Copper Price and Exchange Rate Dynamics in Zambia

Jonathan Chipili

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Copper Price and Exchange Rate Dynamics in Zambia

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Contents

List of tables
List of figures
Abstract
Acknowledgements

1. Introduction 1

2. Literature review 3

3. Model specification and estimation method 6

4. Empirical results and analysis 10

5. Conclusion and policy implications 15

Notes 16

References 17

Appendixes
I. Real Copper Price and Selected Macroeconomic Indicators in Zambia (1994-2012) 19
II. Brief Outline of the BP Method 20

List of tables

1.	Unit root tests	10
2.	Test for number of cointegrating vectors	11
3.	Estimated VECM for the real kwacha/US$ equation	12
4.	Causality test results using VEC approach	12
5.	Weak exogeneity test	12
6.	Variance decomposition of kwacha/US$ exchange rate due to the shock to copper price	13
7.	Detected structural breaks using BP method	13
8.	Summary of EGARCH model results with structural break dummies	14
A1.	Real Copper Price and Selected Macroeconomic Indicators in Zambia (1994-2012)	19

List of figures

1. Kwacha/US$ exchange rate and copper price 9
2. Impulse response of kwacha/US$ to copper price shock 13

Abstract

The kwacha/US$ exchange rate has fluctuated widely post-liberalization period, with large changes attributed to the copper price booms and bursts due to the significant contribution of copper to the Zambian economy. Copper mining is the major source of foreign exchange, contributing over 70% of total export earnings. Largely commodity-dependent economies are, however, vulnerable to commodity price fluctuations as principal commodity exports have a significant bearing on the overall performance of the economy. Thus, the copper price-kwacha/US$ exchange rate relationship is examined in the cointegration framework over the period 1994.1-2012.4 against the background of mixed empirical evidence from previous studies. The analysis is augmented by examining the influence of endogenously detected specific events underlying copper price movements on the kwacha/US$ exchange rate. The estimation results reveal the existence of a long-run equilibrium relationship between the real copper price and the real kwacha/US$ exchange rate. A positive shock to the copper price shifts the kwacha/US$ exchange rate to a new equilibrium level. External factors underlying copper price movements tend to increase persistence in the volatility of the kwacha/US$ exchange rate. Nevertheless, the copper price has a weak short-run effect on the exchange rate. Monetary authorities should, therefore, closely monitor underlying movements in the copper price to ensure that external competitiveness of the economy is safeguarded and macroeconomic stability is maintained.

JEL classification: F31; C22; C32

Keywords: Exchange rate; copper price; structural break; cointegration; EGARCH.

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1. Introduction

The kwacha exchange rate has fluctuated widely post-liberalization period, with large changes attributed to the rise and fall in the copper price due to the significant contribution of copper to the Zambian economy (Citigroup Global Markets, 2009; Barclays Bank Plc Market Update, 2009). Copper mining in Zambia is the major source of foreign exchange as copper exports generate about 70% of total export earnings. However, copper mining currently accounts for about 10% of gross domestic product against 50% in the 1970s (IMF, 2012)[1]. Largely commodity-dependent economies are, however, vulnerable to commodity price fluctuations as principal commodity exports have a significant bearing on the overall performance of the economy (Cerda, 2007). Commodity export prices have a strong bearing on the real exchange rate with countries operating flexible exchange rate regimes experiencing the most impact (Bova, 2009).

By and large, the data in Appendix I suggest limited impact of the copper price boom on the Zambian economy over the period 1994-2012. The nominal kwacha/US$ exchange rate depreciated at an annual average rate of about 15% while the real copper price rose by about 9% over the sample period. The deficit in the current account balance reversed when copper prices recovered post 2000 except for the global financial crisis period (2008/09). It is not evident from the data that the growth in international reserves which occurred during the period 2002-2006, when real copper prices recovered and significantly strengthened, altered the base money and domestic inflation. The growth in base money remained broadly steady at around 30% while foreign reserves accumulation increased moderately at an annual average rate of 49%. The negative correlation of 0.03 between base money and international reserves growth suggests sterilization operations by the central bank to limit the impact of foreign exchange accumulation on base money growth thereby maintaining a steady base money growth path (Böwer et al, 2007). Inflation steadily declined, reflecting the stabilization programme pursued by the government.

While world copper prices picked up, there was no noticeable improvement in fiscal revenue performance. Fiscal revenue (excluding grants) as a percentage of gross domestic product (GDP) fell from around 20% in 1994 to about 18% in 2012. The fiscal deficit as a percentage of GDP improved albeit moderately, especially post global financial crisis. The rise in foreign exchange supply in the retail market was not sufficient to trigger a significant and sustained appreciation of the kwacha. Overall, there is no noticeable change in domestic demand associated with the rise in the copper price over the sample period. Government spending initially rose after the recovery in copper prices but remained stable and later declined. Similarly, household consumption continuously declined.

