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*RESEARCH ARTICLE*

# MONETARY POLICY AND INFLATION CONTROL IN RWANDA; 2006-2015

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***Abstract***

This study assessed the effectiveness of monetary policy to control inflation in Rwanda. It specifically determined the relationship between monetary policy variables and inflation employing vector autoregressive model on quarterly data spanning the period 2006 to 2015. After identifying all the variables to be of the same order i.e. I(1), this study employed the Johnsen cointegration test to determine long run relationships. The results indicated that real output followed by nominal exchange rate, money supply and interest rate significantly drives inflation dynamics in Rwanda. Additionally, results from Vector error correction model showed that only inflation inertia and real output affect inflation in the short-run with 12.3% speed of adjustment to restore long run equilibrium every quarter. Lagged period of inflation was determined to be an important determinant of inflation in short run. Putting together the findings from this study, policy wise would be for the monetary regulatory authority in Rwanda to effectively increase its communication with the public in order to reduce the impact of inflation expectations while also ensuring stable exchange rate movements to reduce the effects of imported inflation.



## Introduction:-

In recent years the tempo of price increases in Rwanda has been kept at moderate level. Inflation, persistent increases in the general prices of goods and services over time, is a common phenomenon in a fast growing economy especially in developing countries. Sometimes, because of their rapidly growing economy, inflation increases dramatically because of the uncontrolled price rise. Moreover, measures taken by the government won't yield because of the uncontrolled phenomena like drought which leads to shortage of food production and supply and changes in international price situations (like that of crude oil) among others, pertaining in these countries.

Monetarists viewed inflation as always and everywhere a monetary phenomenon. As such excess supply of money to the economy by the monetary authority causes increase in the price level. Therefore, monetary policy consists of controlling the supply of money for the purpose of promoting economic growth and stability.

Effective monetary policy is crucial to the health of the economy. According to Mishkin (2004), overly expansionary monetary policy leads to increases in price level, which decreases the efficiency of the economy and hampers economic growth. However, more tighten monetary policy can also produce serious recessions in which output falls and unemployment rises. Tighten monetary policy can, therefore, lead to the general fall of price level

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which hampers financial stability and if persistent can result in financial crises. Effectiveness of monetary policy is hence an important aspect to economic activities.

In line with other Central banks or monetary authorities across the globe, the National Bank of Rwanda (BNR) has the end of attaining price stability while ensuring sustainable economic growth through the means of monetary policy. Monetary policy framework in Rwanda has been transitioning from the use of direct monetary instruments from 1964 to 1990, financial liberalization from 1990 to 1995 and the use of indirect instruments from 1995 to today.

BNR conducts monetary policy based on a monetary targeting framework with the monetary base as operating target and interest rate (the Key Repo Rate) as the policy instrument (BNR, 2013).BNR requires two elements to achieve monetary aggregate target. First, the choice of an operational target by the monetary authority, which incorporates all instruments it uses to implement the monetary policy. Second, a strong relationship between the operational target and the money supply (Munyankindi et al. 2008). Therefore, BNR influences economic trends by indirectly controlling the money supply, through the control of the monetary base as operational target.

BNR is responsible for formulating and implementing monetary policy and hence develops a plan aimed at pursuing key macroeconomic goals including stable prices, full employment, and economic growth, among others. For BNR to implements this plan, it uses the tools of monetary policy to induce changes in interest rates, and the amount of money and credit in the economy. Those policy instruments include open market operations, discount window, reserve requirements and foreign exchange interventions. In 2008, BNR replaced instrument like overnight and 7 days operations that were used to borrow liquidity from banks by repurchase agreement operations (REPO). While repos are used for liquidity absorption, reverse repos are used for liquidity injection. However, reverse repo has not been used since 2009 as the banking sector has sufficient level of excess liquidity. Additionally, Treasury bills are mobilized for government financing or for monetary purposes for absorbing excess liquidity for long duration.

More also, BNR introduced investment facility called deposit facility with which banks are allowed to deposit daily their excess liquidity for a maximum maturity of 28 days at a fixed rate of 7% with a discount option beginning on the 15th day. Finally, BNR plays its role of lender of last resort to banks that are in financial troubles (e.g. in 2009 BNR established an emergency lending facility in response to the liquidity crisis) (Bertuch-Samuels and Bartholomew, 2011). Lastly, commercial banks through their account opened with BNR are required to constitute and maintain reserves calculated on the basis of their liabilities and off-balance commitments held in FRW. However, prior to 2010 this caused some fluctuations in the money markets due to the fact that monetary policy actions were more concentrated at the end of each quarter. To overcome this in 2010 BNR introduced some flexibility by allowing average reserve money in 2010 which later in 2012 shifted to reserve money band of + or - 2% around a central reserve money target (BNR, 2013).

