

VAR approach, the study shows that devaluation shock may affect inflation and output growth via raising money supply and improving balance of trade. However, the real exchange rate changes do not have significant effect on output in the long run.

Akpan (2009) analyzed the relationship between oil price shocks and the Nigerian economy using the VAR approach. The study pointed out the asymmetric effects of oil price shocks; for instance, positive as well as negative oil price shocks significantly increase inflation and also directly increases real national income through higher export earnings, though part of this gain is seen to be offset by losses from lower demand for exports generally due to the economic recession suffered by trading partners.

Alain (2012) carried out a study to identify the main factors underlying inflation in Uganda; he used a single equation Error Correction Model (ECM) based on the quantity theory of money including both external and domestic variables. Over the long run, monetary aggregate, world food prices, and domestic supply and demand effects in agricultural sector are main determinants of inflation in Uganda. While money growth, world food prices, and energy prices, combined with domestic food prices have short term impact on inflation.

3. Material and Methods

3.1 Data Collection

The study used secondary data for time series analysis on the macroeconomic factors that affect inflation in Kenya. Sources of reliable data on these variables included government sources and reliable international sources like CBK and KNBS. Inflation was measured by Consumer Price Index (CPI), interest rate was measured by 91 days Treasury Bill Rate, money supply was measured by M2, Foreign exchange rate was measured in Kenya Shilling to US dollar nominal Exchange rate and oil prices was given by crude oil prices.

3.2 Theoretical Framework

According to Mishkin (1996)

$$M \downarrow = r \uparrow = I \downarrow = Y \uparrow$$

The schematic diagram is a representation of how a monetary tightening is transmitted to the real economy. Where M indicates a contractionary monetary policy, leading to a rise in real interest rates $r (\uparrow)$, which in turn raise the cost of capital thereby causing crowding out of local investments, $I (\downarrow)$ thereby leading to a decline in aggregate demand and a fall in output $Y (\uparrow)$

$$MV=PY$$

Classical economists by the name of Irvin fisher came up with a relationship between quantity of money to nominal income.

Where: M= Quantity of money

P= Price level

Y= Real output=real income

V= Velocity

Working on the assumption that Y is at full employment and that V is constant in the short run,

$$M\bar{V} = P\bar{Y}$$

The equation above now states that, a change in M will cause an equal change in P.

$$M = \left(\frac{1}{v}\right) PY \text{ assuming that } \frac{1}{v} = \text{a constant represented by } k$$

and that when the money market is in equilibrium, $M = M_d$ and so, our equation becomes:

$$M_d = k*PY$$

With the Keynes model of money demand, as demand for real quantity of money (real balances) i.e.,

$$\frac{M^d}{P} = f(i, y)$$

In equilibrium, supply of real money balances is equal to demand of real money balances

$$\frac{M^d}{P} = \frac{M^s}{P} = f(i, Y) \text{ but with inclusion of some other}$$

variables such as Tb rates, exchange rates crude oil prices and gdp or income(Y) it becomes

$$\frac{M^s}{P} = f(\text{Tb rates, crude oil prices, exchange rate and GDP})$$

The monetarist views inflation as always and everywhere a monetary phenomenon (Friedman 1963). Further, macroeconomic theory proposes that growing the money supply in excess of real growth causes inflation. This is also the result from the Friedman model, which assumes “that prices adjust to excess money supply in the money market.” It is on the basis of this assumption that it is possible to invert the real money demand equation as a price equation:

$$P = f(M, y, i)$$

Where P is the price level, M is the nominal money supply, y is real GDP, and i is the nominal interest rate.