Existing empirical evidence on the copper price-kwacha exchange rate link is mixed. Cashin et al. (2002), Bova (2009) and Pamu (2011) provide contradictory results. Cashin et al. (2002) conclude that the kwacha is not a commodity-currency owing to the statistical insignificance of the estimated copper price elasticity coefficient (0.94%) of the real effective exchange rate despite the existence of a long-run cointegrating relationship between the two variables over the period 1980-2002. To the contrary, Bova (2009) finds the kwacha to be a commodity-currency over the period 1997-2008. Pamu (2011) finds no evidence of a long-run cointegrating relationship between the two variables over the period 2000-2009.

The mixed results on the copper price-kwacha/US$ exchange rate motivates this study to provide further insights into the relationship and examine how policy makers might respond to copper price cycles. A bivariate cointegrating framework is employed over the period 1994-2012 using quarterly data to examine the long-run equilibrium relationship between the real copper price and real kwacha/US$ exchange rate. As cointegration in a two-variable framework implies that at least one of the variables must granger cause the other (Amano and van Norden, 1995), long-run causality (or weak exogeneity) is tested in the vector error correction (VEC) framework.

Unlike previous studies on the commodity price-exchange rate relation, the impact of structural breaks (break points or dates) in copper price on the level and volatility of the kwacha/US$ exchange rate is examined in the GARCH framework due to Engle (1982) and Bollerslev (1986). The structural breaks relate to specific events underlying fluctuations in the copper price that constitute the information set agents in the foreign exchange market use in determining the currency value. The motivation is to establish whether structural breaks indirectly increase or reduce returns and/or volatility i.e. affect uncertainty in the foreign exchange market. Structural breaks in the copper price series (returns and conditional variance/volatility) are endogenously determined using the Bai and Perron (2003) least squares method. The EGARCH model is employed to estimate conditional volatility in the kwacha exchange rate and copper price as existing evidence suggests asymmetric behaviour of the two series under study (McAleer and Watkins, 2004; Chipili, 2010).

The empirical results reveal the existence of a long-run equilibrium relationship between real copper price and the real kwacha/US$ exchange rate. A positive shock to the copper price shifts the kwacha exchange rate to a new equilibrium level. External factors underlying copper price movements have the tendency to increase persistence in the kwacha/US$ exchange rate volatility. Nevertheless, copper price has weak short-run effect on the exchange rate.

The rest of the paper proceeds as follows. A review of the literature is presented in section 2 followed by a brief description of the estimated empirical model, estimation method and data in section 3. Section 4 discusses the empirical results. Section 5 concludes and offers policy implications.

2. Literature review

The fundamental equation for exchange rate determination is given by:

$$e_t = (1-\delta)\sum_{j=0}^{\infty}\delta^j E_t f_{t+j} \tag{1}$$

where, e_t is the logarithm of the exchange rate, f_t represents a set of fundamental factors expressed in logarithmic form, δ is the discount factor, and E_t is the rational expectations operator based on information available at time t (Lewis, 1995).

The key variables constituting f_t include real income, money supply, measure of inflation, interest rates, terms of trade and openness. A weak link is, however, documented between fundamentals and the exchange rate (Chipili, 2010)[2]. It is noted that empirical exchange rate puzzles such as purchasing power parity can be resolved if a sufficiently volatile real shock can be found (Amano and van Norden, 1995; Chen and Rogoff, 2002; Koranchelian, 2005). Commodity export prices, especially in commodity-dependent developing countries, are cited among potential factors believed to effectively explain exchange rate fluctuations and help resolve empirical puzzles. This study focuses on a narrow perspective of exchange rate determination similar to Chen and Rogoff (2002) and Cashin et al. (2002).

Commodity export prices and terms of trade tend to be highly correlated such that shocks to the former are directly transmitted to the latter and subsequently to the exchange rate (Hatzinikolaou and Polasek, 2005). The exclusion of terms of trade shocks in empirical exchange rate models is cited as one reason accounting for mixed results (Amano and van Norden, 1995). However, the effect of terms of trade on the real exchange rate is ambiguous, depending on the relative strength of income and substitution effects. The effect of commodity export prices on the exchange rate is predicted to be negative and provide a stronger and direct mechanism through which external shocks are transmitted to the exchange rate (Cashin et al, 2002; Hatzinikolaou and Polasek, 2005). Moreover, individual real commodity prices are more volatile than aggregate price indexes such as terms of trade that do not accurately capture the short-lived booms and long-lived troughs observed in most commodity prices. For this reason, real commodity prices bear a more direct impact on the real exchange rate than aggregate price indexes consistent with the view that volatile real shocks have a considerable explanatory power in exchange rate dynamics (Amano and van Norden, 1995; Chen and Rogoff, 2002; Koranchelian, 2005).

