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# Copper prices and exchange rate movements in Zambia

**Felix Chikumbi**

**Abstract**
This study examines the relationship between the copper price and the nominal exchange rate between the Zambian kwacha and the U.S. dollar. For this purpose the study utilized monthly data on copper prices and the kwacha/US dollar exchange rate for the period 2000 to 2014 and controlled for the effects of domestic productivity, inflation and interest rates on government securities in Zambia and the United States. The study applied econometric techniques of cointegration, granger causality, impulse responses and variance decomposition to analyze interrelationships among these variables. The study found that international copper prices, domestic productivity and short term interest rates on government securities have a positive long run impact on the exchange rate between the two currencies. The study further finds that domestic inflation and short term interest rates on Treasury securities in the United States have a negative effect on the exchange rate between the two currencies in the long run. The study also finds short run causality running from the copper price to the Zambian kwacha/US dollar exchange rate but not from the other variables in the model.

**Keywords:** Exchange rate, Cointegration, impulse response
**JEL Classification:** E43, E44, F31, F39.

## Introduction

Besides interest rates and stock prices, exchange rates are among the most closely watched economic variables because they affect consumers, businesses and exert strong effects on the economy. Movements in exchange rates have both beneficial and adverse effects on the economy. However, it is the adverse effects of exchange rate fluctuations that make a country's exchange rate an important target for monetary policy especially in small open economies where international trade accounts for a sizeable proportion of GDP. An appreciation of the domestic currency benefits consumers by reducing the prices that they pay for imported goods and services but hurts a country's international competitiveness by making its exports expensive in foreign markets. A depreciation of the domestic currency hurts consumers who pay higher prices for imported goods but makes exports cheaper in international markets and hence benefits domestic manufacturers who find it easy to sell more of their goods and services internationally. Exchange rate movements also affect domestic output, unemployment, and inflation. When the domestic currency depreciates, domestic goods become cheaper for foreigners. This increases exports, aggregate demand and domestic output. On the other hand, imports become expensive in domestic markets increasing the prices and inflation.

Ball (2012, p. 521) [4] notes that exchange rate fluctuations create risk for exporters and financial investors and have the potential to destabilize the economy. For this reason monetary policymakers and governments the world over seek to stabilize exchange rates. When the domestic currency rises in value, domestic industries become less competitive while a fall in the value of the domestic currency stimulates inflation in the economy. The recognition of price stability as the primary long term goal of monetary policy by most central banks implies that exchange rate stability has beneficial effects for price stability and long term economic growth. As noted by Xu (2000) [29], "exchange rate stability provides a firm anchor for domestic price stability that is conducive to sustained long-run economic growth". Furthermore, a stable domestic currency stabilizes consumer prices and promotes certainty in the economy and makes it easy for businesses and consumers involved in international trade to plan for the future.

Therefore, "central banks globally endeavor to stabilize exchange rates in order to moderate the adjustment and uncertainty costs that a volatile exchange rate imposes on the economy" (Chipili, 2014) [10].

The current international monetary and exchange rate system came into effect in March 1973. Although it is a hybrid of fixed and flexible exchange rates, most countries operate under flexible exchange rates and allow their exchange rates to fluctuate in response to market forces. Central banks in these countries may intervene in the foreign exchange markets from time to time to prevent large changes in exchange rates. Countries that have embraced a floating exchange rate regime have also seen increased variability in exchange rates. As observed by Mankiw (2010, p. 361) [19], the abandonment of the Bretton Woods system of fixed exchange rates in the early 1970's, has resulted in increased real and nominal exchange rate volatility.

Zambia adopted a floating exchange rate regime in 1994 as part of the IMF/World Bank supported structural adjustment programme (SAP) of the 1990s. Since that time the exchange rate between the kwacha and foreign currencies is market determined though the Bank of Zambia intervenes in the foreign exchange market when need arises. However, before 1994, the country operated under fixed exchange rates form the time of independence in 1964 to 1982 and from 1987 to 1991. The country adopted a form of fixed exchange rates called a crawling peg between 1983 and 1985. Subsequently, in 1994, the country adopted a flexible exchange rate arrangement.

Movements in the kwacha/US dollar exchange rate reflects the interaction of both domestic and external factors ranging from changes in the economic and policy environment to shifts in the expectations of asset holders and changes in copper prices. However, in most cases, changes in global copper prices play a dominant role in exchange rate movements in Zambia because copper exports constitute the main foreign exchange earner for the country. According to the Ebury Special Report (2015), copper accounts for 75% of Zambia's overall exports implying that copper prices have a greater scope to affect the exchange rate. The performance of the kwacha against the US dollar and other major currencies since 1994 is mixed at best but has historically followed the behavior of international copper prices. A study by Bova (2009) [7] found that the kwacha is a commodity currency because if followed the copper price in the long run with similar patterns of volatility. In certain years, the kwacha has enjoyed relative stability as was the case in the years from 2002 to 2005 (FNDP, 2006). Though stable in certain years, the kwacha/US dollar exchange rate has also fluctuated substantially mainly due to changes in copper prices on the world market.

In the second half of the year 2005, the kwacha underwent a dramatic appreciation against the US dollar and all other major currencies that lasted until September 2006. Although, the attainment of the Highly Indebted Poor Countries (HIPC) completion point and subsequent debt relief played a role in this appreciation (Fynn, Haggblade, 2006) [14], a major reason cited for the strengthening kwacha was an increase in copper prices and capital movements (Weeks, Seshamani, Mukungu, Patel, 2007) [28]. The appreciation of the kwacha led to fears of loss of international competitiveness among exporters of manufactured and agricultural products. During the global economic crisis that started in 2007, the kwacha depreciated by 40% between October 2008 and April 2009 and then appreciated continuously beginning in May 2009. This depreciation of the kwacha was attributed to the collapse in copper prices and the resulting sharp reduction in copper revenues. The depreciation of the kwacha fuelled inflation as a result of increases in the price of imported goods and services.

