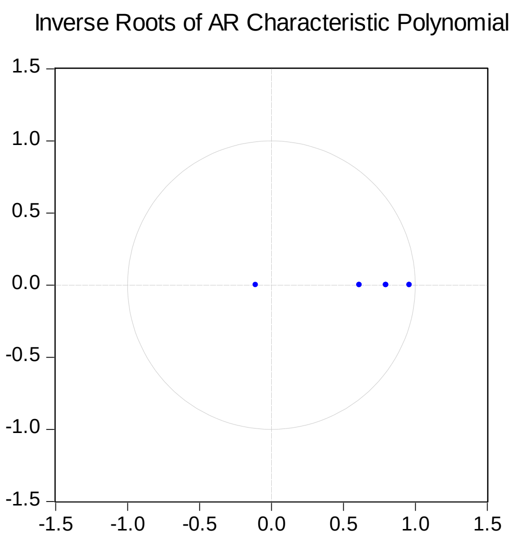
The Structural VAR was of main interest in identifying the impact of policy instruments on macroeconomic variables. To do this, a reduced form VAR for each of the policy instruments was run. Running a VAR model requires that all the variables be stationary, thus the two VAR models are estimated using the variables in their level form.

[5] Prior to 2012, the proxy used for the policy rate is the 91-day Treasury bill rate.

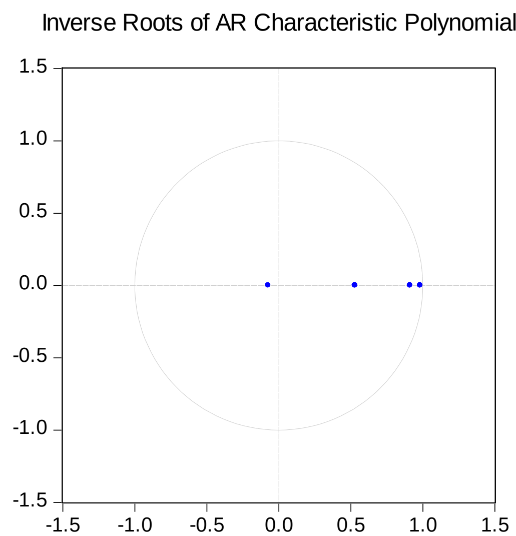
The first VAR model was estimated using 1 lag based on the SIC, FPE and HQ information criteria. The Taylor Rule estimated at 1 lag appears to be a good model with a coefficient of determination of 86%. The coefficients are as expected with policy rate being affected positively by changes in output gap and inflation gap but negatively by changes in the exchange rate. The dummy is also noted to be statistically insignificant and so the interest rate-based rule model is estimated for the whole period under study. The model output and its diagnostics are shown in appendix A. Additionally, the AR unit root graph is shown in figure 2 below and indicates stability of the model.

The second VAR model estimated to draw out the McCallum rule was also estimated using 1 lag. The model has a coefficient of determination of about 99% reflecting a good measure of fit. However, the variable signs are not as expected with money supply responding positively to output gap, and negatively to both inflation gap and exchange rate changes. The model output and the diagnostic tests of this model are presented in appendix B while the AR unit root graph is shown in figure 2 below.