A number of studies assessed the relationship between monetary policy variables and inflation. However, these studies revealed mixed results. There has been surprisingly not many studies inflation in Rwanda despite the importance of price stability. While the central bank conducts its monetary targeting framework to ensure price stability, there should be enough studies and researches that link inflation and monetary policy variables to better forecast with certainty the inflation rate in Rwanda that is consistent with macroeconomic stability in the future. BNR needs, therefore, to identify a more reliable relationship between monetary variables and inflation that is likely to prevail in the future to support the decision of the Monetary Policy Committee (MPC) about the monetary policy stance because any unreliability of this relationship raise concerns about the usefulness of those variables as a guide to the conduct of monetary policy. Thus, in recent years the relative importance of monetary policy in the control of inflation remains to be determined.The main objective of this study was,therefore, to apply an econometric model best suited to identifying whether monetary variables are related to inflation in Rwanda. Specifically, it aimed to assess to what extent monetary policy variables affect inflation using the vector autoregressive model on quarterly time series data from 2006-2015.

The rest of the paper is organized as follows: section 2 discusses theoretical and empirical literature; section 3 presents the methodology, section 4 presents the results while section 5 summarizes the findings and discusses policy recommendations.

## Review of relevant literature:-

The relationship between monetary policy and inflation is discussed widely in the literature. The basic theory this study relied on is the quantity theory of money. This theory explains that change in prices is basically due to changes in the money supply. The quantity theory of money is better explained by the following equation normally refers to equation of exchange.

$MV = PY$ 2.1

Where: M, Y, and P respectively denote measures of the nominal quantity of money, real transactions or physical output per period, and the price level, with V then being the corresponding monetary velocity.

The equation of exchange shows that an increase in the quantity of money (M) must be reflected in one of the other three variables. Specifically, the price level (P) must rise, output (Y) must rise, or velocity (V) must fall. The quantity theory of money assumes that at full employment, the level of transaction (national output) and velocity of money, average number of transactions made with each unit of money, are constant. Therefore, movements in the price level result only from changes in money supply. Kromtit (2015) and Kigabo (2008) argue that when velocity of money and output are held constant, the elasticity of price with respect to money growth shows that there is a direct proportional relationship between the general price level (inflation) and the growth rate of money supply. This means, therefore, in a regression of price level on money supply growth, the coefficient of money is estimated to be one.

Algebraically,

$$\varepsilon_{pm} = \frac{\%\, changeinpricelevel}{\%\, changeinmoneygrowth} = 1$$

Where: $\varepsilon_{pm}$: Elasticity of price with respect to money growth.
This can be shown throughout the following procedures.

From the definition of elasticity of price of price with respect to money growth we have:

$$\varepsilon_{pm} = \frac{\frac{\partial P}{P}}{\frac{\partial M}{M}} = \frac{\partial P}{\partial M} * \frac{M}{P} \qquad 2.2$$

By solving equation 1 for P and V, we obtain the following identities:

$$P = \frac{MV}{Y} \text{or} V = \frac{PY}{M} \qquad 2.3$$

Besides, by totally differentiating the equation of exchange using the quotient rule, the following identity is obtained:

$$M\partial V + V\partial M = P\partial Y + Y\partial P \quad 2.4$$

Pigou (1947) argues that at full employment in any economy the velocity (V) of money supply and output are constant. Therefore, at full employment changes in velocity and output are equal to zero.

From equation 2.4, therefore, $M\partial V = 0$ and $P\partial Y = 0$
Thus, $V\partial M = Y\partial P$ 2.5
By arranging, we have:

$$\frac{\partial P}{\partial M} = \frac{V}{Y} \quad 2.6$$

Incorporating equation 2.6 in equation 2.2, we have:

$$\varepsilon_{pm} = \frac{V}{Y} * \frac{M}{P} \quad 2.7$$

Moreover, from equation 2.2, $V = \frac{PY}{M}$. Substituting this into 2.7, we have:

$$\varepsilon_{pm} = \frac{PY/M}{Y} * \frac{M}{P} = 1 \quad 2.8$$

Equation 2.8 reveals that assuming velocity of money and output to be constant, a permanent increase in money growth leads to a proportional increase in the general price level (Wen, 2006).