This study examines empirically the dynamic relationship between international copper prices and the nominal exchange rate between the Zambian kwacha and the US dollar using cointegration, granger causality, and impulse response and variance decomposition techniques. The results of the study indicate that an increase in copper prices, domestic productivity and interest rates on Zambian treasury bills leads to an increase in the exchange rate (appreciation of the kwacha against the US dollar). However, an increase in domestic inflation and short-term interest rates on US treasury bills leads to a fall (depreciation) of the kwacha in the long run. Granger causality tests show that the copper price affects the kwacha/US dollar exchange rate in the short run and long run.

The next sections in this paper discusses in detail the theory and empirical studies on exchange rate determination, types of data, and methods used in the study. The paper ends with a discussion of the data anlysis and findings of the study.

## Literature review

This section gives an overview of theories of exchange rate determination and empirical studies conducted by researchers in different countries begining with the theoretical literature which is then followed by the empirical literature.

### Theoretical Literature

According to Salvatore (2013, p. 463) [25], modern theories of exchange rate determination are based on the monetary approach and the portfolio balance approach to the balance of payments developed since the late 1960. These two theories view the exchange rate as a purely financial phenomenon and attempt to explain both the short run and long run behavior of exchange rates. While traditional theories of exchange rate determination emphasize the role of trade flows, modern theories focus on the role of financial transactions. As Mishkin (2010, p. 441) [20] notes, traditional supply and demand approaches to exchange rate determination emphasized the role of import and export demand. The shift from traditional to modern theories of exchange rates reflects the rapid increase in the volume of international financial transactions in the past 40 years of flexible exchange rates compared to trade flows.

According to Mishkin (2010, p. 439) [20], the factors below determine exchange rates in the long run:

**The Price Level:** The *theory of purchasing power parity (PPP)* shows that exchange rates between any two countries adjust to reflect changes in the price levels of the two countries. This theory assumes that trade barriers and transportation costs are low between the two countries and that the respective countries produce an identical good. This theory implies that an increase in the domestic price level, assuming the foreign price level remains constant, reduces the demand for domestic goods and causes the domestic currency to depreciate. An increase in the foreign price level has the opposite effect and therefore causes the local currency to depreciate. The theory of purchasing power parity is simply an extention of the law of one price to international trade.

**Trade Barriers:** Barriers to free trade such as *tariffs* and *quotas* also affect exchange rates between any pair of currencies. An increase in tariffs on imported goods or a lower quota on imported goods increases the demand for domestic goods and service and causes the domestic currency to appreciate in the long run.

**Imports and Export:** If foreigners buy more of domestically produced goods and services (increase in exports), the demand for domestic goods increase leading to an appreciation of the domestic currency.

On the other hand, an increase in imports (domestic residents increase purchase of foreign goods), leads to a depreciation of the domestic currency because the demand for domestic goods falls.

**Productivity:** An increase in a country's productivity raises the output of domestic sectors that produce traded goods. The effect of this increase in productivity is to reduce the price of domestically produced traded goods relative to foreign-traded goods leading to a higher demand for domestic traded goods. The increase in the demand for domestically traded goods leads to an appreciation of the domestic currency. If productivity in a country falls relative to another country, the domestic currency will depreciate in the long run.

According to the asset market approach, exchange rates in the short run depend on the decision to hold domestic or foreign interest-bearing assets such as securities or bonds. This approach is based on the theory of asset demand which presupposes that the demand for an asset depends on the expected rate of return on an asset relative to other assets.

**Domestic and Foreign Interest Rates:** The interest rate on domestic securities or bonds relative to the interest rate on foreign assets is an important factor influencing exchange rates. If the domestic interest rate increases, the relative return on domestic assets increases. This increases the demand for domestic assets and causes the domestic currency to appreciate. If the foreign interest rate rises, the relative return on foreign assets increases and causes the domestic currency to depreciate.

**Expectations and Exchange Rates:** The current value of the exchange rate also depends on expectations about the future value of the exchange rate because the demand for domestic assets depends on the future resale price. Factors that increase the future value of the exchange rate cause the domestic currency to appreciate and factors that cause a fall in the expected future exchange depreciate the domestic currency.

## Empirical Literature

Bova (2009) [7] investigated whether the Zambian kwacha was a commodity currency using cointegration and EGARCH methodology for the period 1997 to 2008 using daily and monthly data. The study found a positive long run relationship between the real exchange rate and the copper price and concluded that in countries operating under a floating exchange rate that depend on commodity exports, the domestic currency follows the price of the main exported commodity and exhibits its pattern of volatility.

Cashin, Cespedes, Sahay (2002) [8] examined the relationship between real exchange rates of 58 commodity exporting countries and the real prices of their commodity exports using monthly data for the period 1980 to 2002. Using cointegration methodology, their study found that the real exchange rates and real commodity prices for two-fifths of the commodity-exporting countries have a long run relationship.

Zakaria, Ahmad, Iqbal (2007) [30] also examined the relationship between the between the Pak-rupee and Pakistan's twelve major trading partners for the period 1983 to 2004 using quarterly data. The study employed the Method of Generalized Moments (GMM) and found that the nominal exchange rates depend on endogenous and policy variables such as the relative inflation rate at home and abroad, monetary policy, terms of trade, trade policies and capital mobility. Bashir, Javed, Raza, Ali, Hassan (2013) [5] studied exchange rate determination in Pakistan using daily data for the period 2000 to 2013. Their study focused on examining the empirical relationship between the nominal exchange rate, the domestic price level, and the foreign price level using cointegration methodology. The study found a postive relatioship betweeen the domestic price level and the nominal exchange rate but the foreign price level had a negative relationship with the nominal exchange rate in the long run.

Razi, Shafiq, Ali, Khan (2012) [24] also investigated exchange rate determinants in Pakistan for the period 2001 to 2011 using multiple regression and found that GDP, interest rates, inflation rate, and the current account affect the exchange rate. The sudy found that GDP had the greatest impact on the exchange rate.