Therefore,

$$P = f(\text{Int, Exc, Cop, m2}) \dots \dots \dots (3.1)$$

Where:

P= dependent variable (CPI)

Exc= independent variable (exchange rate)

Int= independent variable (interest rate)

m2= independent variable (money supply)

Cop= independent variable (crude oil prices)

3.3 Model Specification

This study has used the Augmented Dickey–Fuller (ADF) which attempts to retain the validity of test based on white noise errors in the regression model by ensuring that the errors are indeed white-noise. The ADF test the null hypothesis that $|\rho| = 0$ against an alternative that $|\rho| < 0$ in the autoregressive equations:

1. ADF without intercept and trend

$$\Delta y_t = \rho y_{t-1} + \sum_{i=1}^k \delta_i \Delta y_{t-i} + u_t \dots \dots \dots (3.2)$$

2. ADF with an intercept but no trend

$$\Delta y_t = \alpha + \rho y_{t-1} + \sum_{i=1}^k \delta_i \Delta y_{t-i} + u_t \dots \dots \dots (3.3)$$

3. ADF with both intercept and trend

$$\Delta y_t = \alpha + \beta_t + \rho y_{t-1} + \sum_{i=1}^k \delta_i \Delta y_{t-i} + u_t \dots \dots \dots (3.4)$$

(Dickey and Fuller, 1979).

Cointegration test was used to identify equilibrium or a long-run relationship among the variables. The Johansen and Juselius (1990) approach was based on maximum likelihood estimates and gives maximum Eigen Value and Trace Value test statistics for detecting number of cointegration vectors. This procedure provides framework for cointegration test in the context of vector autoregressive approach. Johansen method is explained as follows:

$$X_t = A_0 + \sum_{j=1}^k A_j X_{t-j} + \varepsilon_t \dots\dots\dots (3.5)$$

Where A_0 is an $(n \times 1)$ vector of constants, X_t is an $(n \times 1)$ vector of non stationary I(1) variables, k is the number of lags, A_j is a $(n \times n)$ matrix of coefficients and ε_t is assumed to be a $(n \times 1)$ vector of Gaussian error terms.

According to Engel and Granger (1987), if the variables are integrated of order I(1) and are cointegrated, then there must exist at least one way causation. If the variables are cointegrated, the existence of an error-correction representation may take the following form:

$$\Delta X_t = \alpha_1 + \sum_{i=1}^k \alpha_{11}(i) \Delta X_{t-i} + \sum_{j=1}^k \alpha_{12}(j) \Delta Y_{t-j} + \delta ECM_{t-1} + \varepsilon_{xt} \dots\dots\dots (3.6)$$

$$\Delta Y_t = \alpha_2 + \sum_{i=1}^k \alpha_{21}(i) \Delta X_{t-i} + \sum_{j=1}^k \alpha_{22}(j) \Delta Y_{t-j} + \gamma ECM_{t-1} + \varepsilon_{yt} \dots\dots\dots (3.7)$$

where ECM explains the error-correction mechanism term and α_1/α_2 are constant terms. This ECM_{t-1} is the one period lagged value of the estimated error of the cointegration regression obtained from OLS (Ordinary Least Squares) estimation. The logic behind this model is that generally a long-run equilibrium relationship between two economic variables exists. But, in the short run there can be disequilibrium. Therefore, the error correction mechanism corrects a proportion of disequilibrium in the next period. So, the error correction process is an instrument of reconciling short-run and long-run behavior. In the error correction model α_{11}/α_{21} and α_{12}/α_{22} are the short-run dynamic coefficients and δ/γ is the long-run coefficient, $\varepsilon_{xt}/\varepsilon_{yt}$ are white-noise residuals. The absolute value of δ/γ determines how quickly the equilibrium is restored. Conversely, in the absence of cointegration, a vector autoregression (VAR) needs to be constructed using first differences of the variables. To explore long-run relationship between macro economic variables and inflation, following econometric models was specified in the study.

$$CPI = \alpha_0 + \alpha_1(COP_{t-1}) + \alpha_2(EXC_{t-1}) + \alpha_3(M2_{t-1}) + \alpha_4(INT_{t-1}) + \mu_t \dots\dots\dots (3.8)$$

To capture both the short-run dynamics between time series and their long-run Equilibrium relations following models were estimated.

$$\Delta CPI = \beta_1 \Delta COP + \beta_2 \Delta EXC + \beta_3 \Delta M2 + \beta_4 \Delta INT + \gamma \varepsilon_{t-1} + \mu_t \dots\dots\dots (3.9)$$

4. Results

Data was analyzed using EViews Version 7. The results of these statistical tests aided in the fulfillment of the study objectives by answering the research questions.