Studies on monetary policy-inflation relationship cover many today international studies. A number of country specific studies use various econometric models to assess the impact of monetary policy to control inflation. Using multiple regression model and the ordinary least squares (OLS) estimation techniques with data spanning 1973-2010, Asuquo (2012) showed that monetary variables including money supply, interest rate and exchange rate had significant impact on inflation in Nigeria. In contrast, Kromtit (2015) used similar technique with the only differences in the covered period, 1986-2013, results found that interest rate and exchange rate insignificantly impact inflation in Nigeria while gross domestic product has a positive significant relationship with inflation. Again, Danjuma et al. (2012) also used the same technique to examine the impact of monetary policy on inflation in Nigeria over the period 1980– 2010, results revealed that liquidity ratio and interest rate were the main monetary policy instruments in combating inflation in Nigeria while broad money supply, cash reserve ratio and exchange rate insignificantly affect inflation.

Apere and Karimo (2014) investigated the relationship between monetary variables, output and inflation. Results from VAR(1) revealed that in the short run is the level of production that controls inflation while in the long run it is monetary policy variables that matter. In contrast, applying the dynamic model, Durevall et al. (1999) realized that inflation in Kenya is affected by excess supply of money and interest rate in the short run while the exchange rate, foreign prices affect inflation in the long run.

Abdul (2006) using correlation analysis investigated the linkage between the excess money supply growth and inflation in Pakistan using the data from 1960 to 2005. The results indicate that there is a one to one positive association between money growth, real income and inflation in Pakistan.

Misas, Lopez and Querubín (as cited in Ignacio, 2008) through neuronal network models evaluated the relationship between monetary policy variables especially money supply and inflation Their results showed the presence of asymmetries between monetary policy and inflation explains the non-linear relationship between these variables in Columbia despite the use of monetary aggregates as explanatory variables for inflation. These results are consistent with those of Jalil and Melo (as cited in Ignacio, 2008). In contrast, employing a different approach, vector error correction (VEC) model, Ignacio (2008) used quarterly data from 1982 to 2007 in Columbia, found a close relationship between inflation and money supply. Similar results were found by Misas, Posada and Vásquez (as cited in Ignacio, 2008).

Godson (2013) analyzed the effect of monetary policy on inflation in Ghana using annual data from 1985-2009. The results from ordinal least square method found a significant impact of money supply, interest rate and exchange rate on inflation in Ghana. Those results are consistent with those of Mathew (2007). Moreover, using results from Johansen cointegration test and an error correction model, this study found that inflation inertia is the main determinant of inflation in Ghana using annual data from 1960-2003.

As far as Rwanda is concerned, there are a small number of studies that links monetary policy variables and inflation in the period under study. Kigabo et al. (2008), using evidence from VAR(2), found significant impact of money supply and exchange rate on inflation while interest rate insignificantly affect inflation. Their results supported the BNR monetary policy during their study period. Finally, Kigabo (2008), using results from error correction model, indicated that inflation inertia was the main determinant of inflation followed by production and money growth.

Applying VAR approach on data spanning 1997 to 2009, Gichondo and Kimenyi (2012) modelled inflation in Rwanda, the study found a significant relationship between inflation and monetary aggregate, exchange rate, gross domestic product while interest rate insignificantly affect inflation. Nuwagira (2015) investigated evidence of exchange rate pass-through to inflation in Rwanda using structural vector autoregressive (SVAR) with data spanning from 2000 to 2014. The result of the study found although significant and persistent, the degree of exchange rate pass-through was small. Finally, Kigabo et al. (2015) investigated the relationship between economic growth and financial sector development in Rwanda using vector autoregressive model. Their results showed that t a monetary policy shock has significant effects on output and not on inflation. In contrast to previous studies, their study found a small significant relationship between interest rate, repos rate, and bank loans to private sector even if the magnitude of the effect was small.

# Methodology:-

**Variable selection, model development and data source:-**

In line with existing theories and empirical studies, this study modeled inflation to be function of monetary policy variables including broad monetary aggregate, interest rate and exchange rate and a set of intervening variables that affect domestic price level namely real output and international oil prices and follows:

$$CPI_t = f(M3_t, ER_t, REPO_t, GDP_t, INTOIL_t)$$

Where:$CPI$: Consumer price index a proxy for inflation, M3:broad monetary aggregate proxy for money supply, ER: nominal exchange rate, REPO: repo rate a proxy for interest rate, GDP: Real Gross Domestic Product (RGDP) and $INTOIL$: International oil prices.