Figure 2: AR unit root graphs



AR graph for Taylor based rule



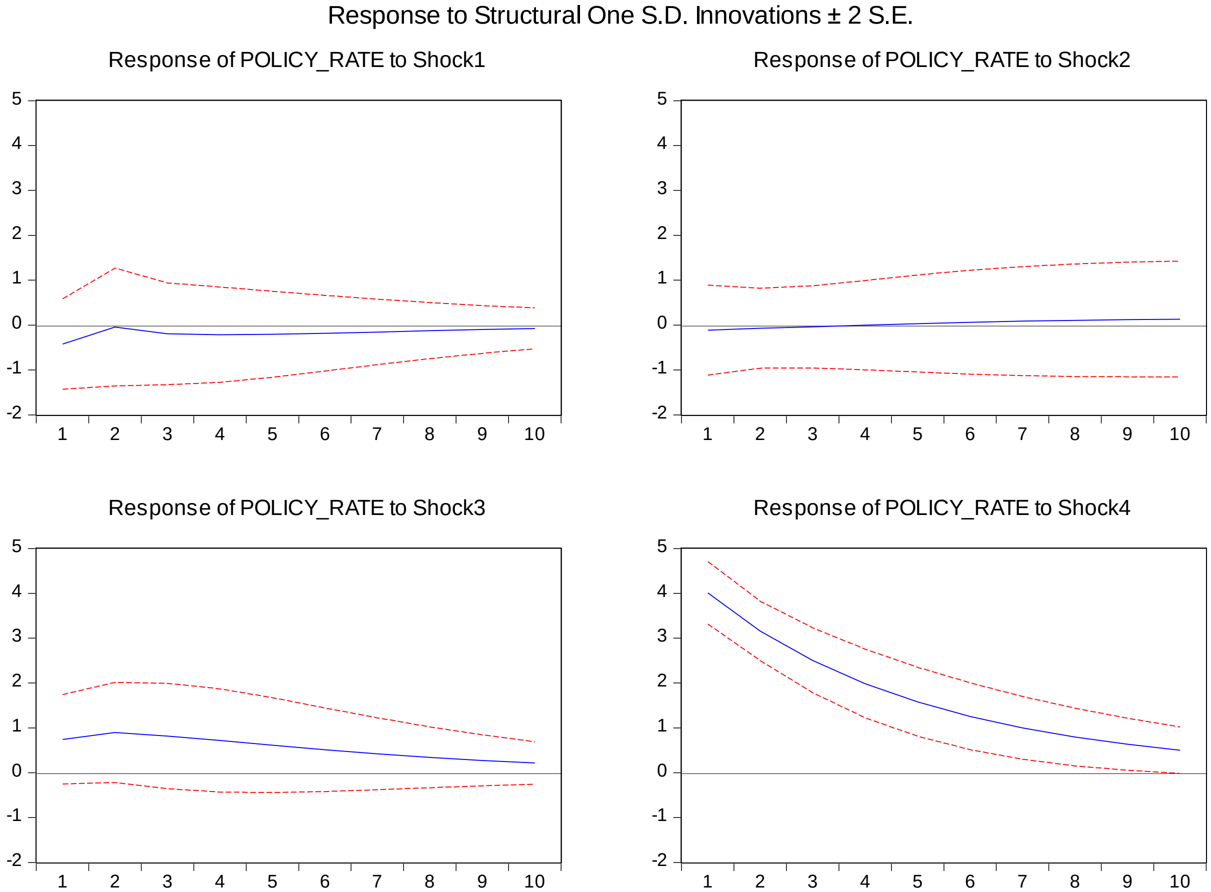
AR graph for McCallum based rule

Based on the above stable reduced VAR models, the SVAR orthogonal matrix can be estimated. The response of the policy instruments to the macroeconomic changes can thus be obtained from the SVAR impulse response functions. The estimated system of shocks from the SVAR for the Taylor based rule and McCallum based rule is shown in Appendix A3 and B3 respectively.

5.3. Impulse Response Functions

Impulse response functions, also referred to as dynamic multipliers, have been widely used for establishing interrelationships amongst variables in a SVAR model. Impulse response functions trace the effect of a one standard deviation shock to one of the innovations on current and future values of the endogenous variable (Enders, 2015). In this study, the endogenous variables are considered to be the interest rate (giving a Taylor rule-based model) and money supply (giving a McCallum rule). Therefore, the response of these endogenous variables to a shock to any of the other macroeconomic variables is of primary interest.

Figure 3: Impulse Response Functions for Policy Rates*



*The red lines represent 95% confidence interval
Shock 1 represents Output gap
Shock 2 represents Exchange rates
Shock 3 represents Inflation gap
Shock 4 represents Policy rates

From the impulse response functions above (Figure 3), it can be observed that the policy rate generally responds positively to a shock from output gap and inflation gap particularly in the first quarter and the effects dying down within a quarter. This is as expected as an increase in actual output over the target output would require a positive response from the policy makers as a contractionary measure. However, this response is statistically insignificant showing the central bank behaviour may be consistent in that the response is as expected but not sufficient as the response is not significant. Shocks to exchange rates appear to trigger no response from the central bank which would be expected in a floating exchange rate regime.

Table 1 in Appendix C shows the accumulated impulse response of policy rates to shocks from the targets. Though insignificant, the policy rates react positively to a structural one standard deviation (2.91) shock to inflation gap showing a 5.05 increase after 2 years.

Figure 4: Impulse Response functions of output and inflation gap due to policy rates.