Asari, Baharuddin, Jusoh, Mohamad, Shamusudini, Jusoff (2011) [2] also investigated the relationship between the interest rate, inflation rate, and exchange rate volatility for the period 1999 to 2009 using monthly data in Malaysia. The study used the vector error correction model (VECM) and cointegration techniques and found a postive relationship between interest rates and the exchange rate. Furthermore, the study found a negative relationship between inflation and exchange rate volatility.

Ho, Ariff (2014) [15] investigated the effects of parity and nonparity factors on exchange rate movements for seven Latin American countries for the period 1991 to 2005 based on a pooled time series regression model. The model included the consumer price index (CPI), money market rates such as treasury bills yields to determine interest rates differentials. They found that nonparty factors such as reserves, trade balance, sovereign debt, and capital flows are important drivers of currency movements. In addition, they found that price and interest parity factors affect exchange rates in both the short run and long run.

Tafa (2015) [27] studied the impact of interest rates on exchange rate fluctuations in Albania using regression analysis for the period 2002 to 2014 and found that interest rates on deposits had a postive effect on the exchange rate.

Chowdhury (2014) [11] examined exchange rate determinants in Bangladesh for the period 1990 to 2011 using regression analysis and found that the inflation rate, GDP growth rate, interest rate, and the current account balance affected the exchange rate postively.

Oriavwote, Oyovwi (2012) [23] investigated factors that determine the real exchange rate in Nigeria for the period 1970 to 2010 using cointegration and error correction models. The study found that capital flows, the price level, and the nominal exchange rate are important factors that determine the real exchange rate in Nigeria. In another study, Ayinla (2014) [3] applied granger causality to study exchange rate determinats in Nigeria for the period 1980 to 2013. The study found that the past exchange rate, production, consumer price index (inflation) and the money supply all affect the exchange rate.

Lily, Kogid, Mulok, Sang, Asid (2014) [18] investigated the relationship between foreign direct investment (FDI) inflows and exchange rate movements in ASEAN economies of Malaysia, Philippines, Thailand and Singapore for the period 1971 to 2011 using the ARDL model. The study found that the exchange rate and FDI have a significant long run relationship in Singapore, Malaysia and the Philippines. Abdoh, Yusuf, Zulkifli, Bulot, Ibrahim (2016) [1] also examined the macroeconomic determinants of the exchange rate in ASEAN countries. Using multiple regression analysis and annual data for the period 2005 to 2014, they found that exports were the most significant factor influencing exchange rates while interest rates and inflation rates have no significant impact on the exchange rate in these countries.

Hsing (2016) [17] examined exchange rate determinants between the South African rand and the United States the period 2000 to 2014 based on quarterly data. Based on EGARCH techniques, the study found a positve relationship between the exchange rate and the yield on South African government bonds, US real GDP, US stock price and the South African inflation rate. However, the nominal exchange rate was found to be negatively related to the 10-year US government bond yield, South African Real GDP, the South African Stock price and US inflation.

Suthar (2008) [26] studied the relationship between the Indian rupee and the US dollar using monthly data for the period 1996 to 2007. The study used the method of ordinary least squares (OLS) and found that the Reserve Bank of India (RBI) bank rate, interest rate differentials, and foreign exchange reserves have a significant effecct on the exchange rate between the two currencies.

Benazic, Skabic (2016) [6] used the ARDL model to study the relationship between foreign currency flows and the exchange rate in Croatia using quarterly data for the period December 1998 to March 2013. Using cointegration approach, the study found a long run relationship between FDI inflows, consumer prices, and external debt. The sudy found that, in the short run, positive changes in consumer prices, the ratio between foreign currency deposits and savings deposits and between total time and savings deposits and FDI caused the exchange rate to appreciate. In addition, the study indicated that postive changes in the ratio between loans indexed to foreign currency and total loans, international reserves, and external debt led to a depreciation of the exchange rate. Changes in export/import coverage were found to have no significant impact on the exchange rate.

Hsieh (2009) [16] examined the determinants of the rupiah/dollar exchange rate in Indonesia for the period 1997 to 2007 using quarterly data. Their study was based on four models of the exchange rate namely the purchasing power parity model, uncovered interest rate model, monetary model, and the Mundell-Fleming model. The results of the study suggested that an increase in interest rates and inflation rate caused the rupiah to depreciate. Results from the Mundell-Fleming model indicated that an increase in the domestic interest rate and expected inflation would cause a depreciation of the IDR/USD exchange rate whereas a higher ratio of government spending/GDP or a higher stock price would lead to a real appreciation.

## Data and methodology

This section describes the type and sources of data used in the study, the model and econometric procedures followed in the data analysis.

**Data Sources:** This study is based on monthly time series data for the period 2000 to 2014 and uses data obtained from the Central Statistical Office (CSO), Bank of Zambia (BOZ), the Federal Reserve Bank (FED) and the International Monetary Fund (IMF).

**Model Specification:** Based on the predictions of economic theory and using natural logarithms of the respective data series, the nominal exchange rate between the kwacha and the US dollar (LNEXRATE) is expressed as a function of the consumer price index (LCPI), index of industrial production (LGDP), copper price (LCPRICE), the 3-month Zambian Treasury Bills' rate (LTBILL) and the 3-month US Treasury Bills' rate (LUSTBILL). These variables are specified in the following general model:

$$LNEXRATE_t = f\ (LCPI_t,\ LGDP_t,\ LCPRICE_t,\ LTBILL_t,\ LUSTBILL_t)$$

The nominal exchange rate between the kwacha and the dollar (LNEXRATE) in this study is defined as the price of one kwacha (K1) in terms of the US dollar (number of US dollars per Zambian kwacha). LCPI is the headline measure of consumer prices in Zambia and captures the cost of a basket of goods purchased by the typical urban consumer. In this study, LCPI represents the effects of domestic inflation on the nominal exchange rate between the kwacha and the US dollar.