This study used entirely secondary data from the National Bank of Rwanda (BNR) data base. These included quarterly data spanning the period from 2006 to 2015 the aforementioned variables. The Consumer Price Index (CPI) is used as a measure of inflation. The National Institute of Statistics of Rwanda (NISR) uses Modified formula Laspeyres (ML) to calculate the index (CPI). NISR uses ML method to suit items replacement in the index basket from time to time due to a number of reasons like smooth substitution of new items and frequent weight update every month (Msokwa, 2012). Two measures of inflation namely core and headline inflation are collected by NISR but this study adopted the former in order to avoid volatility in a key price index used to guide monetary policy settings (Gichondo and Kimenyi, 2012). Similar to other studies (Kigabo et al. 2007), (Gichondo and Kimenyi, 20012), (Kigabo et al. 2015) among others, this study used real gross domestic product, the value of all final goods and services produced by an economy in a given year adjusted for inflation, as a proxy for output. Additionally, this study used repo rate, as a proxy of interest rate because the repo market is one of the largest short-term lending markets in Rwanda since 2008. BNR uses repo as policy instrument to regulate liquidity in banking financial system. More also, this used broad monetary aggregate because starting 1995 BNR pursued a monetary targeting regime with broad money supply M3 as a nominal anchor to achieve its ultimate objective of low and stable inflation. Finally, this study used international oil prices in order to capture the effect of imported inflation.

**Data processing and analysis:-**

**Testing for unit root:-**

Testing for the order of integration is standard in applied econometric work because knowing the order of integration is crucial for setting up an econometric model and do inference (Sjöö, 2008). This study applied the Augmented Dickey-Fuller (ADF) unit root test in order to analyze the presence of a unit root. The ADF test includes the lagged values of the dependent variable.

$$\Delta y_t = a_1 + \gamma y_{t-1} + a_2 t + \sum_{i=1}^{k} \alpha_i y_{t-1} + \varepsilon_t$$

Where: $y_t$: represent a $n$x1 vector of variables under study $a_1$: is an intercept, t is linear time trend, k is the number of lagged first differences, and $\varepsilon_t$ is error term. The null hypothesis is unit root and the alternative hypothesis is level stationarity. If the coefficient of $y_{t-1}$(i.e$\gamma$) is significantlydifferent from zero, then the null hypothesis is rejected. Otherwise it is accepted.

**Testing for long run equilibrium: Cointegration test:-**

Testing for unit roots precedes cointegration test. After classifying variables as integrated of order I(0), I(1), I(2) etc. is possible then to set up models that lead to stationary relations among those variables, and where standard inference is possible (Sjöö, 2008). There are several tests for cointegration. Sjöö (2008) argues that the Johansen test is the most fundamental test) given that it has all desirable statistical properties.

Starting with a VAR model of order k with lags given by:

$$\Phi(\mathrm{L})\mathrm{y_t} = \mathrm{c} + \varepsilon_t$$

Where: $\Phi(\mathrm{L}) = \Phi_0 L^0 - \Phi_1 L^1 - \cdots - \Phi_k L^k$ and $\varepsilon_t$ is residual term such that $\varepsilon_t \sim N_k(0, \Sigma)$. $y_t$is a k-vector of non-stationary I(1) variables.

This above VAR in levels can be transformed to a vector error correction model (VECM), by using the difference operator $\Delta = 1 - L$or $L = 1 - \Delta$. After this transformation one lag is lost leading to $k - 1$ lags in the VECM. Vector error correction models are the basic VAR, with an error correction term incorporated into the model. Vector error correction mechanism was used to distinguish between shocks with permanent and transitory effects.

The VECM model is given as:

$$\Delta y_t = \sum_{i}^{k-1} \Gamma_i y_{t-i} + \Pi y_{t-i} + c + \varepsilon_t$$

Where $\Gamma_i$ and $\Pi$ are matrices for variables.

The number of cointegrating vectors is identical to the number of stationary relationships in the Π-matrix [see Gichondo and Kimenyi (2012) and Sjöö (2008) among others]. If the Π-matrix is filled with zeros then there are no cointegrating vectors. Otherwise, the number of non-zero parameters in Π-matrix represents variables which are stationary or number cointegrating vectors. The rank of Π-matrix, therefore, determines the number independent rows in Π, and hence also the number of cointegrating vectors. The rank (r) of Π is given by the number of significant eigenvalues found in estimates of Π-matrix ($\widehat{\Pi}$). Johansen's method relies, therefore, on estimating the Π-matrix based on an unrestricted VAR and test the number of non-zero eigenvalues of Π (which equals r) applying trace or maximum eigenvalue statistics.

**VAR mode approach:-**

Vector autoregressive (VAR) models have a long tradition as tools for multiple time series analysis. Vector autoregressive models became popular for economic analysis when Sims (1980) advocated them as alternatives to simultaneous equations who demonstrated that VARs provide a flexible and tractable framework for analyzing economic time series. One of the critics of the model is that it has no theory foundation.