Commodity prices capture the role of the external sector and thus confer information about world business cycles (Amano and van Norden, 1995). In the long run, changes in commodity export prices tend to affect the real exchange rate, wages, employment, output and profitability with most studies analysing this in the context of the Dutch-Disease (Edwards, 1985). The rise in the price of the dominant export commodity improves the country's terms of trade, increases export income and consequently generates a trade surplus. As domestic income and expenditure are stimulated, they generate expectations of higher prices in the economy, leading to an appreciation of the exchange rate (Hatzinikolaou and Polasek, 2005). An appreciated exchange rate benefits domestic customers via lower priced imports but external competitiveness is lost. A trade surplus generated by a boom in commodity export prices leads to the accumulation of international reserves. Accordingly, the monetary base expands thereby generating excess liquidity in the banking system. If reserves are not fully sterilized, inflation increases and consequently the real exchange rate appreciates. Similarly, an increase in commodity export prices results in higher disposable income which boosts demand for both tradeable and non-tradeable goods (income effect) leading to higher relative price for non-tradeables. The real exchange rate subsequently appreciates and resources are re-allocated from the tradeable to the non-tradeable sector. Further, periods of rising and high commodity prices are associated with strong growth (Böwer et al, 2007).

Edwards (1985) developed a model for the Colombian real exchange rate and considered the interaction between coffee price (principal export), money creation, inflation and the real exchange rate. He found evidence of the rise in world coffee price negatively affecting the real peso exchange rate (appreciating) in addition to raising money supply as real exchange rate appreciation was accommodated. Strong exchange rate pass-through to domestic prices was also established.

Cashin et al. (2002) developed a long-run equilibrium exchange rate model for 58 commodity-exporting countries, including Zambia. A real commodity price index[3] constructed for main export commodities was used. Copper and sugar prices were used for Zambia. They found a long-run co-movement between real commodity prices and the real exchange rate in the majority of the 58 commodity-dependent low-income countries considered. Causality was found to run from real commodity prices to the real exchange rate based on weak exogeneity tests conducted in the vector error correction framework with a faster speed of adjustment (half-life) at eight months in line with PPP than Rogoff's (1996) three to five years. Chen and Rogoff (2002) also found evidence of commodity export prices having a strong bearing on real exchange rates for OECD countries (Australia, Canada and New Zealand) investigated with a significant share of commodities in total exports. The only exception was Canada where the results were less robust compared with the other two countries as the proportion of commodity export in total exports was relatively small (25%) compared with Australia (over 60%) and New Zealand (over 50%).

Employing cointegration analysis over the period 1984.1-2003.1, Hatzinikolaou and Polasek (2005) found evidence of the nominal Australian dollar being a commodity-currency with the long-run commodity price elasticity of the exchange rate of 0.94%. In addition, commodity prices proved useful in modelling exchange rate behaviour as purchasing power parity (PPP), and uncovered interest rate parity (UIP) could not be rejected when included in the specification (see Hatzinikolaou and Polasek, 2005; Bjørnland and Hungnes, 2008). Employing the local-to-unity asymptotics approach, Chen and Rogoff (2012) established that export prices bear a strong contemporaneous relationship with real exchange rates of commodity dependent economies. However, the predictive power of export prices on future exchange rate movements was found to be low. Finally, Wu (2013) confirmed the Chilean peso as a commodity-currency, largely driven by movements in the copper price.

3. Model specification and estimation method

Model specification and cointegration analysis

Similar to Cashin et al. (2002), Equation 1 is modified and the estimated empirical model is specified as:

$$e_t = \gamma_0 + \gamma_1 cup_t + \varepsilon_t \tag{2}$$

where, e_t is the logarithm of the real kwacha/US$ exchange rate, cup_t is the logarithm of the real copper price, and ε_t is the error term.

To determine both the short- and long-run copper price elasticity of the real kwacha/US$ exchange rate, a bivariate vector equilibrium correction model (VECM) in e_t and cup_t is estimated over the period 1994q1-2012q4 using the Johansen cointegration method. This is preceded by the analysis of time series properties of the two data series using the augmented Dickey-Fuller (ADF) and Phillips and Perron (PP) unit root tests and the determination of the lag length of the VAR in levels that ensures that residuals are free of serial correlation.

Thus, given Equation 2, the stochastic vector process is defined as $z_t = (e_t, cup_t)'$ and re-parameterized as a VECM as:

$$\Delta z_t = \omega D_t + \Pi z_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta z_{t-i} + \varepsilon_t \tag{3}$$

where, Δ is the difference operator; z_t is an $(nx1)$ vector of non-stationary variables in levels; D_t is an $(nx1)$ vector of deterministic variables: intercept, time trend, seasonal or intervention dummies; ω is a matrix of coefficients on deterministic variables; $\Pi = -(\Pi_1 - \Pi_2 - ....\Pi_{p,} - I)$ is an (nxn) impact matrix of unknown coefficients, a product of α and β' matrices that contains information about the long-run relationship among z_t variables; $\Gamma_i = (I - \Gamma_1 - \Gamma_2 - .... - \Gamma_p)$, the short-run response matrix with $i = 1,2,3,..., p$, is a matrix of parameter coefficients on lagged first difference of z_t variables; ε_t is an $(nx1)$ vector of Gaussian innovations; p is the lag length for the VAR; and $t = 1,2,......,T$. α is an (nxr) matrix of coefficients reflecting how quickly each variable in z_t adjusts towards the equilibrium once a disequilibrium occurs while β' is an (rxn) matrix representing cointegrating vector(s) with long-run coefficients among z_t. The rows of β' also known as the cointegrating rank (r) of Π form the r distinct cointegrating vectors such that the elements in $\beta' z_t$ are stationary even though z_t is itself non-stationary. The null hypothesis of r cointegrating vectors (H $_0$: $\Pi = \alpha\beta'$) is tested using the trace (λ_{trace}) and maximal eigenvalue ($\lambda_{\max}$) tests.