The variable LGDP is the index of industrial productivity in Zambia and is used as a proxy for gross domestic product (GDP) due to non availability of monthly GDP figures. LGDP captures the effects of domestic productivity on the nominal exchange rate between the two currencies. The copper price (LCPRICE) used in the study is the spot price of copper on the London Metal Exchange (LME). LTBILL is the 3-month BOZ Treasury bills rate and represents the effects of domestic interest rates on the Zambian Kwacha/US dollar exchange rate. LUSTBILL is the 3-month Treasury bills' rate in the United States (US) and capture the effects of short term interest rates in the US on the exchange rate between the two currencies. Consequently, the regression model for the study is specified as follows:

$$LNEXRATE_t = \beta_0 + \beta 1\ LCPI_t + \beta 2\ LGDP_t + \beta 3\ LCPRICE_t + \beta 4\ LTBILL_t + \beta_4\ LUSTBILL_t + \varepsilon_t \quad (1)$$

Where, $\varepsilon_t$, is the disturbance or error term.

**Unit Root Tests:** A unit root test is a test of stationarity or nonstationarity in a time series. It is conducted to ascertain whether variable included in a model are stationary or not and avoid spurious regression results. This study used the Augmented Dickey Fuller (ADF) test to test for a unit root. The ADF test is implemented by running the following regression:

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \sum_{j=1}^{m} \alpha_j \Delta Y_{t-j} + \varepsilon_t \text{ ----------(2)}$$

$\varepsilon_t$ is a pure white noise error term and $\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$, $\Delta Y_{t-2} = (Y_{t-2} - Y_{t-3})$ etc. in order to obtain an unbiased estimate of δ, the number of lagged difference terms included in the test should be enough so that the error tem is serially uncorrelated. In this test, the hypotheses for the test are as stated below:
$H_0$: *θ = 0 (Data Series has a unit root)*
$H_1$: *θ < 0 (Data series is stationary)*

**Cointegration Test**
Cointegration exists when two or more integrated variables have a linear combination of them that is stationary, *I (0)*. If variables are cointegrated, they move closely together in the long run and the linear combination among them represents the long run or equilibrium relationship between these variables.
Cointegration means that there is a long run relationship to which these variables converge over time. An appropriate method used to test for the existence of a long run relationship in multivariate studies like this one is the Johansen (1988) maximum likelihood test. The Johansen test provides two test statistics called the *trace Statistic* and the *maximum eigenvalue statistics*. In the trace statistic, the null hypothesis that there are at most *r* cointegrating relations and the alternative hypothesis is that there are *m* cointegrating relations (series are stationary), where, *r* = 0, 1,..... *k* – 1. The Trace statistic is given by:

$$Q_r = -T \sum_{i=r+1}^{k} \log (1 - \lambda_i) \text{ ----------(3)}$$

Where *r =1, ……., k-1* where λ is the $i^{th}$ largest eigenvalue

The maximum eigenvalue statistic tests the null hypothesis that there are *r* cointegrating relations against the alternative hypothesis of *r* +1 cointegrating relations and is given by:

$$Q_{\max} = -T \log (1 - \lambda_i) = Q_r - Q_{r-1} \text{ ----------(4)}$$

**Vector Error Correction Model (VECM):** A Vector Error Correction Model (VECM) is a VAR model in first differences. According to Engle and Granger (1987), if two variables are cointegrated, then there also exists an error correction mechanism among them that corrects automatically for deviations from their long run equilibria. The VECM model enables us to model the short run correction mechanism of a system of variables to their long run equilibrium. The VECM (*p*) form is written as follows:

$$\Delta Y_t = \delta + \Pi y_{t-1} + \sum_{n=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \mathcal{E}_t \ (5)$$

Where $\Delta Y_t = y_t - y_{t-1}$

Π is the impact matrix which determines the extent to which variables in the VAR system are cointegrated. The matrix $\Pi = \alpha\beta'$ where $\alpha$ is the vector of adjustment parameters and $\beta$ is matrix of cointegrating vectors. If Π = 0, variables in the system are not cointegrated. On the other hand if Π<*r*, variables are cointegrated in the system where *r* is the number of endogenous variables in the system. Equation (5) examines both long run and short run relationships among variables. Π captures long run relationships among variables while $\Gamma_i$ captures short run relationships among variables.

**Results and empirical findings**
This section presents results of data analysis and findings beginning with unit root tests.

**Unit Root Tests:** Unit root tests were conducted on the respective data series using the Augmented Dickey Fuller (ADF) test to ascertain whether they are stationary or nonstationary. The results of the ADF test on the natural logarithms of the nominal exchange rate (LNEXRATE), consumer price index (LCPI), index of industrial production (LGDP), copper price (LCPRICE), Zambian 3-month Treasury bills rate (LTBILL) and the US 3-month Treasury bills' rate (LUSTBILL) are tabulated below:

**Table 1:** ADF Test for Natural Logarithms of Data Series

| | Computed | | Critical Values | | |
|---|---|---|---|---|---|
| **Variable** | **ADF Statistic** | **Lag Length** | **1%** | **5%** | **10%** |
| LNExrate | -2.506664 | 1 | -4.01499 | -3.43746 | -3.14294 |
| LCPI | -2.053454 | 1 | -4.01499 | -3.43746 | -3.14294 |
| LGDP | -0.684990 | 10 | -4.01835 | -3.43907 | -3.14389 |
| LCPRICE | -1.896991 | 1 | -4.01499 | -3.43746 | -3.14294 |
| LTBILL | -1.149877 | 4 | -2.57940 | -1.94282 | -1.61539 |
| LUSTBILL | -0.233954 | 2 | -2.57923 | -1.94279 | -1.61541 |

The results in the table indicate that the computed ADF statistic for each respective data series is less than the critical values at the 1%, 5%, and 10% level of significance. Therefore, the null hypothesis of a unit root in each data series is rejected. This shows that the natural logarithms of the nominal exchange rate, consumer price index, index of industrial production, copper price, 3-month Zambian Treasury bill and the 3-month US Treasury bills rate are nonstationary.