The general form of VAR is the following:

$$y_t = c + \boldsymbol{\Phi_1} y_{t-1} + \cdots + \boldsymbol{\Phi_k} y_{t-k} + \varepsilon_t$$

With

$$\varepsilon_t \sim iidN(0, \Sigma)$$

Where, $y_t$: is an $n$x1 vector of variables that are integrated of order one i.e. I(1) and$c$ is an intercept, $\varepsilon_t$: error terms or innovations. $\varepsilon_t$is independent and identically distributed with mean zero and covariance $\Sigma$. There are $nk^2$ parameters in Φ matrix with $n$ representing number of variables and $k$ representing lag length. Under this study $y_t$ represented the aforementioned six variables of interest.

Specifically, for this study we tested the following model:

$$\text{lcpi}_t = \propto_{0i} + \sum_{i=1}^{p} \propto_{1i}\ lcpi_{t-1} + \sum_{i=1}^{p} \alpha_{2i} lrgdp_{t-1} + \sum_{i=1}^{p} \propto_{3i}\ lm3_{t-1} + \sum_{i=1}^{p} \alpha_{4i} repo_{t-1} + \sum_{i=1}^{p} \propto_{5i}\ ler_{t-1} + \sum_{i=1}^{p} \alpha_{6i} lintoil_{t-1} + v_i$$

Where: All the variables are defined as before and $v_i$: the impulses or shocks and k: lag length.. $\propto_{0i}$, $\propto_{1i}$-$\alpha_{6i}$ are parameters to be estimated. All the variables are transformed into natural logarithms except for repo rate.

Theoretically, an increase in money supply, exchange rate and international oil prices is expected to cause inflationary pressure; hence their coefficients are expected to have positive signs. On the other hand, coefficient for GDP was expected to possess negative sign. Moreover, it is expected that a high inflationary rate for the previous period may be built into negotiations and thus result in an inflationary spiral. Therefore the sign for the coefficient of the lagged inflation is expected to be positive (Gichondo and Kimenyi, 2012).

## Research Discussion and Results:-

The main objective of this study was to determine the relationship between monetary policy and inflation in Rwanda. Before testing for long run relationship it was important to test stochastic properties of the variables under study.

**Data stationarity:-**

Theory cautions thatin order to apply standard inference procedures in econometric empirical studies, the variables in the system need to be stationary due to the facteconometric analysis is widely built on assumption of stationarity. This study employed Augmented Dicky Fuller (ADF) unit root tests to show the order of integration of each time series of the variables under study and the lag length has been established using the Schwarz information criterion. The results of the stationary tests are represented in the table below.

**Table 4.1:-**Unit root test results.

| Variable | ADF Test | | |
|---|---|---|---|
| | **Level** | **1st difference** | **I(d)** |
| LCPI | -1.904586 | -3.833067* | I(1) |
| LRGDP | -1.204410 | -8.458152* | I(1) |
| LER | -1.277877 | -4.289253* | I(1) |
| LINTOIL | -2.296754 | -5.074850* | I(1) |
| LM3 | -0.403576 | -3.182941** | I(1) |
| REPO | -1.248171 | -5.887373* | I(1) |

Note: *(**) denote significant at 1% and 5% level of significance respectively.

The results from ADF indicated that that the null hypothesis of non-stationary cannot be rejected at any common level of significance for all the series at their levels. However, all these series become stationary if they are first differenced. Hence, all the variables are classified as integrated of order one. Having confirmed the existence of stationarity, then we tested for co- integration between the series under this study.

**Long run relationship: Cointegration analysis:-**

This study employed Johansen cointegration technique to identify and clarify the long run relationships between integrated variables. The results from Johnsen cointegration test are summarized below.

**Table 4.2:-**Johnsen cointegration test results.

| Hypothesized No of CEs | Trace statistics | 0.05 critical value | P-value | Maximum Eigen Statistics | 0.05 critical value | P-value |
|---|---|---|---|---|---|---|
| None * | 140.5467 | 95.75366 | 0.0000 | 72.26681 | 40.07757 | 0.0000 |
| At most 1 | 68.27987 | 69.81889 | 0.0659 | 27.74311 | 33.87687 | 0.2256 |
| At most 2 | 40.53676 | 47.85613 | 0.2039 | 20.83479 | 27.58434 | 0.2863 |
| At most 3 | 19.70197 | 29.79707 | 0.4433 | 13.95862 | 21.13162 | 0.3684 |
| At most 4 | 5.743344 | 15.49471 | 0.7256 | 5.628835 | 14.26460 | 0.6612 |
| At most 5 | 0.114509 | 3.841466 | 0.7351 | 0.114509 | 3.841466 | 0.7351 |

Source: Author's estimation

* denotes rejection of the hypothesis at the 0.05 level

The results indicate that both Trace statistic and Maximum Eigen Statistic identify one cointegrating equation at 5% level of significance.