4.1 Unit Root Test

Before conducting tests for cointegration and causality, the stationarity properties of the variables have been checked by using Augmented Dickey-Fuller (ADF) unit root test. The table 4- 1 shows the results of ADF unit root test.

Table 4.1: ADF Test Result

Variables	Description	Level: Trend and Intercept	first difference: Trend and Intercept
Crude oil prices	Probability	0.4534	0.0000
	test statistics	-2.258015	-7.441049
	at 5%	-3.444487	-4.030157
Exchange rate	Probability	0.5364	0.0000
	test statistics	-2.107697	-9.012429
	at 5%	-3.444487	-4.030157
Interest rate	Probability	0.4715	0.0000
	test statistics	-2.224962	-7.674992
	at 5%	-3.444487	-4.030157
Money Supply	Probability	0.9354	0.0000
	test statistics	-1.030102	-13.44466
	at 5%	-3.444487	-4.030157
CPI	Probability	0.8816	0.0000
	test statistics	-1.307982	-7.426852
	at 5%	-3.444487	-4.030157

The reported result in table 4-1 reveals that the hypothesis of a unit root can't be rejected in all variables in levels. However, the hypothesis of a unit root is rejected in first differences at 0.05 level of significant which indicates that all variables are integrated of degree one. That means all the variables achieve stationarity only after first difference.

4.2 Co-integration Test

Table 4.2: Co-integration Test Results

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.344794	08.7480	69.81889	0.0000
At most 1 *	0.233739	5.05175	47.85613	0.0091
At most 2	0.087331	1.24030	29.79707	0.3428
At most 3	0.061543	.634858	15.49471	0.3099
At most 4	0.012271	.568054	3.841466	0.2105
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				
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.344794	3.69627	33.87687	0.0001
At most 1 *	0.233739	3.81144	27.58434	0.0070
At most 2	0.087331	1.60545	21.13162	0.5869
At most 3	0.061543	.066804	14.26460	0.3720
At most 4	0.012271		3.841466	0.2105

	1.568054
Max-eigenvalue 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	

At 5 per cent significance level, the trace test indicates 2 cointegrating equations while the maximum eigenvalue test indicates 2 cointegrating equation among the variables. As the maximum eigenvalue test is usually preferred for trying to pin down the number of cointegrating vectors (Enders 2004), we conclude that there are 2 cointegrating equation among the variables based on this test.

4.3 The Long Run Estimation

Table 4.3: The long run equation results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	36.88092	4.559045	8.089616	0.0000
COP(-1)	0.036043	0.020354	1.770813	0.0790
ER(-1)	0.006371	0.063143	0.100893	0.9198
IR(-1)	0.713502	0.093633	7.620203	0.0000
M2(-1)	6.14E-05	1.88E-06	32.63161	0.0000

The long run equation is given by:

$$CPI_{t-1} = \alpha_0 + \alpha_1(COP_{t-1}) + \alpha_2(EXC_{t-1}) + \alpha_3(M2_{t-1}) + \alpha_4(INT_{t-1}) + \mu_t \tag{4.1}$$

$$CPI_{t-1} = 36.88 + 0.036(COP_{t-1}) + 0.006(EXC_{t-1}) + 6.14(M2_{t-1}) + 0.71(INT_{t-1}) + \mu_t \tag{4.2}$$

The long run equation suggests that money supply and interest rate have significant positive impact on consumer price index in the long run at 95% confidence level, with exception of crude oil price which has significant positive impact in the long run at 90% confidence level and exchange rate which has insignificant positive impact in the long run at 95% confidence level. As expressed in equation (4.2) above, the results show that in the long run an increase of 1% of crude oil prices will increase inflation by 0.036%. The growth of exchange rate with 1% increases the inflation by 0.006%. An increase in money supply by 1% increases insignificantly inflation by 6.14% and 1 percentage point increase in the interest rate increases the inflation with 0.71%.