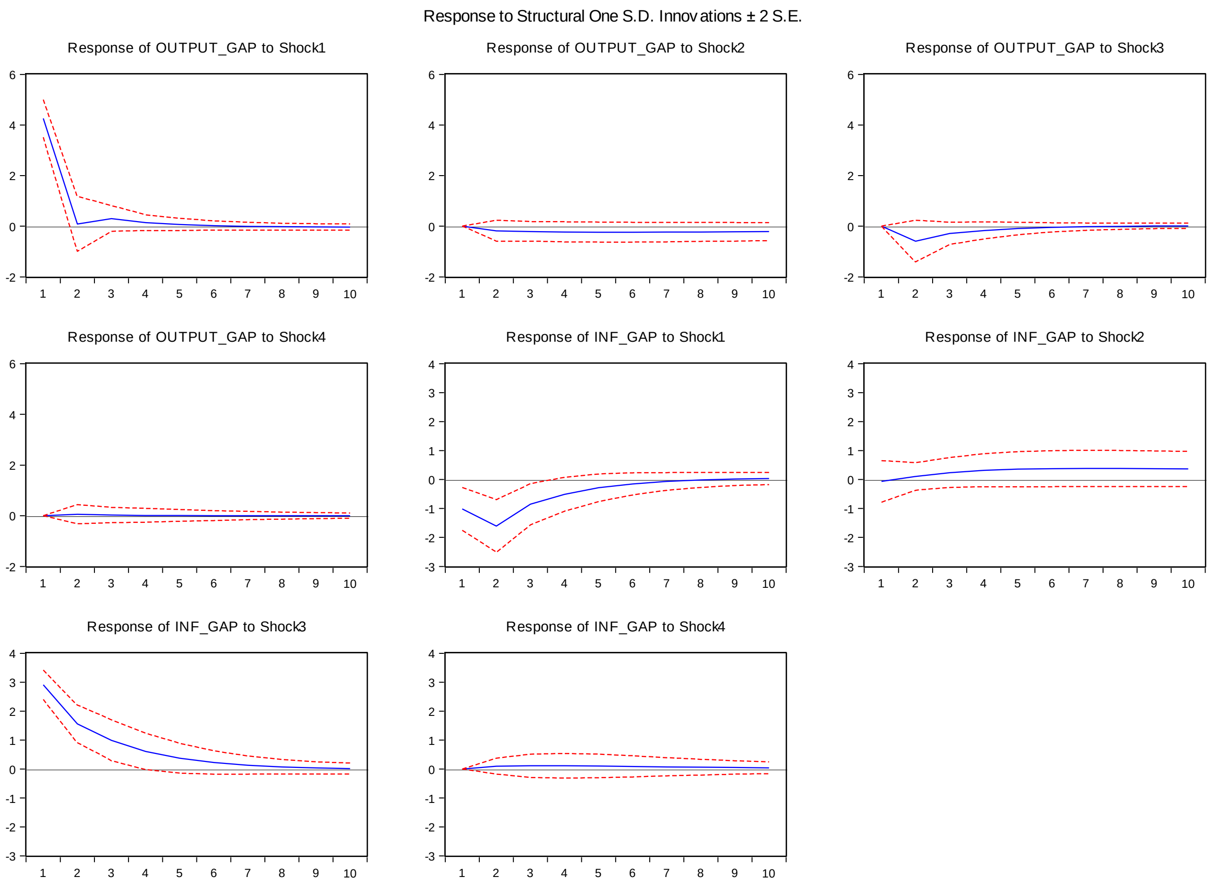