With cointegration confirmed, causality must exist in at least one direction. This can be established using the VEC procedure suggested by Engle and Granger (1987) as follows:

$$\Delta e_t = c_1 + \sum_{i=1}^{p-1} \delta_{1i} \Delta e_{t-1} + \sum_{j=1}^{p-1} \psi_{1j} \Delta cup_{t-j} + \alpha_1 \, ecm_{t-1} + \varepsilon_t \tag{4}$$

$$\Delta cup_t = c_2 + \sum_{i=1}^{p-1} \delta_{2i} \Delta e_{t-1} + \sum_{j=1}^{p-1} \psi_{2j} \Delta cup_{t-j} + \alpha_2 \, ecm_{t-1} + \varepsilon_t' \tag{5}$$

where, c_1 and c_2 are constant terms; α_1 and α_2 are error correction terms corresponding to the cointegrating Equation 3; and ε_t and ε_t' are serially-uncorrelated disturbance terms. e_t is Granger caused by cup_t if all the ψ_{1j} in Equation 4 are non-zero (Granger non-causality or short-run causality) or if α_1 is non-zero (long-run causality/weak exogeneity test). Similarly, cup_t is Granger caused by e_t if all the δ_{2i} in Equation 5 are non-zero (Granger non-causality or short-run causality) or if α_2 is non-zero (long-run causality/weak exogeneity test). Bi-directional long-run causality exists when weak exogenity is rejected for two variables. Weak exogeneity implies that a weakly exogenous variable does not adjust to re-establish the long-run equilibrium following a shock.

Detection of structural breaks in copper price and exchange rate dynamics

A further examination of the copper price-exchange rate relationship is conducted by accounting for the effect of structural breaks in the copper price series (returns and conditional variance) on the level and volatility of the kwacha/US$ exchange rate in the GARCH framework. The Bai and Perron (2003) least squares method (hereinafter called BP method and briefly explained in Appendix II) is used to detect possible structural breaks in the copper price series. The copper price returns and conditional variance are constructed using the log first difference and EGARCH (1, 1) model, respectively. The constructed series are then used in the BP method to detect break points or dates.

The impact of break points on the kwacha/US$ exchange rate is in turn assessed in the EGARCH (1, 1) mean and conditional variance equations to determine whether they increase or reduce returns and volatility, respectively.

The detected structural break dates are converted into break date dummies, taking the value of one from the detected date onwards and zero otherwise. Each break date is assumed to be independent of the other(s). The break dummies are subsequently introduced in the EGARCH (1, 1) mean and conditional variance equations 6 and 7 as follows:

$$\Delta e_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \Delta e_{t-i} + \sum_{j=1}^{n} \phi_j RBD_j + \varepsilon_t \tag{6}$$

$$\varepsilon_t \left| I_{t-1} \sim N(0, h_t) \right.$$

$$h_t = \alpha_0 + \alpha \left[\frac{|\varepsilon_{t-1}|}{\sqrt{h_{t-1}}} \right] + \gamma \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} + \beta h_{t-1} + \sum_{j=1}^{n} \theta_j VBD_j \tag{7}$$

where, Δe_t is the logarithmic first difference in e_t; ε_t is residuals used to test for the presence of ARCH/GARCH effects in e_t; I_{t-1} is the information set at time $t-1$; q and n refer to the lag length; h_t is the conditional variance of e_t derived from the EGARCH (1, 1) model; RBD_j and VBD_j are, respectively, dummies representing break dates detected in the copper price returns and conditional variance series using the BP method; $\alpha_0, \alpha_i, \alpha, \gamma, \beta, \phi_1, \ldots, \phi_n$ and $\theta_1, \ldots, \theta_n$ are parameter coefficients to be estimated.

Volatility persistence in the exchange rate is captured by the size of β while α reflects the magnitude of the shock on conditional variance. Asymmetric or leverage effects are captured via a statistically significant γ which can take on either a positive or negative sign. RBD_j and VBD_j may be different.

The break date dummies may affect the value of the kwacha/US$ (depreciate/appreciate) and/or increase (dampen) uncertainty in the foreign exchange market. Hence, specific events relating to each RBD_j and VBD_j are identified and their impact on the level and volatility of the kwacha/US$ exchange rate assessed as they form part of the information set used by the market in influencing the value of kwacha exchange rate. Positive (negative) ϕ_j in Equation 6 imply that the respective RBD_j deprecates (appreciates) the real kwacha/US$ exchange rate. A positive (negative) θ_j in Equation 7 signifies an increase (decrease) in the real kwacha/US$ volatility corresponding to a particular VBD_j.