The following table represents the coefficients for long run relationship and

**Table 4.3:-**Long run results.

| Variable | Coefficient | SE | T-statistics |
|---|---|---|---|
| LRGDP | -2.70612 | -0.17810 | -15.1947 |
| LM3 | 0.624115 | 0.08243 | 7.57117 |
| REPO | 0.012032 | 0.00330 | 3.64269 |
| LER | 0.995358 | 0.17254 | 5.76895 |
| LINTOIL | -0.02885 | -0.02386 | -1.20917 |

Source: Author's estimation

The relationship depicted by the long run results showed that in the long-run, broad monetary aggregate, nominal exchange rate and interest rate (repo rate) exert positive influences on general prices while real output affect prices negatively. Evidence form the above long run coefficients indicate that real output explains inflation more than any other variable, followed by exchange rate, money supply and interest rate.

**Short run relationship: Vector Error Correction Model:-**
Having determined the variables as integrated of order I(1) i.e. they are non-stationary at their levels but stationary after their first differencing and once again having approved the existence of co-integration test, we can, then, formulate an error correction model.

**Table 4.4:-**Short run results.

| Regressors | Coefficient | T-statistics | P-value |
|---|---|---|---|
| ECM | -0.122898 | -2.398015 | 0.0229 |
| D(LCPI(-1)) | 0.596768 | 3.217074 | 0.0031 |
| D(LRGDP(-1)) | -0.217522 | -2.550034 | 0.0161 |
| D(LM3(-1)) | 0.000899 | 0.018673 | 0.9852 |
| D(REPO(-1)) | -0.002547 | -0.798493 | 0.4309 |
| D(LER(-1)) | -0.597163 | -1.694425 | 0.1005 |
| D(LINTOIL(-1)) | 0.016261 | 1.150737 | 0.2589 |
| Intercept | 0.014004 | 2.358964 | 0.0250 |

Source: Author’s estimation

The results form VECM indicated that only previous period of inflation and real gross domestic product positively and negatively respectively affect inflation in the short-run with medium(12.3%) speed of adjustment of the price level to the long-run equilibrium path. However, monetary policy variables namely broad monetary aggregate M3, exchange rate and repo rate don’t affect price level. These results confirm the economic theory which asserts that monetary policy does not affect prices in the short-run (because economic theory postulates that prices are sticky in the short-run) but instead might affect output. These results are consistent with Gichondo and Kimenyi, (2012).

Overall, empirical results of this study revealed that output, nominal exchange rate, money supply represented by broad monetary aggregate M3 and repo rate a proxy of interest rate, drive inflation in the long-run. However, only lagged consumer price index and real output significantly affect inflation in the short-run. These results indicate that current monetary policy actions are effective in controlling inflation pressures in Rwanda.

**Diagnostic test:-**
The estimated model was tested for serial correlation, autoregressive conditional heteroscedasticity, heteroscedasticity and normality. The results are presented in the table below.

**Table 4.5:-**Diagnostics results.

| Test | F-statistics | P-value |
|---|---|---|
| 1. Normality: Jarque-Bera statistic | 0.305376 | 0.858398 |
| 2. Serial correlation: Breusch-Godfrey serial correlation LM test | 1.037156 | 0.3169 |
| 3. Autoregressive conditional heteroscedasticity: ARCH LM test | 0.543854 | 0.4658 |
| 4. Heteroscedasticity: White heteroscedasticity test | 2.325685 | 0.3729 |

Source: author’s estimation

The results indicate that the residuals are normally distributed, homoscedastic and serially uncorrelated.

## Conclusion:-

This study aimed to assess the relationship between monetary policy variables and inflation in Rwanda using vector autoregressive model with data spanning 2006 to 2015. This study first assessed stochastic properties of the variables and results from Augmented Dickey Fuller (ADF) statistics indicate that the null hypothesis of unit root was not rejected at levels but rejected for all the variables at first difference. Having identified all the variables to be of the same order this study employed Johnsen cointegration test to assess long run relationship. The most implication of our results is that in the long run real output, exchange rate and money supply were found to be important determinants of prices while international oil prices insignificantly affect price level. In contrast to previous studies conducted in Rwanda, Kigabo et al. (2008) which found a close relationship between money supply and inflation, this study revealed a high, 0.68, relationship between the two variables. Monetary aggregating targeting framework requires two important assumptions for it to be valid. First, there has to be a close relationship between central bank’s intermediate variable (i.e. broad monetary aggregate) and its ultimate objective (low and stable inflation rate). Secondly, there have to be a stable money multiplier. This study therefore calls for further empirical studies that analyses the stability of money multiplier to ensure the current BNR monetary policy stance is appropriate.