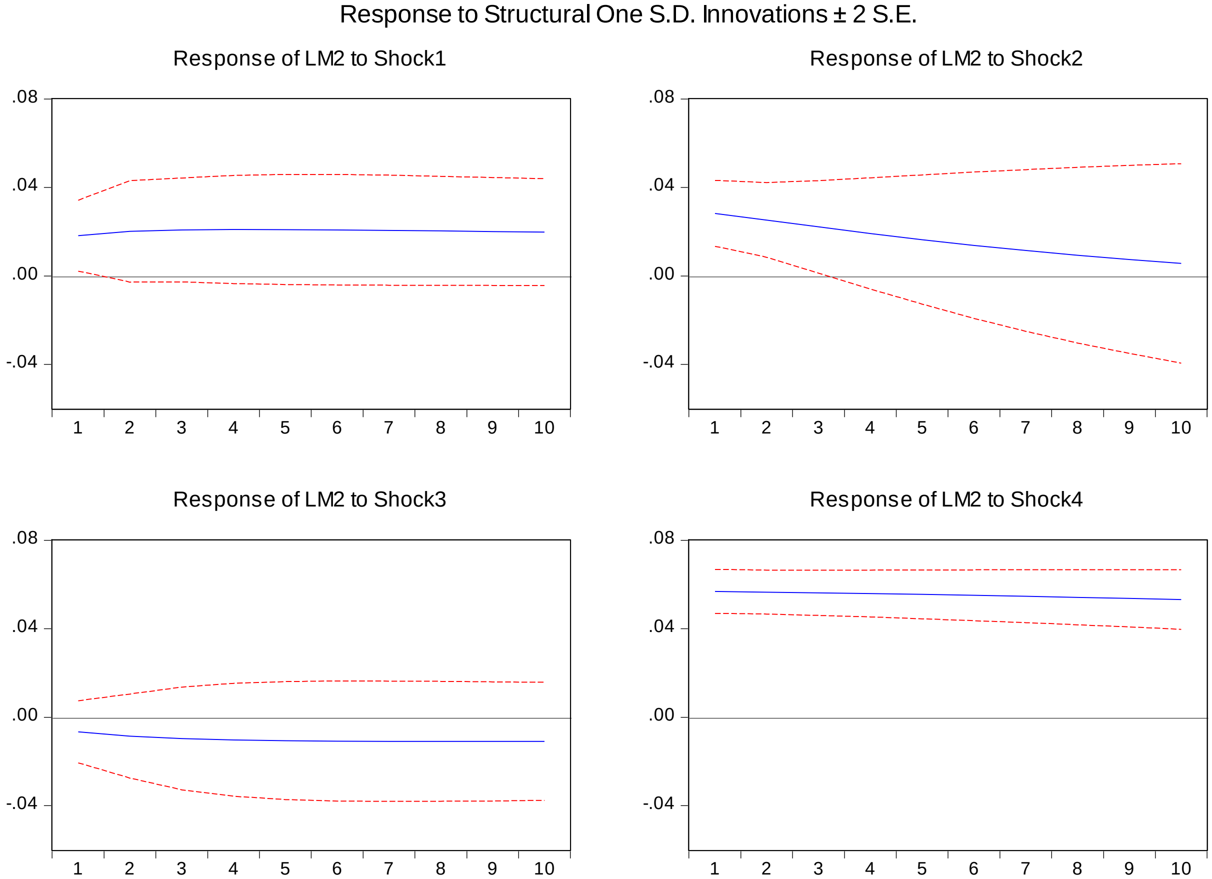