**Order of Integration:** Since the respective data series in the model are found to be onstationary, the appropriate next step is to establish the order of integration of the variables. A time series is integrated of order *n, I(n),* if differencing it *n times* makes it stationary. The table below shows results of the ADF test applied to the first differences of the logarithms of the respective data series:

**Table 2:** ADF Test Results for 1st Differences of Data Series

| Variable | Computed ADF Statistic | Lag Length | Critical Values 1% | 5% | 10% |
|---|---|---|---|---|---|
| ΔLNEXRATE | -9.352211 | 0 | -4.01499 | -3.43746 | -3.14294 |
| ΔLCPI | -6.729693 | 0 | -4.01499 | -3.43746 | -3.14294 |
| ΔLGDP | -5.075342 | 9 | -4.01835 | -3.43907 | -3.14389 |
| ΔLCPRICE | -7.896379 | 0 | -4.01499 | -3.43746 | -3.14294 |
| ΔLTBILL3 | -6.088673 | 3 | -2.57940 | -1.94282 | -1.61539 |
| ΔLUSTBILL | -10.42180 | 1 | -2.57923 | -1.94279 | -1.61541 |

The table shows that the computed ADF statistic for the various data series exceeds the respective critical values at the 1%, 5%, and 10% level of significance. Therefore, we reject the null hypothesis of a unit root and conclude that the variables in the model are stationary. Since the variables become stationary after the first differences, they are integrated of order 1. Hence, we can safely conclude that LNEXRATE, LCPI, LGDP, LCPRICE, LTBILL, LUSTBILL are all integrated of order 1, that is *I* (1).

**Cointegration Test:** The fact that the natural logarithms of the kwacha/US dollar nominal exchange rate, consumer price index, index of industrial production, copper price, 3-month Zambian Treasury bill and the 3-month US Treasury bills rate are all integrated of order 1 means that there is a chance that the respective variables in our model are cointegrated. Therefore, the Johansen methodology was applied to test for cointegration among the variables in the model and to determine the maximum number of cointegrating vectors or equation and ascertain wthere there is a long run relationship among the variables of interest. This test requires running a VAR and specifying the appropriate lag length for the test by use of various information criteria and choosing the appropriate test assumption. The table below shows the optimal lag lengths suggested by the various information criteria:

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 150.3081 | NA | 6.48e-09 | -1.826685 | -1.710384 | -1.779454 |
| 1 | 1601.242 | 2773.305 | 1.08e-16 | -19.73724 | -18.92314 | -19.40663 |
| 2 | 1763.629 | 298.0514 | 2.19e-17 | -21.33708 | -19.82516 | -20.72307 |
| 3 | 1893.789 | 229.0163 | 6.67e-18 | -22.52898 | -20.31926* | -21.63158 |
| 4 | 1963.202 | 116.8601 | 4.41e-18 | -22.95193 | -20.04440 | -21.77115* |
| 5 | 1996.311 | 53.22453 | 4.64e-18 | -22.91532 | -19.30999 | -21.45115 |
| 6 | 2038.733 | 64.97573 | 4.37e-18 | -22.99662 | -18.69348 | -21.24906 |
| 7 | 2087.212 | 70.57135 | 3.85e-18 | -23.15459 | -18.15364 | -21.12364 |
| 8 | 2135.113 | 66.09090* | 3.46e-18* | -23.30523* | -17.60647 | -20.99089 |

It is clear from the table above that the optimal lag length for the VAR chosen by the Schawrtz Information Criteria (SC) is 3, Final Prediction Error (FPE), Akaike Information Criteria (AIC) and Likelihood-Ratio (LR) suggest a lag length of 8, and the Hannan-Quinn Information Criteria (HQ) suggest a lag length of 4. In this study, the Johansen cointegration test was implemented by running a VAR with 4 lags and using option 3 in EVIEWS 8.0. The table below shows the results of the Johansen cointegration test:

| **Unrestricted Cointegration Rank Test (Trace)** | | | | |
|---|---|---|---|---|
| **Hypothesized No. of CE(s)** | **Eigenvalue** | **Trace Statistic** | **0.05 Critical Value** | **Prob.**** |
| None * | 0.190922 | 117.4290 | 95.75366 | 0.0007 |
| At most 1 * | 0.153974 | 83.31950 | 69.81889 | 0.0029 |
| At most 2 * | 0.136217 | 56.39939 | 47.85613 | 0.0064 |
| At most 3 * | 0.096522 | 32.82363 | 29.79707 | 0.0217 |
| At most 4 * | 0.077739 | 16.48154 | 15.49471 | 0.0354 |
| At most 5 | 0.021215 | 3.452317 | 3.841466 | 0.0632 |
| Trace test indicates 5 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 No. of CE(s) | Eigenvalue | Max-Eigen Statistic | 0.05 Critical Value | Prob.** |
| None | 0.190922 | 34.10948 | 40.07757 | 0.2015 |
| At most 1 | 0.153974 | 26.92011 | 33.87687 | 0.2676 |
| At most 2 | 0.136217 | 23.57576 | 27.58434 | 0.1502 |
| At most 3 | 0.096522 | 16.34209 | 21.13162 | 0.2055 |
| At most 4 | 0.077739 | 13.02922 | 14.26460 | 0.0776 |
| At most 5 | 0.021215 | 3.452317 | 3.841466 | 0.0632 |
| Max-eigenvalue test indicates no cointegration at the 0.05 level | | | | |
| * denotes rejection of the hypothesis at the 0.05 level | | | | |
| **MacKinnon-Haug-Michelis (1999) p-values | | | | |

The results of the Trace test show that the variables in the model are cointegrated and that there are 5 cointegrating vectors at the 5% level of significance. However, the maximum Eigen value statistics shows no evidence of cointegration. According to when the two tests are in conflict, the Trace statistic is more robust to skewness and excess kurtosis in residuals than the Maximum Eigen value statistic. This position is also affirmed by who states that when the two tests are in conflict, the Trace statistic is more reliable. However, the current practice is only to consider results based on the Trace statistic.