Additionally, results from VECM showed that in the short run, only inflation inertia followed by real output were found to be important in determining the level of inflation with other variables have no effect on inflation. The existence of no impact of money policy variables on inflation in short run conformed to economy theory which suggests that in the short run monetary policy doesn't affect inflation as long as prices are sticky. Putting together these results, policy implications would be for the monetary authority in Rwanda (BNR) to continue taking appropriate policy measures to control money supply and hence inflation through continued better coordination between monetary policy and fiscal policy that would increase production complimented by effective communication with the public to reduce the impact of inflation inertia. Additionally, BNR should also take appropriate measures to tackle exchange rate movements to reduce inflation pressures on imported inflation.

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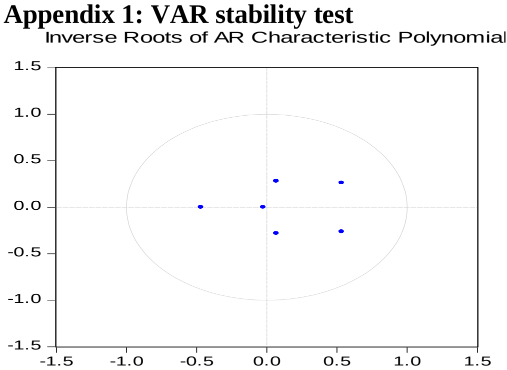
## Appendices:-

### Appendix 1: VAR stability test




**Appendix 2:-**Cointegration results.

| | | | | |
|---|---|---|---|---|
| Date: 04/22/16 Time: 22:05 | | | | |
| Sample (adjusted): 2006Q3 2015Q4 | | | | |
| Included observations: 38 after adjustments | | | | |
| Trend assumption: Linear deterministic trend | | | | |
| Series: LCPI LRGDP LM3 REPO LER LINTOIL | | | | |
| Lags interval (in first differences): 1 to 1 | | | | |
| Unrestricted Cointegration Rank Test (Trace) | | | | |
| Hypothesized | | Trace | 0.05 | |
| No. of CE(s) | Eigenvalue | Statistic | Critical Value | Prob.** |
| None * | 0.850694 | 140.5467 | 95.75366 | 0.0000 |
| At most 1 | 0.518130 | 68.27987 | 69.81889 | 0.0659 |
| At most 2 | 0.422059 | 40.53676 | 47.85613 | 0.2039 |
| At most 3 | 0.307420 | 19.70197 | 29.79707 | 0.4433 |
| At most 4 | 0.137679 | 5.743344 | 15.49471 | 0.7256 |
| At most 5 | 0.003009 | 0.114509 | 3.841466 | 0.7351 |
| Trace test indicates 1 cointegrating eqn(s) at the 0.05 level | | | | |
| * denotes rejection of the hypothesis at the 0.05 level | | | | |
| **MacKinnon-Haug-Michelis (1999) p-values | | | | |
| Unrestricted Cointegration Rank Test (Maximum Eigenvalue) | | | | |
| Hypothesized | | Max-Eigen | 0.05 | |
| No. of CE(s) | Eigenvalue | Statistic | Critical Value | Prob.** |
| None * | 0.850694 | 72.26681 | 40.07757 | 0.0000 |
| At most 1 | 0.518130 | 27.74311 | 33.87687 | 0.2256 |
| At most 2 | 0.422059 | 20.83479 | 27.58434 | 0.2863 |
| At most 3 | 0.307420 | 13.95862 | 21.13162 | 0.3684 |
| At most 4 | 0.137679 | 5.628835 | 14.26460 | 0.6612 |
| At most 5 | 0.003009 | 0.114509 | 3.841466 | 0.7351 |
| | | | | |
| Max-eigenvalue test indicates 1 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 3:-**Vector Error Correction Estimates