Figure 4 above indicates the response of the targets to shock in the policy rate instrument. Both inflation gap and output gap do not respond significantly to shock in the policy rate. This suggests the weak transmission mechanism between interest rates and inflation gap as argued by Chileshe et.al (2014). It is also observed that inflation gap does have a negative significant response to a shock in the output gap indicating the quick response of price changes due to output changes. This however is contrary to expectations as inflationary pressure is expected to increase with output. It could be explained by the high import dependence and exchange rate pass through so that increase in output increases domestic consumption reducing some inflationary effects.

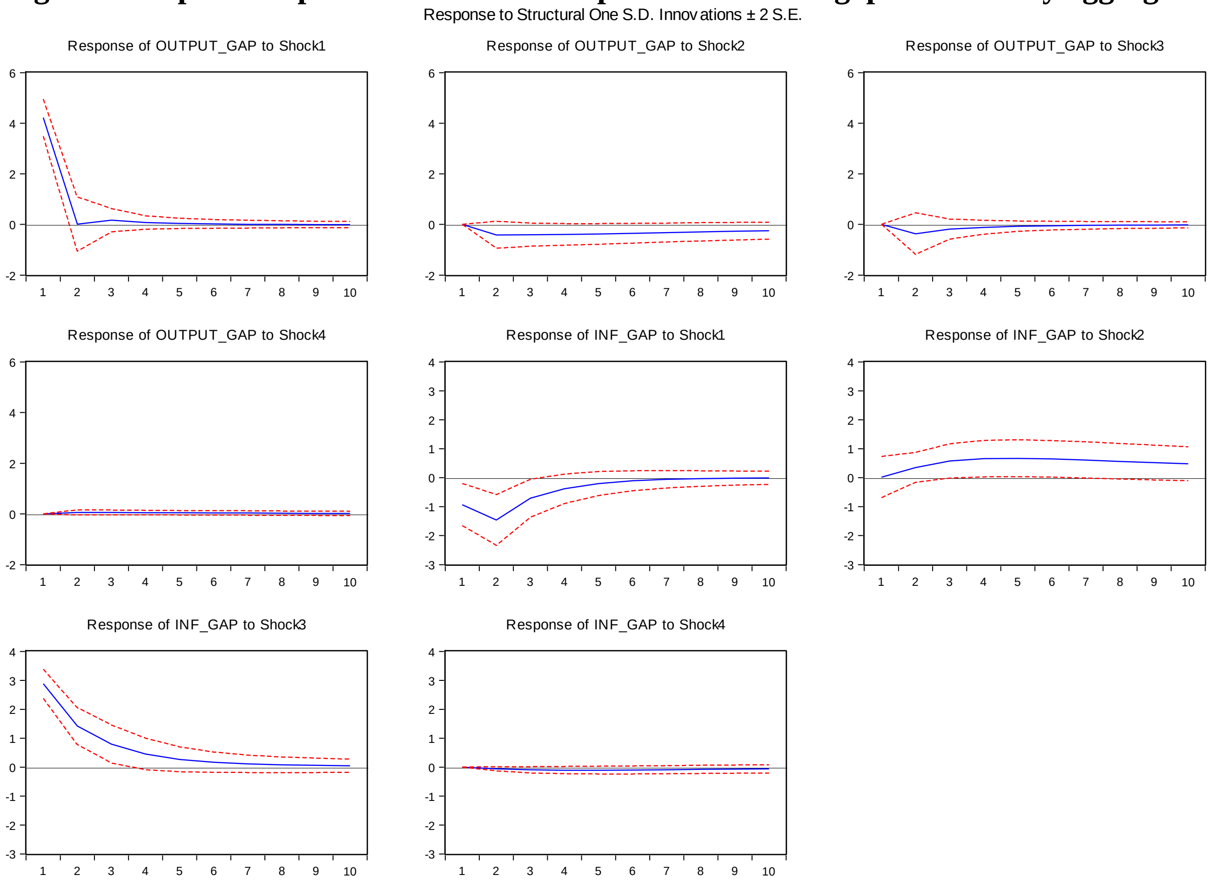
Figure 5: Impulse Response Functions for Money Supply



The impulse response functions of money supply reflect the central banks response to changes in the macro economy using monetary aggregates (see Figure 5). Generally, a shock to the inflation gap or output gap requires that money supply fall to reduce inflation or output. The response functions indicate that monetary aggregates too do not have a significant reaction to both shocks in inflation and output. Inflation as expected appears to trigger a negative response while output appears to trigger a positive response. Exchange rates, however trigger an immediate positive significant reaction from money supply. A depreciation would generally imply increased demand for domestic currency to allow for purchase of imported goods.

Table 2 in appendix C similarly shows a consistent negative response of policy rates due to inflation shocks and positive responses to output shocks. A one standard deviation (2.88) shock in the inflation gap will lead to a 1.5%, 3.5% and 7.5% decrease in money supply over a 2 quarter, 1 year and 2-year period respectively. Since price stability is the main objective of the central bank, the results also suggest the banks' behaviour may be consistent but not sufficient to effect a significant change in inflation.

Figure 6: Impulse response functions of output and inflation gap to monetary aggregates



Similar to policy rates, inflation gap and output gap do not have a significant response to a shock in the monetary aggregates. This again indicates a weak transmission from monetary aggregates (M2) to policy targets i.e. inflation and output gap as argued by Pamu (2005) and Mutoti (2006). This weak transmission channel could also explain the insignificant negative response of money supply when there is a shock to inflation. Inflation gap appears to respond significantly to changes in exchanges rates over the 3 to 6th quarter which may indicate a good intermediate target as changes in exchange rate appear to trigger responses from the inflation gap though the response is not immediate.

5.4. Variance Decomposition Functions

The variance decomposition function gives the proportion of variation in each series caused by a shock to the series. It decomposes variation in an endogenous variable into the component shocks of the other endogenous variables. The tables below show the variance decomposition of the policy instruments.