Therefore, cointegration test shows that the kwacha/US dollar nominal exchange rate (LNEXRATE), the consumer price index (LCPI), the index of industrial production (LGDP), the copper price (LCPRICE), the 91-day Zambian Treasury bill's rate (LTBILL) and the 91-day US Treasury bill's rate are cointegrated. The results of the first normalized cointegrating vector are shown in the table below:

| **1 Cointegrating Equation(s):** | | **Log likelihood** | **1989.104** | | |
|---|---|---|---|---|---|
| **Normalized cointegrating coefficients (standard error in parentheses)** | | | | | |
| LNEXRATE | LCPI | LGDP | LCPRICE | LTBILL3 | LUSTBILL |
| 1.000000 | 13.42957 | -19.76498 | -7.815648 | -5.230529 | 0.573827 |
| | (6.84343) | (15.2995) | (2.69954) | (1.37294) | (0.57732) |

The equation shows that there is a positive long run relationship between the nominal exchange rate, domestic productivity, the spot copper price, and the 3-month Zambian treasury bills' rate. However, the nominal exchange rate is negatively related to domestic inflation and the 3-month Treasury bills rate in the long run.

**Vector Error Correction Model (VECM):** The table below shows the estimated vector error correction model (VECM) that describes the short run adjustment mechanism of the variables towards their long run equilibrium values.

| **Cointegrating Eq:** | **CointEq1** | **CointEq2** | **CointEq3** | **CointEq4** | **CointEq5** | |
|---|---|---|---|---|---|---|
| LNEXRATE(-1) | 1.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | |
| LCPI(-1) | 0.000000 | 1.000000 | 0.000000 | 0.000000 | 0.000000 | |
| LGDP(-1) | 0.000000 | 0.000000 | 1.000000 | 0.000000 | 0.000000 | |
| LCPRICE(-1) | 0.000000 | 0.000000 | 0.000000 | 1.000000 | 0.000000 | |
| LTBILL3(-1) | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 1.000000 | |
| LUSTBILL(-1) | -0.082033 | 0.030033 | 0.026922 | -0.110347 | 0.014873 | |
| | (0.01302) | (0.04217) | (0.02086) | (0.07793) | (0.07918) | |
| | [-6.29915] | [ 0.71220] | [ 1.29092] | [-1.41604] | [ 0.18785] | |
| C | 8.363957 | -4.357569 | -5.022627 | -8.531063 | -2.448759 | |
| Error Correction: | D(LNEXRATE) | D(LCPI) | D(LGDP) | D(LCPRICE) | D(LTBILL3) | D(LUSTBILL) |
| CointEq1 | -0.154370 | 0.003197 | -0.001696 | -0.037974 | -0.153253 | -0.109384 |
| | (0.04472) | (0.00882) | (0.00363) | (0.08780) | (0.20567) | (0.46394) |
| | [-3.45206] | [ 0.36233] | [-0.46725] | [-0.43249] | [-0.74515] | [-0.23577] |

The table shows that about 15.4% of the disequilibrium is corrected in the following month by changes in the kwacha/US dollar nominal exchange rate, 0.3% of disequilibrium is corrected by changes in domestic inflation, 0.2% of disequilibrium is corrected by changes in domestic productivity, 3.8% of disequilibrium is corrected by changes in the spot copper price, 15.3% by changes in the 3-month Zambian T-bill rate and about 10.9% of disequilibrium is corrected by changes in the 3-month US treasury bills rate.

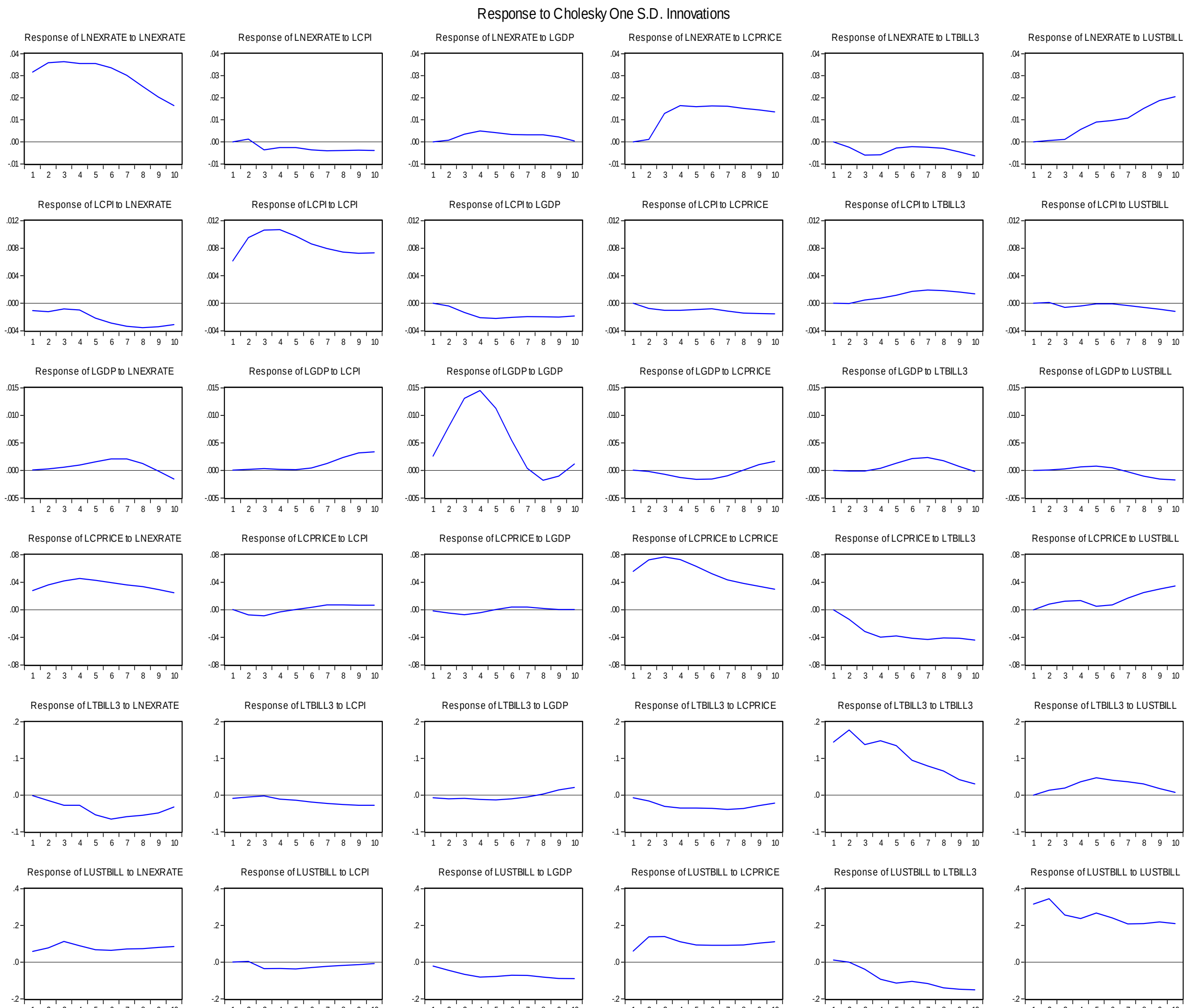
**Granger Causality Tests:** This section presents results of the VECM system estimation and Granger causality tests carried out using the Wald coefficient restriction tests.