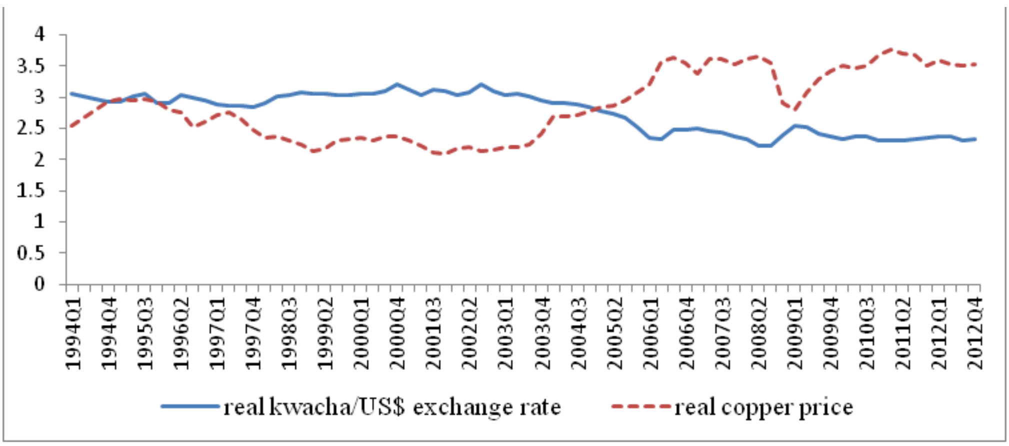
Data sources and description

The log level plot of quarterly observations of the real kwacha/US$ exchange rate (e_t) and real copper price (cup_t) obtained from Datastream are displayed in Figure 1. Real copper price is defined as the nominal London Metal Exchange copper price grade A cash (in US$/metric tonne) deflated by the US consumer price index (US CPI). The real kwacha/US$ exchange rate is defined as the nominal kwacha/US$ deflated by the price ratio of US CPI to Zambia CPI such that an increase (decrease) represents a depreciation (appreciation).

A visual inspection of Figure 1 reveals a generally declining trend in the real kwacha/US$ exchange rate, while the copper price largely trended upwards over the sample period. Specifically, the copper price trended downwards from 1995 until about 2001 when a recovery in the metal price occurred. The recovery is attributed to strong global demand, especially high growth rates in China. However, copper prices fell drastically in early 2008 but remained above the pre-2001 level. The falling trend was quickly reversed in 2009 as prices picked up sharply and maintained an upward trend.

While the plot in Figure 1 suggests a close relationship between the two series over the sample period (with a computed high negative correlation coefficient of 0.9), the similarity in swings and turning points for the kwacha/US$ exchange rate and copper price are not apparent. Some periods indicate a positive covariance between the two series while a negative covariance is observed in other periods and no discernible pattern is detected in some periods. A formal determination of the direction and strength of the relationship follows.

Figure 1: Kwacha/US$ exchange rate and copper price



4. Empirical results and analysis

Both the real exchange rate and copper price series are I(1) as they are level non-stationary but first difference stationary (Table 1). Cashin et al. (2002) argue that the non-stationarity of the real exchange rate could be attributed to macroeconomic disturbances such as shocks to real commodity prices that may cause the real exchange rate to persistently deviate from PPP. Further, cointegration between the real exchange rate and real commodity prices is expected.

Table 1: Unit root tests

Variable	ADF			P-P	
	level	First difference	lags	level	First difference
real kwacha/US$ exchange rate	-3.86	-12.93***	0	-3.89	-13.90***
real copper price	-2.45	-14.41***	0	-2.58	-14.52***

Critical values are MacKinnon (1990) one-sided p-values. ***, ** and * imply 1%, 5% and 10% levels of significance, respectively. A constant and linear trend is included in both ADF and PP unit root tests.

To determine the existence of cointegration between the real copper price and the real kwacha/US$ exchange rate, the unrestricted VAR(2) was estimated where the optimal lag length of two was chosen on the basis of Akaike information and Schwarz information criteria. An intercept was included in the cointegrating equation and VAR whereas a linear trend was only included in the cointegrating equation to take account of trends evident in the series observed in Figure 1. In addition, three impulse dummies, namely, D1995q3, D2006q1 and D2008q4, were included to capture large exogenous shocks and obtain a well-specified model. $D1995q3$ captures supply shocks (drought) as well as banking crises that induced demand for foreign assets. $D2006q1$ relates to the improvement in the performance of the external sector and positive sentiments following the attainment of the Highly Indebted Poor Countries Initiative Completion Point and the Multilateral Debt Relief Initiative that attracted portfolio flows. $D2008q4$ reflects political uncertainty surrounding the illness and eventual passing of the Republican President and subsequent Presidential by-elections, worsening of the global financial crisis and deterioration in copper prices.

Both the trace and maximum eigenvalue test statistics in Table 2 confirm the existence of one cointegrating relation between the real kwacha/US$ exchange rate and real copper price at the 5% significance level consistent with previous studies on commodity price-exchange rate studies (Cashin et al, 2002; Hatzinikolaou and Polasek, 2005). The cointegration equation fits reasonably well and passes all the misspecification tests (Table 3).