Table 4: Variance Decomposition of Policy Rate

Period	S.E.	Output gap	Exchange rate	Inflation gap	Policy rate
1	4.255912	1.070979	0.076712	3.277814	95.57449
2	4.301480	0.660348	0.065990	4.894794	94.37887
3	4.326632	0.638373	0.057287	5.828086	93.47625
4	4.338248	0.681704	0.050695	6.478321	92.78928
5	4.346222	0.735906	0.049576	6.924167	92.29035
6	4.353001	0.780846	0.056117	7.224726	91.93831
7	4.359330	0.812800	0.071170	7.422999	91.69303
8	4.365373	0.833284	0.094506	7.550749	91.52146
9	4.371129	0.845209	0.125176	7.630871	91.39874
10	4.376571	0.851363	0.161838	7.679467	91.30733

The results in Table 4 show policy rates are mainly explained by their own factors which explain over 90% over the medium term. Inflation gap is the second biggest factor explaining changes in policy rate. This proportion is quite small at 3.3% but increases to about 7% after 6 quarters. Exchange rates and output gap do not explain much about the policy rates over the entire period indicating that inflation gap plays a relatively more important role in explaining the policy rate.

Table 5: Variance Decomposition of Money Supply

Period	S.E.	Output gap	Exchange rates	Inflation gap	Money Supply
1	4.220783	7.482240	18.12868	1.000979	73.38811
2	4.257169	8.421660	16.48057	1.343266	73.75450
3	4.284015	9.034534	14.95430	1.629175	74.38199
4	4.304997	9.479702	13.56470	1.861887	75.09371
5	4.322549	9.812556	12.31544	2.052808	75.81920
6	4.337319	10.06650	11.20215	2.211775	76.51958
7	4.349689	10.26311	10.21642	2.346260	77.17421
8	4.359995	10.41693	9.347974	2.461716	77.77338
9	4.368547	10.53813	8.585910	2.562101	78.31386
10	4.375625	10.63397	7.919416	2.650309	78.79630

Table 5 gives the variance decomposition of money supply. All the variables significantly explain a proportion of the money supply forecast error variance with money supply itself explaining the largest portion. Unlike policy rate, exchange rates explain the second biggest proportion of money supply which decreases in the medium term. The output gap explains the third proportion which increases in the 7th quarter to be the second biggest factor explaining money supply changes. For money supply unlike policy rates, inflation gap seems to play a smallest role in explaining its changes.

6. Summary and Conclusions

Using an SVAR model, this study was able to obtain impulse response functions showing the policy rates reaction to shocks in inflation gap, output gap and exchange rate synonymous to an extended Taylor-rule Function. The results showed that the policy rate does respond as expected with regards to inflation gap shocks but this response like that of the output gap and exchange rates are insignificant. This is may indicate the Central Banks' attempt to follow a systematic rule-based monetary policy but having little effect due to the poor transmission existing between policy rates and inflation gap as observed by inflation gaps insignificant response to shocks in the policy rates. Similarly, the monetary aggregates rule also does not respond significantly to changes in output gap and inflation gap. Despite the poor transmission channel existing amongst these variables, exchange rate and output gaps explain significant proportions of money supply indicating it may be more reactive to these variables than the policy rate. Additionally, money supply is seen to be significantly respond to changes in exchange rates. Sanchez-Fung (2002) suggests insignificant reaction functions may indicate discretionary behaviour over a systematic rule of the part of the central bank.
Exchange rates explain a significant proportion of monetary aggregates relative to inflation gap and a shock to exchange rates causes a significant reaction in the inflation gap and monetary aggregates. This could suggest exchange rates playing a significant role as an intermediate target. According Taylor (1999) research has indicated that the central bank may have to react to exchange rates when setting interests rates or use monetary aggregates which automatically affect exchange rates. Therefore, the central bank may consider managing the exchange rate in line with monetary policy to ensure the policy instruments are more effective.

6.1. Limitations of Study

This study was limited by unavailability of data. Output, which was proxied by the industrial production index, was only available for the period 2000 to 2016 in quarterly series. Consequently, all other variables where restricted to this period and some series like fiscal deficit6 and copper prices were left out.

Target output was obtained using Hendrick Prescott filter. This was because only annual GDP growth rate targets were available and not GDP targets. The use of a trend series could lead to smoothen data and consequently provide a poor representative of the actual targets set by the policy makers.