**Long Run Causality:** The coefficient of the cointegrating equation or error correction term or the speed of adjustment towards long run equilibrium is negative (-0.154370) and significant (*P-value* = 0.0007 is less than 5%). Therefore, there is long run causality running from the domestic inflation rate, domestic production, global copper prices, 3-month Zambian Treasury bills' rate, and the 3-month US Treasury bill's rate to kwacha/US dollar nominal exchange rate. :

**Short Run Causality:** Granger causality tests were conducted to determine if there is short run causality running from the independent variables in the model to the kwacha/US dollar nominal exchange rate using Wald Statistics. The results show that there is no short run causality running from inflation in Zambia, domestic productivity, the 3-month Zambian Treasury bill rate and the 3-month US Treasury bills' rate to the kwacha/US dollar nominal exchange rate. However, there Wald test finds evidence of short run causality running from the spot copper price to the kwacha /US dollar nominal exchange rate. This result is shown in the table below:

| Wald Test: LCPRICE to LEXRATE | | | |
|---|---|---|---|
| Equation: EQ01 | | | |
| Test Statistic | Value | df | Probability |
| F-statistic | 3.291704 | (4, 136) | 0.0131 |
| Chi-square | 13.16682 | 4 | 0.0105 |
| Null Hypothesis: C(17)=C(18)=C(19)=C(20)=0 | | | |
| Null Hypothesis Summary: | | | |
| Normalized Restriction (= 0) | | Value | Std. Err. |
| C(17) | | -0.017473 | 0.045261 |
| C(18) | | 0.170533 | 0.048778 |
| C(19) | | -0.074785 | 0.049429 |
| C(20) | | 0.014317 | 0.045640 |
| Restrictions are linear in coefficients. | | | |

**Impulse Response Functions:** Impulse response functions were used to visually assess the dynamic interactions among variables in the model using cholesky decomposition.




The figure shows that the response of LNEXRATE to a one standard deviation (SD) innovation in the LCPI is negative and remains negative over time. A shock to LGDP is a gradual positive change that dies out over time. A shock to the copper price (LCPRICE), the response of LNEXRATE is significant and positive change from the second month to the fourth month after which it declines but remains positive in the long run. A shock to LTBILL is negative up to the third period but recovers over time and remains negative while a shock to LUSTBILL is positive and sustained over time.

**Variance Decomposition:** The results of the variance decomposition for LNEXRATE for ten periods are shown in the table below. From the table, it can be seen that in the short run (month 3), innovation or shock to LNEXRATE accounts for 93.82% of variation in LNEXRATE, a shock to LCPI accounts for 0.38% of the fluctuation in LNEXRATE. An impulse to LGDP and LCPRICE accounts for 0.32% and 4.35% variation in LNEXRATE respectively. We also see that LTBILL and LUSTBILL account for 1.08% and 0.04% of the variation in LNEXRATE respectively. In the long run (month 10), own shock to the LNEXRATE accounts for

72.9% of fluctuations in LNEXRATE while the contribution of the copper price (LCPRICE) and LUSBILL increase to 14.1% and 10.2% of the fluctuations in LNEXRATE. A unitary shock to LGDP contributes 0.69% variation in LNEXRATE and an innovation to LTBILL accounts for 1.28% fluctuation in LNEXRATE.