4.4 Error Correction Model

Table 4.4: Short Run estimation

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CCOP	0.008912	0.011908	0.748361	0.4557
CER	0.019990	0.036918	0.541466	0.5892
CIR	0.151116	0.065718	2.299454	0.0232
CM2	2.70E-05	4.94E-06	5.477810	0.0000
ERROR(-1)	-0.074236	0.023475	-3.162386	0.0020

The short run equation is given by:

$$\Delta CPI = \beta_1 \Delta COP + \beta_2 \Delta EXC + \beta_3 \Delta M2 + \beta_4 \Delta INT + \gamma \epsilon_{t-1} + \mu_t \tag{4.3}$$

$$\Delta CPI = 0.0089 \Delta COP + 0.0199 \Delta EXC + 2.7 \Delta M2 + 0.15 \Delta INT - 0.07 \epsilon_{t-1} + \mu_t \tag{4.4}$$

The short run equation suggest that oil price and exchange rate have insignificant positive short run relationship with inflation However, interest rate and money supply have significant positive impact on inflation in the short run at 95% confidence level. The error term coefficient is significant which implied that inflation adjusted 7.4% percent in one month to the long-run equilibrium.

4.5 Residual Diagnostic Tests

The desired properties of a good time series model were tested. They included that the residuals should not have serial correlation, they should be normally distributed and their variance is homoskedastic.

4.5.1 Heteroskedasticity Test

Table 4.5: Heteroskedasticity Test Results

Heteroskedasticity Test: ARCH			
F-statistic	0.093661	Prob. F(1,127)	0.7601
Obs*R-squared	0.095066	Prob. Chi-Square(1)	0.7578

The null hypothesis in this test states that error term is homoscedastic. The results from table 4-5 indicate that the p-value is greater than 10%, therefore we cannot reject the null hypothesis. The error term is homoscedastic, meaning that it has a constant variance of errors.

4.5.2 Test of serial correlation

The Breusch-Godfrey test for higher-order serial correlation was used.

Table 4-6 Serial Correlation Test Results

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	11.20700	Prob. F(2,116)	0.0000
Obs*R-squared	2.726117	Prob. Chi-Square(2)	0.2559

The serial correlation test indicates that there was no serial correlation, meaning that when one error term occurs it does not influences the outcome of the next error term in our model.

4.5.3 Test of Normality

The Jargue-Bera Test was used to test the model on whether the residual was normally distributed. Results from figure 1 indicate that the p-value is more than 5%; we cannot reject the null hypothesis which states the error terms are normally distributed. Therefore, the error terms are normally distributed.