| Date: 05/02/16 Time: 11:10 | | | | | | |
|---|---|---|---|---|---|---|
| Sample (adjusted): 2006Q3 2015Q4 | | | | | | |
| Included observations: 38 after adjustments | | | | | | |
| Standard errors in ( ) & t-statistics in [ ] | | | | | | |
| Cointegrating Eq: | CointEq1 | | | | | |
| Error Correction: | D(LCPI) | D(LRGDP) | D(LM3) | D(REPO) | D(LER) | D(LINTOIL) |
| CointEq1 | -0.122898 | 0.611506 | 0.024399 | -3.877936 | 0.013838 | 0.402430 |
| | (0.05125) | (0.05869) | (0.18091) | (3.13168) | (0.02387) | (0.65317) |
| | [-2.39802] | [ 10.4198] | [ 0.13487] | [-1.23829] | [ 0.57981] | [ 0.61612] |
| D(LCPI(-1)) | 0.596768 | -0.174210 | -0.952816 | 5.997259 | 0.025928 | -4.429565 |
| | (0.18550) | (0.21242) | (0.65480) | (11.3352) | (0.08638) | (2.36417) |
| | [ 3.21707] | [-0.82012] | [-1.45514] | [ 0.52908] | [ 0.30015] | [-1.87363] |
| D(LRGDP(-1)) | -0.217522 | 0.639716 | 0.005229 | -5.216475 | 0.045377 | -0.530345 |
| | (0.08530) | (0.09768) | (0.30110) | (5.21243) | (0.03972) | (1.08715) |
| | [-2.55003] | [ 6.54911] | [ 0.01737] | [-1.00078] | [ 1.14234] | [-0.48783] |
| D(LM3(-1)) | 0.000899 | -0.127944 | -0.486709 | 4.084524 | -0.010466 | -0.469229 |
| | (0.04812) | (0.05510) | (0.16986) | (2.94040) | (0.02241) | (0.61328) |
| | [ 0.01867] | [-2.32193] | [-2.86540] | [ 1.38911] | [-0.46707] | [-0.76512] |
| D(REPO(-1)) | -0.002547 | -0.002231 | -0.001984 | -0.009954 | -0.001293 | 0.002074 |
| | (0.00319) | (0.00365) | (0.01126) | (0.19488) | (0.00149) | (0.04065) |
| | [-0.79849] | [-0.61100] | [-0.17622] | [-0.05108] | [-0.87078] | [ 0.05103] |
| D(LER(-1)) | -0.597163 | -0.182394 | -1.351372 | -11.70644 | 0.545587 | -3.025616 |
| | (0.35243) | (0.40357) | (1.24403) | (21.5354) | (0.16412) | (4.49163) |
| | [-1.69443] | [-0.45195] | [-1.08628] | [-0.54359] | [ 3.32436] | [-0.67361] |
| D(LINTOIL(-1)) | 0.016261 | 0.022570 | 0.121141 | 0.745687 | -0.010638 | 0.272394 |
| | (0.01413) | (0.01618) | (0.04988) | (0.86351) | (0.00658) | (0.18010) |
| | [ 1.15074] | [ 1.39478] | [ 2.42855] | [ 0.86355] | [-1.61656] | [ 1.51245] |
| C | 0.014004 | 0.015711 | 0.092085 | -0.274874 | 0.002643 | 0.112745 |
| | (0.00594) | (0.00680) | (0.02096) | (0.36276) | (0.00276) | (0.07566) |
| | [ 2.35896] | [ 2.31111] | [ 4.39430] | [-0.75773] | [ 0.95591] | [ 1.49014] |
| R-squared | 0.460118 | 0.834739 | 0.369182 | 0.155718 | 0.458432 | 0.236228 |
| Adj. R-squared | 0.334146 | 0.796178 | 0.221991 | -0.041281 | 0.332066 | 0.058015 |
| Sum sq. resids | 0.005850 | 0.007671 | 0.072896 | 21.84488 | 0.001269 | 0.950278 |
| S.E. equation | 0.013965 | 0.015991 | 0.049294 | 0.853324 | 0.006503 | 0.177977 |
| F-statistic | 3.652529 | 21.64726 | 2.508184 | 0.790449 | 3.627811 | 1.325537 |
| Log likelihood | 112.8782 | 107.7291 | 64.95012 | -43.40089 | 141.9201 | 16.16349 |
| Akaike AIC | -5.519907 | -5.248900 | -2.997375 | 2.705310 | -7.048428 | -0.429657 |
| Schwarz SC | -5.175152 | -4.904145 | -2.652620 | 3.050065 | -6.703673 | -0.084902 |
| Mean dependent | 0.015106 | 0.019079 | 0.044827 | -0.183947 | 0.007665 | -0.012634 |
| S.D. dependent | 0.017114 | 0.035420 | 0.055886 | 0.836238 | 0.007957 | 0.183376 |

**Appendix 4:-**Diagnostic tests.

**4.1. Heteroscedasticity Test: ARCH**

| | | | |
|---|---|---|---|
| F-statistic | 0.543854 | Prob. F(1,35) | 0.4658 |
| Obs*R-squared | 0.566135 | Prob. Chi-Square(1) | 0.4518 |

**4.2. Breusch-Godfrey Serial Correlation LM Test**

| | | | |
|---|---|---|---|
| F-statistic | 1.037156 | Prob. F(1,29) | 0.3169 |
| Obs*R-squared | 1.312105 | Prob. Chi-Square(1) | 0.2520 |

**4.3. Normality test .**