| Period | S.E. | LNEXRATE | LCPI | LGDP | LCPRICE | LTBILL3 | LUSTBILL |
|---|---|---|---|---|---|---|---|
| 1 | 0.031563 | 100.0000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 2 | 0.047868 | 99.58954 | 0.060006 | 0.022172 | 0.051861 | 0.258589 | 0.017831 |
| 3 | 0.061995 | 93.81718 | 0.382104 | 0.323861 | 4.353910 | 1.082479 | 0.040467 |
| 4 | 0.073947 | 88.94598 | 0.395359 | 0.662131 | 7.980504 | 1.407492 | 0.608530 |
| 5 | 0.084252 | 86.29950 | 0.401250 | 0.757262 | 9.744017 | 1.198434 | 1.599538 |
| 6 | 0.092800 | 84.23035 | 0.487424 | 0.748492 | 11.09301 | 1.042267 | 2.398460 |
| 7 | 0.099655 | 82.18950 | 0.586496 | 0.751975 | 12.26581 | 0.964760 | 3.241454 |
| 8 | 0.105151 | 79.54904 | 0.669078 | 0.765193 | 13.09927 | 0.947487 | 4.969929 |
| 9 | 0.109874 | 76.27370 | 0.735091 | 0.742525 | 13.73232 | 1.037418 | 7.478946 |
| 10 | 0.114027 | 72.88301 | 0.799504 | 0.690264 | 14.17078 | 1.280833 | 10.17560 |

**Diagnostic Testing:** The estimated VECM model was subjected to a number of diagnostic tests to determine if serial correlation, heteroscedasticity is present and whether the residuals are multivariate normal.

**Serial correlation:** Both the correlogram Q-statistics and the Breusch-Godfrey Serial correlation LM test indicated absence of serial correlation. In testing for serial correlation, the hypotheses are as follows: *$H_0$: No serial correlation vs $H_1$: Serial correlation present*

| Breusch-Godfrey Serial Correlation LM Test: | | | |
|---|---|---|---|
| F-statistic | 1.651825 | Prob. F(2,134) | 0.1956 |
| Obs*R-squared | 3.873805 | Prob. Chi-Square(2) | 0.1441 |

Since the *P-value* is more than 5% as shown in the table above, the null hypothesis of no serial correlation in the residuals cannot be rejected. Hence, the estimated model has no serial correlation present. Results of the Q-statistics can be accessed from the appendix.

**Heteroscedasticity:** Heteroscedasticity test was conducted using the Breusch-Pagan-Godfrey test. In this case the hypotheses are as follows:

*$H_0$: No heteroscedasticity vs $H_1$: heteroscedasticity present*

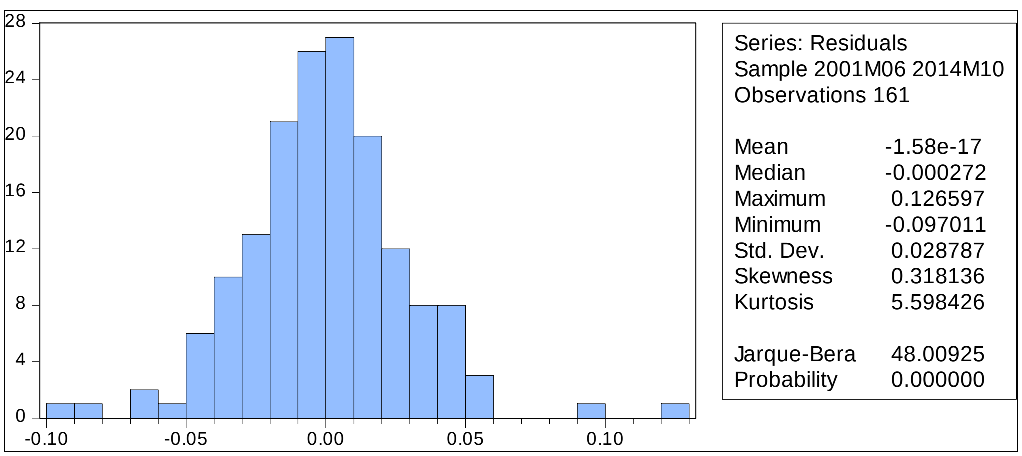
The results of this test are shown in the table below:

| Heteroskedasticity Test: Breusch-Pagan-Godfrey | | | |
|---|---|---|---|
| F-statistic | 1.105963 | Prob. F(25,135) | 0.3445 |
| Obs*R-squared | 27.36874 | Prob. Chi-Square(25) | 0.3377 |
| Scaled explained SS | 44.90142 | Prob. Chi-Square(25) | 0.0086 |

Since the *p-value* was found to be more than 5%, the null hypothesis of no heteroscedasticity in the residuals could not be rejected. Hence, the estimated model has no heteroscedasticity.

***Normality:*** The normality of the residuals was tested using the multivariate Jarque-Bera test. The hypotheses are as follows:

***$H_0$:*** *Residuals are multivariate normal vs $H_1$: Residuals not multivariate normal*




As can be seen above, the computed *p-value* of the Jarque-Bera statistic is less than exceeds 5%. Therefore, the test rejected the null hypothesis that the residuals are multivariate normal on the basis of excess kurtosis. The normality test relies on the skewness and kurtosis of the residuals. Since the assumption of normality was rejected on the basis of excess kurtosis and the residuals were found to be moderately symmetrical, the results of the analysis are not affected.

**Conclusion**

This paper examined the relationship between the Zambia/US dollar nominal exchange rate and the international copper price using cointegration, granger causality, and impulse response and variance decomposition techniques. In this analysis, domestic productivity, domestic inflation, and the Zambian and US 3-month Treasury Bills' rates were used as control variables. The paper finds that the Zambia/US dollar exchange rate follows the behavior of global copper prices in both the short run and long run. The study further finds that an increase in the copper price on the world market leads to an appreciation of the kwacha against the US dollar and a fall in the copper price results in the kwacha's depreciation against the US dollar. The study also established that domestic productivity, domestic inflation and both the Zambian and US Treasury Bill' rates have a significant effect on the kwacha/US dollar exchange rate in the long run. Results based on granger causality also indicate that there is long run causality running from the independent variables in the model to the kwacha/US dollar nominal exchange rate. The study also finds short run causality running from the copper price to the nominal exchange rate between the kwacha and the US dollar.

Upon examination of the estimated impulse response functions, we find that a shock to the copper price has a positive and significant impact on the nominal exchange rate between the two currencies that persists in the long run. Since large movements or shocks to the copper price would impact the excahnge rate signuficantly, this study has important implications for monetary policy.

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