Table 2: Test for number of cointegrating vectors

	95% critical values	Trace test statistics (λ_{trace})		95% critical values	Maximum eigenvalue statistics ($\lambda_{\max}$)
$r = 0$ **	25.9	27.1	$r = 0$ **	19.4	22.7
$r = 1$	12.5	4.3	$r = 1$	12.5	4.3
Optimal lag		2	Optimal lag		2**

**denotes rejection of the hypothesis at 5% significance level.

The existence of cointegration between the kwacha/US$ exchange rate and copper price implies that deviations from the long-run relationship are self-correcting. In the long run, a 10% increase in the real copper price leads to about 4.8% appreciation in the real kwacha/US$ exchange rate. This result is in line with the evidence for currencies of other commodity-exporting countries (Cashin, et al, 2002; Koranchelian, 2005). The statistical significance of the elasticity of the real kwacha/US$ exchange rate with respect to the real copper price renders support for the kwacha as a commodity currency – movements in the real kwacha/US$ exchange rate are affected by movements in the real copper price over time.

Fluctuations in the real copper price typically entail an adjustment in the real kwacha/US$ exchange rate. The error correction term reflecting disequilibrium in the exchange rate indicates a moderate speed of adjustment whereby about 18% of a disequilibrium value of the real kwacha/US$ exchange rate is removed every quarter. The weak exogeneity result (Table 5) indicates that only the real copper price adjusts to close any deviations from the long-run whenever a disturbance occurs. This result is counterintuitive: the nominal kwacha/US$ exchange rate has little short-term influence on copper production and/or exports (Weeks, 2013).

While the real copper price and real kwacha/US$ exchange rate move together in the long run, in the short term, the VECM result indicates that the real kwacha/US$ exchange rate is driven by its own past values. This result is reinforced by the granger non-causality test (Table 4), variance decomposition results (Table 6) and impulse response analysis (Figure 2). The granger non-causality test indicates that short-run movements in real copper price do not help predict part of the short-run movements in the real kwacha/US$ exchange rate similar to Chen and Rogoff (2012). In addition, the impulse response analysis suggests that the impact of copper price shocks on the real kwacha exchange rate only takes effect in the second quarter. Overall, a positive shock to the copper price shifts (appreciates) the real kwacha exchange rate to a new equilibrium level by the sixth quarter. The exchange rate is, however, characterized by overshooting behaviour (over reaction) prior to shifting to the new equilibrium level. Further, the variation in the exchange rate due to the copper price shock progressively increases from quarter two (Table 6).

The weaker role of real copper prices on the kwacha exchange rate reflects the argument that changes in market expectations due to news such as economic shocks, unexpected political and social events dominate short-term currency movements. Moreover, the contemporaneous relationship between commodity prices and exchange rates is ambiguous despite some evidence of the existence of strong long-run co-movement (Akram, 2009).

Events in 2006.1 and 2008.4 exerted statistically significant influence on the real kwacha/US$ exchange rate over the sample period. Improvement in the external sector and positive news relating to debt relief in 2006 induced a real appreciation of the kwacha, while political uncertainty in 2008 depreciated the real kwacha exchange rate. However, the supply shocks in 1995 had little statistical impact on the exchange rate.

Table 3: Estimated VECM for the real kwacha/US$ equation

$$\Delta e_t = \underset{(-1.38)}{-0.009} + \underset{(1.88)^{*}}{0.223}\,\Delta e_{t-1} \underset{(-3.03)^{***}}{-0.357}\,\Delta e_{t-2} \underset{(-1.35)}{-0.079}\,\Delta cup_{t-1} + \underset{(0.28)}{0.017}\,\Delta cup_{t-2}$$

$$\underset{(1.08)}{-0.063}\,D1995q3 \underset{(-2.80)^{**}}{-0.163}\,D2006q1 + \underset{(1.80)^{*}}{0.103}\,D2008q4 \underset{(-2.03)^{**}}{-0.178}\,ecm_{t-1}$$

$$ecm_{t-1} = e_{t-1} + \underset{(11.6)^{***}}{0.476}\,cup_{t-1} + \underset{(2.6)^{**}}{0.003}\text{Trend (1994q1)} + 4.227$$

R^2 = 0.42; serial correlation LM-statistic = 5.85[0.2105]; normality test: J-B test = 1.6877[0.7930]; White's heteroskedasticity test: χ^2 (69) = 68.21191[0.50423] . ***,**,*=1%, 5%, and 10% significance level, respectively. t-statistics are reported in parenthesis.