[6] Only available in annual series

6.2. Areas of Further Research

There is much more research that can be done in this area. A study using policy rates for the period that Central Bank has used it as a policy instrument and money supply for the period that monetary aggregates where the policy instrument can be considered. Another study could include more variables such as overnight lending rate, oil prices, international reserves, fiscal deficit as government decisions/activity plays a key role in economies. Furthermore, a cointegrated Structural VAR model could also be considered to allow for long term effects. The Dynamic Stochastic General Equilibrium (DSGE) models can also be considered to get a wider picture of how the monetary policy variables react to macroeconomic changes.

Taylor (1993) states that quarterly time series would be good for studying changes in interest rates since changes in interest rates generally can't be held constant in a quarter. However, monthly data is also considered to better representation of central banks behaviour as the banks are likely to react within a short period. Thus, further research may be done with monthly and a better representation can be established from this.

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Appendix

Appendix A: Taylor Rule Based-Model

A1: Taylor rule based output

	Output gap	*Exchange rate*	*Inflation gap*	*Policy rate*	*Dummy*
Output gap(-1)	-0.027834	0.012860	-0.246968	0.093897	0.001767
	(0.13368)	(0.02108)	(0.09633)	(0.12939)	(0.00393)
	[-0.20822]	[0.61004]	[-2.56374]	[0.72568]	[0.44938]
Exchange rate(-1)	-0.506728	0.872658	0.447681	0.128942	0.010501
	(0.40775)	(0.06430)	(0.29384)	(0.39468)	(0.01199)
	[-1.24274]	[13.5712]	[1.52357]	[0.32670]	[0.87580]
Inflation gap(-1)	-0.184944	0.001717	0.507332	0.097711	-0.002663
	(0.14746)	(0.02325)	(0.10626)	(0.14273)	(0.00434)
	[-1.25423]	[0.07382]	[4.77438]	[0.68458]	[-0.61405]
Policy rate(-1)	0.017222	0.001187	0.019589	0.786680	-0.000750
	(0.04824)	(0.00761)	(0.03476)	(0.04669)	(0.00142)
	[0.35703]	[0.15611]	[0.56354]	[16.8489]	[-0.52888]
Dummy(-1)	1.313401	0.581110	-1.390903	-0.549217	0.938413
	(1.73287)	(0.27327)	(1.24876)	(1.67734)	(0.05096)
	[0.75794]	[2.12648]	[-1.11383]	[-0.32743]	[18.4153]
C	2.537055	0.571408	-1.069937	1.999446	-0.001399
	(2.09715)	(0.33072)	(1.51127)	(2.02995)	(0.06167)
	[1.20976]	[1.72776]	[-0.70797]	[0.98497]	[-0.02269]
R-squared	0.075975	0.904448	0.522348	0.864103	0.935473

A2: Diagnostics

Diagnostic	***Test***	***Null Hypothesis***	***P-values***	***Summary***
Heteroscedasticity	Whites Heteroscedasticity Test	Homoscedasticity	0.001	Heteroscedastic residuals
Autocorrelation	LM Autocorrelation Test	No autocorrelation	0.4528	Uncorrelated residuals
Normality	Jarque-Bera	Normality of residuals	0.000	Not Normally distributed residuals

A3 Estimated Short Run coefficients

$$\varepsilon_1 = 4.255912u_1$$
$$(0.00)$$
$$\varepsilon_2 = 0.005357\varepsilon_1 + 0.692307u_2$$
$$(0.7891) \qquad (0.00)$$
$$\varepsilon_3 = -0.238461\varepsilon_1 - 0.098206\varepsilon_2 + 2.910406u_3$$
$$(0.0046) \qquad (0.8495) \qquad (0.00)$$
$$\varepsilon_4 = -0.038033\varepsilon_1 - 0.139103\varepsilon_2 + 0.255274\varepsilon_3 + 4.011792u_4$$
$$(0.7571) \qquad (0.8454) \qquad (0.1325\ ) \qquad (0.00)$$