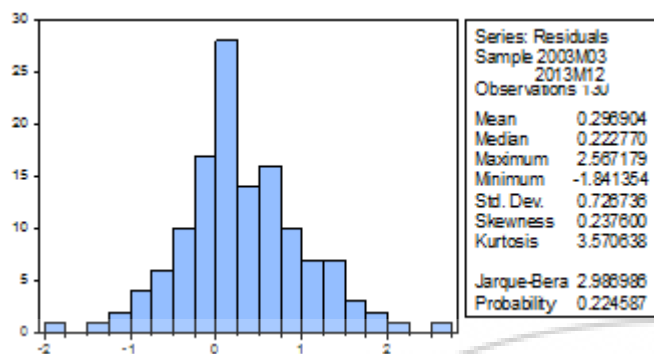


Figure 1: Normality test results

4.6 Granger Causality Test

Table 4.7: Results of Granger Causality Test

Pairwise Granger Causality Tests			
Lags: 6			
Null Hypothesis:	Obs.	F-Statistic	Prob.
COP does not Granger Cause CPI	126	1.27290	0.2754
CPI does not Granger Cause COP		2.33650	0.0365
M2 does not Granger Cause CPI	126	1.83696	0.0981
CPI does not Granger Cause M2		1.64283	0.1418
ER does not Granger Cause CPI	126	0.46117	0.8357
CPI does not Granger Cause ER		1.19463	0.3143
IR does not Granger Cause CPI	126	3.76887	0.0019
CPI does not Granger Cause IR		1.36061	0.2366
M2 does not Granger Cause COP	126	3.06996	0.0080
COP does not Granger Cause M2		1.37185	0.2320
ER does not Granger Cause COP	126	2.64504	0.0194
COP does not Granger Cause ER		0.83580	0.5447
IR does not Granger Cause COP	126	1.08567	0.3753
COP does not Granger Cause IR		1.24935	0.2867
ER does not Granger Cause M2	126	2.73031	0.0163
M2 does not Granger Cause ER		1.52822	0.1752
IR does not Granger Cause M2	126	1.80152	0.1050
M2 does not Granger Cause IR		4.32670	0.0006
IR does not Granger Cause ER	126	1.14214	0.3427
ER does not Granger Cause IR		3.37703	0.0042

From the results in table 4-8 it was observed that at lag 6 there were seven (7) cause relationships which were significant at 5%. The number of significant reduced as the lags increased beyond lag 7. The null hypothesis with a p-value which is less than 5% significant level should be rejected. It was observed that changes in CPI granger cause changes in crude oil prices, changes in interest rates granger cause changes in CPI, changes in money supply granger cause changes crude oil price, changes in exchange rate granger cause changes crude oil price, changes in money supply granger cause changes in exchange rate, changes in money supply granger cause changes in interest rate, and changes in exchange rate granger cause changes in interest rate.

5. Conclusions and Recommendation

According to the VECM model estimated in the study, crude oil prices, interest rates and money supply were found to exert a significant lagged influence on the inflation. All the variables except exchange rate have positive and significant effects on the fluctuation of price level in long run. The positive effect of money supply to changes in prices result

conformed to our a priori expectation as a unit rise in the money supply in the economy was supposed to result in a rise in the inflation since increases in money supply lead to increase in the aggregate demand. Given the higher coefficient of money supply, it seems that money supply is more relevant in price determination in Kenya than crude oil prices and interest rate. Considering the short run effects of these variables on inflation, only interest rate and money supply are the significant variable. The impact is positive as increase in interest rate results in increased cost of production that lead to decrease in the supply of goods in the market. The limited goods have to compete with the available money in circulation and thus increase in inflation. Exchange rate may not directly control inflation in the short run and long run, but it helps to restructure the price mechanism of both import and export, such that Shilling depreciation subtly tends to moderate prices in Kenya, especially imported price inflation. The findings presented in this study demonstrate that oil price shocks do not have direct substantial effects on inflation in the short run but in the long run.

Following the analysis and the findings of this research work, these recommendations are made to curb inflation in the Kenyan economy:

- a) In order to ensure that the Kenya Bank’s Reference Rate KBRR is effective in managing the cost of borrowing, the level of government borrowing from the domestic market should be lowered, commercial banks should be compelled to ensure that their computations of the variable K is as realistic as possible and where they disregard the law, proper action should be taken and any reference rate must have proper oversight to prevent abuses and errors.
- b) On the determining power of money supply (M2), greater efforts should be made to make available, short, medium and long term loans to productive investments like small scale industries/businesses as they constitute an integral part of the growth and transformation process of an agro based economy like that of Kenya.
- c) Exchange policy should be designed to bridge the savings investment gap, enhance government revenue and reduce the fiscal gap through the curtailment of deficits and guarantee of external balance in the long run..
- d) Focus should also be given to develop indigenous energy sources like gas hydrates, shell gas, coal-bed methane, underground coal gasification, wind, solar, nuclear energy etc to prevent the negative macroeconomic consequences of oil price fluctuations, which is expected to rise further with the recent unrest in oil-rich countries
- e) The study recommended that further study should be carried out using different sets of macro-economic variables and other econometric models to understand the inflation determinants in Kenya.

References

[1] Akpan, E. O. (2009). “Oil Price Shocks and Nigeria’s Macroeconomy”. A Paper Presented at the Annual Conference of CSAE Conference, Economic Development in Africa, March 22 - 24, Oxford

[2] Allain, K. (2012), “Dynamics of Inflation in Uganda”, African Development Bank Group, working paper No. 152

- [3] Andrew, B., Armando, M., Jan, V., Michal, A. and Rafael, P. (2013), "Forecasting and Monetary Policy Analysis in Low-Income Countries: Food and non-Food Inflation in Kenya", IMF Working Paper, WP/13/61.
- [4] Berument, H. and Pasaogullari, M. (2003) "Effects of the Real Exchange Rate on Output and Inflation: Evidence from Turkey", *The Developing Economies*, 41 (4):401-43
- [5] Dickey, D.A., and Fuller, W.A. (1979), "Distribution of Estimators for Autoregressive Time Series with a Unit Root," *Journal of the American Statistical Association*, 74, 427-431.
- [6] Engle, R. F. and Granger, C. W. J. (1987) 'Cointegration and Error Correction: Representation, Estimation, and Testing'. *Econometrica*, 55, 251 – 276
- [7] Johansen, S. and Juselius, K. (1990) "Maximum Likelihood Estimation and Inferences on Cointegration – with applications to the demand for money". *Oxford Bulletin of Economics and Statistics*, 52
- [8] Mishkin, F. S. (1996), "Symposium on the Monetary Transmission Mechanism." *Journal of Economic Perspectives* 9: 3–10.
- [9] Ndung'u N, Dick D. (2001), "A Dynamic Model of Inflation for Kenya, 1974 – 1996", *Journal of African Economies*, vol. 10, Oxford University Press.
- [10] Ndung'u, N. (1993), "Dynamics of the Inflationary Process in Kenya", Göteborg, Sweden: University of Göteborg.
- [11] Ndung'u, N. (1997), "Price and Exchange Rate Dynamics in Kenya: An Empirical Investigation (1970–1993)", AERC Research Paper, no. 58. Nairobi: African Economic Research Consortium.
- [12] Ndung'u, N. (1999) "Monetary and Exchange Rate Policy in Kenya" AERC Research Paper No. 94, March 1999
- [13] Nguyen, T.T.V and Seiichi, F (2007), "The Impact of Real Exchange on Output and Inflation in Vietnam: A VAR Approach". <http://www.econ.kobe-u.ac.jp/doc/seminar/DP/files/0625.pdf>. [Accessed: July 7, 2014].
- [14] Odusola, A.F. and Akinlo, A.E. (2001), "Output, Inflation and Exchange Rate In Developing Countries: An Application to Nigeria", *The Development Economies*, 39 (2): 199-222.
- [15] Sargent, Thomas J. (1982). "The Ends of Four Big Inflations." In *Inflation: Causes and Effects*, ed. Robert E. Hall. Chicago, Ill.: University of Chicago Press for the National Bureau of Economic Research.

Author Profile



Maureen W. Gathuu holds a B.Sc in Financial Engineering from Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya



Dr. George Kosimbei lectures in the School of Economics at Kenyatta University. He is a holder of a PhD in Economics from Kenyatta University, Nairobi, Kenya