Table 4: Causality test results using VEC approach

H_0: real copper price (cup_t) does not Granger-cause real kwacha/US$ exchange rate (e_t)	H_0: real kwacha/US$ exchange rate (e_t) does not Granger-cause real copper price (cup_t)
$\psi_1 = \psi_2 = 0$ $\chi^2(2)$ [p-value]=1.8643[0.3937]	$\delta_1 = \delta_2 = 0$ $\chi^2(2)$ [p-value]=1.1530[0.5619]

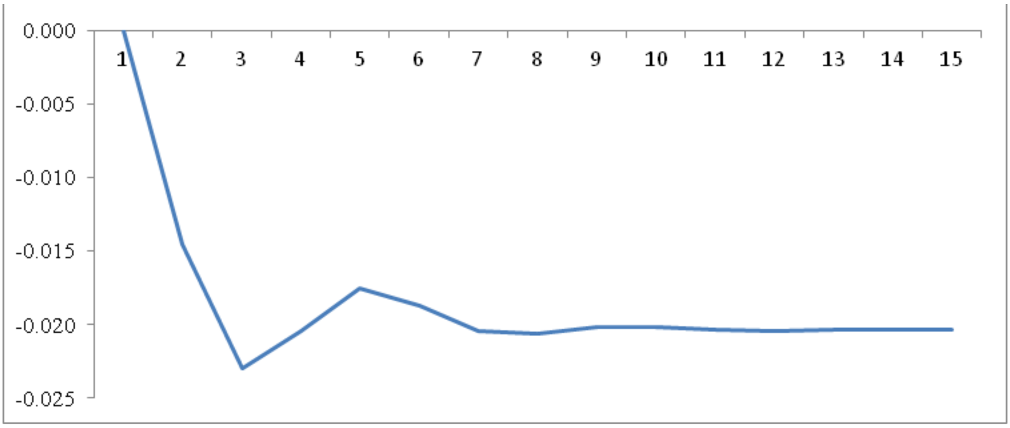
Table 5: Weak exogeneity test

H_0: real kwacha/US$ exchange rate is weakly exogenous (α_1 =0)	H_0: real copper price is weakly exogenous (α_2 =0)
$\chi^2(1)$ [p-value]=3.7497[0.0528]	$\chi^2(1)$ [p-value]=8.3965[0.0038]

Table 6: Variance decomposition of kwacha/US$ exchange rate due to the shock to copper price

Forecast Horizon (quarters)	1	2	3	4	10	15
Standard Error	0.00	2.86	7.44	9.83	13.35	14.66

Figure 2: Impulse response of kwacha/US$ to copper price shock



The outcome of the Bai and Perron method is reported in Table 7. Structural breaks are only detected in the copper price volatility series. The nature of events surrounding the real copper price volatility relate to the pick-up in demand for copper due to growth in China and the emergence of the global financial crisis in 2003 and 2008, respectively.

The results of the EGARCH model estimation incorporating copper price structural breaks are reported in Table 8. The first column reports the results without structural breaks while the second column captures the effects of structural breaks on the volatility of real kwacha/US$ exchange rate. Overall, the identified events have a tendency to increase volatility persistence in the real kwacha/US$ exchange rate. The pick-up in demand for copper relating to strong economic growth in China characterizing volatility in the real copper price impacted positively on the real kwacha/US$ exchange rate volatility. On the contrary, events surrounding the 2008 global financial crisis had a dampening effect on the real kwacha/US$ exchange rate volatility.

Table 7: Detected structural breaks using BP method

Variable	Break date dummies	Nature of event
cup_t	2003q3 2008q3	pickup in demand for copper by China emerging effects of the global financial crisis

Table 8: Summary of EGARCH model results with structural break dummies

	(1)	(2)
Mean equation		
α_0	-0.003	0.0004
	(-0.76)	(0.13)
α_1	0.001	0.024
	(0.02)	(0.43)
Variance equation		
α_0	-1.831	-0.958
	(-2.57)*	(-2.25)**
α	0.394	0.252
	(3.53)***	(2.93)***
γ	0.134	0.196
	(2.06)**	(2.78)***
β	0.748	0.876
	(6.98)***	(13.7)***
2003q3		0.143
		(2.67)***
2008q3		-0.222
		(-3.26)***
$\upsilon_t Q(5)$	1.4128[0.923]	0.6119[0.987]
$\upsilon_t^2 Q(5)$	7.1060[0.213]	2.9735[0.704]
ARCH LM	0.165[0.6843]	0.001[0.9737]
Log L	373.08	376.12
AIC	-3.2342	-3.2434
SBC	-3.1437	-3.1227

The lag length for $\upsilon_t Q$ and $\upsilon_t^2 Q$ is set at 9 according to Tsay (2001): $k = \ln(T)$ where k is lag length and T is the number of observations. Bollerslev-Wooldridge robust standard errors and variance are used to take care of the non-normality property of the data series and ensure consistent coefficient estimates are derived. z-statistics are reported in parenthesis, p-values in square brackets. ***,**,* refer to statistical significance at 1%, 5% and 10%, respectively. $\upsilon_t Q(5)$ and $\upsilon_t^2 Q(5)$ are tests for serial correlation and heteroskedasticity based on the Ljung-Box Q-statistic conducted on standardized (υ_t) and squared standardized (υ_t^2) residuals, respectively; LogL=loglikelihood value; AIC=Akaike information criteria; and SBC=Shwartz information criteria.

5. Conclusion and policy implications

The study examined the real copper price-kwacha/US$ exchange rate relationship post liberalization period (1994-2012) using quarterly data against the background of mixed results from existing empirical studies on Zambia. Similar to previous studies, cointegration analysis was employed. In addition, the influence of specific events underlying copper price movements detected endogenously using the BP method on the level and volatility of the kwacha/US$ exchange rate, never examined thus far in the literature, was investigated.