Note: Values in parenthesis are the respective p-values

Appendix B: McCallum Based model

B1 Vector Autoregression Model

	Output gap	*Exchange rate*	*Inflation gap*	*Money Supply*	*Dummy*
Output gap(-1)	-0.027421	0.012759	-0.235101	0.000374	0.001255
	(0.13240)	(0.02093)	(0.09492)	(0.00206)	(0.00385)
	[-0.20711]	[0.60959]	[-2.47688]	[0.18163]	[0.32571]
Exchange rate(-1)	-0.686358	0.856258	0.596491	-0.007175	0.003031
	(0.44919)	(0.07101)	(0.32203)	(0.00699)	(0.01307)
	[-1.52799]	[12.0583]	[1.85231]	[-1.02707]	[0.23188]
Inflation gap(-1)	-0.123861	0.006945	0.487397	-0.000613	-0.001451
	(0.14393)	(0.02275)	(0.10318)	(0.00224)	(0.00419)
	[-0.86057]	[0.30522]	[4.72362]	[-0.27367]	[-0.34636]
Money supply(-1)	0.835221	0.078791	-0.915066	0.984793	0.044401
	(1.06227)	(0.16793)	(0.76155)	(0.01652)	(0.03091)
	[0.78626]	[0.46919]	[-1.20159]	[59.6094]	[1.43641]
Dummy(-1)	0.502034	0.505921	-0.620888	0.035921	0.900430
	(1.97133)	(0.31164)	(1.41325)	(0.03066)	(0.05736)
	[0.25467]	[1.62343]	[-0.43933]	[1.17165]	[15.6967]
C	-3.930590	-0.048077	6.839028	0.220607	-0.380876
	(8.88264)	(1.40421)	(6.36800)	(0.13815)	(0.25848)
	[-0.44250]	[-0.03424]	[1.07397]	[1.59691]	[-1.47353]
R-squared	0.083455	0.904759	0.531103	0.995104	0.937327

B2 Diagnostics

Diagnostic	*Test*	*Null Hypothesis*	*P-values*	*Summary*
Heteroscedasticity	Whites Heteroscedasticity Test	Homoscedasticity	0.024	Heteroscedastic residuals
Autocorrelation	Autocorrelation LM Test	No autocorrelation	0.2805	Uncorrelated residuals
Normality	Jarque-Bera	Normality	0.000	Not Normally distributed residuals

B3 Estimated Short run Coefficients

$$\varepsilon_1 = 4.220783u_1$$
$$(0.00)$$
$$\varepsilon_2 = 0.001445\varepsilon_1 + 0.681344u_2$$
$$(0.9420) \quad (0.00)$$
$$\varepsilon_3 = -0.220439\varepsilon_1 + 0.029873\varepsilon_2 + 2.882677u_3$$
$$(0.0087) \quad (0.9543) \quad (0.00)$$
$$\varepsilon_4 = 0.003733\varepsilon_1 + 0.041534\varepsilon_2 - 0.002303\varepsilon_3 + 0.056843u_4$$
$$(0.0321) \quad (0.0001) \quad (0.3427) \quad (0.00)$$

Note: Values in parenthesis are the respective p-values

Appendix C

Table 1: Accumulated Impulse response functions for Policy rates.

Period	*Output_gap*	*Exchange rates*	*Inflation_gap*	*Policy rate*
1	-0.424676	-0.113658	0.742950	4.011792
2	-0.471401	-0.186615	1.637959	7.173069
3	-0.667666	-0.226567	2.453500	9.679140
4	-0.881671	-0.229318	3.173082	11.66750
5	-1.088227	-0.197590	3.786540	13.24690
6	-1.271386	-0.135917	4.298324	14.50244
7	-1.425771	-0.049481	4.718526	15.50107
8	-1.551072	0.056661	5.059331	16.29568
9	-1.649533	0.177933	5.332977	16.92808
10	-1.724463	0.310372	5.550768	17.43143

Table 2: Accumulated impulse response functions for monetary aggregates

Period	*Output gap*	*Exchange rates*	*Inflation gap*	*Policy rate*
1	0.018150	0.028252	-0.006639	0.056843
2	0.038256	0.053502	-0.015180	0.113360
3	0.059003	0.075663	-0.024818	0.169563
4	0.079974	0.094852	-0.035070	0.225431
5	0.100929	0.111254	-0.045671	0.280933
6	0.121739	0.125086	-0.056471	0.336032
7	0.142338	0.136565	-0.067380	0.390694
8	0.162688	0.145903	-0.078345	0.444885
9	0.182771	0.153299	-0.089328	0.498575
10	0.202576	0.158938	-0.100303	0.551737

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