The existence of a long-run equilibrium relationship between real copper price and the real kwacha/US$ exchange rate was established. A positive shock to copper price shifts the real kwacha exchange rate to a new equilibrium level preceded by overshooting behaviour. However, the copper price has weak a short-run impact on the exchange rate. External events underlying copper price movements tend to increase volatility persistence in the kwacha exchange rate.

The empirical results signify the important role of copper price in the kwacha rate dynamics that policy makers should integrate in the overall macroeconomic policy framework. Shocks to the copper price form an integral part of overall exchange rate management in Zambia. Monetary authorities should therefore closely monitor underlying developments in the copper price in order to design appropriate policy response to ensure that external competitiveness of the economy is safeguarded and macroeconomic stability is maintained.

Notes

1. Zambia was the ninth largest producer of copper in 2006 (British Geological Survey, 2008).

2. Fundamentals account for a small proportion of the observed changes in exchange rates; changes in exchange rates take place even when there are no detectable changes in fundamentals; exchange rates deviate from their equilibrium level implied by purchasing power parity (PPP) in the short run where such deviations are large and persist for a long time due to sluggish prices.

3. The real commodity price index is defined as the world (nominal) price for each country's commodity exports relative to the world price of manufactured goods.

4 Represents spot US$ retail purchases of foreign exchange by banks, the primary source of foreign exchange, in which all exporters are allowed to participate. Mining companies were allowed to directly sell export proceeds in the retail market in 1996.

References

Akram, Q.F. 2009. "Commodity prices, interest rates and the dollar". Energy Economics, 31: 838´51.

Amano, R.A. and S. van Norden. 1995. "Exchange rates and oil prices". Bank of Canada Working Paper No. 95´8.

Bai, J. and P. Perron. 1998. "Estimating and testing linear models with multiple structural change". Econometrica, 66(1): 47´78.

Bai, J. and P. Perron. 2003. "Computation and analysis of multiple structural change models". Journal of Applied Econometrics, 18: 1´22.

Barclays Bank Zambia PLC Market Update, various daily issues in 2009.

Bjørnland, H.C. and H. Hungnes. 2008. "The commodity currency puzzle". The IUP Journal of Monetary Economics, 6.2: 7´30.

Bollerslev, T. 1986. "Generalized autoregressive conditional heteroskedasticity". Journal of Econometrics, 31: 307´327.

Bova, E. 2009. "Is the Zambian kwacha a commodity currency? The co-movement between copper prices and the exchange rate". NCCR Trade Regulation, Swiss National Centre of Competence in Research Working Paper No.2009/11, March.

Böwer, U., A. Geis and A. Winkler. 2007. Commodity Price Fluctuations and their Impact on Monetary and Fiscal Policies in Western and Central Africa. European Central Bank Occasional Paper No. 60, April.

British Geological Survey. 2008. "List of countries by copper mine production". accessed January 2010.

Cashin, P., L. Céspedes and R. Sahay. 2002. "Keynes, cocoa, and copper: In search of commodity currencies". IMF Working Paper No. WP/02/223.

Cerda, R.A. 2007. "Market power and primary commodity prices: The case of copper". Applied Economics Letters, 14: 775´78.

Chen, Y. and K. Rogoff. 2002. "Commodity currencies and empirical exchange rate puzzles". IMF Working Paper No. WP/02/27.

Chen, Y. and K. Rogoff. 2012. "Are the commodity currencies an exception to the rule?" Global Journal of Economics, 1(1): 401´428.

Chipili, J.M. 2010. "Macroeconomic effects of exchange rate volatility in Zambia". PhD Thesis, University of Leicester, available at http://hdl.handle.net/2381/8309

Citigroup Global Markets/Citigroup Zambia Daily Market Commentary, various daily issues in 2009 and 2010.

Edwards, S. 1985. "Commodity export prices and the real exchange rate in developing countries: Coffee in Colombia". NBER Working Paper No.1570.

Engle, R.F. 1982. "Autoregressive conditional heteroskedasticity with estimates of the variance of the United Kingdom inflation'. Econometrica, 50: 987´ 1007.

Engle, R. F. and C. W. Granger. 1987. "Co-integration and error correction: Representation, estimation and testing", Econometrica, 55: 251´ 276.

Hatzinikolaou, D. and M. Polasek. 2005. "The commodity-currency view of the Australian dollar: A multivariate cointegration approach". Journal of Applied Economics, Volume VIII, No. 1 (May): 81´ 99.

Inclán, C. and G.C. Tiao. 1994. "Use of cumulative sums of squares for retrospective detection of changes of variance". Journal of the American Statistical Association, 89(427): 913´ 23.

IMF. 2012. IMF Country Report No. 12/200, Zambia-2012 Article IV Consultation, July

Koranchelian, T. 2005. "The equilibrium real exchange rate in a commodity exporting country: Algeria's experience". IMF Working Paper No. WP/05/135.

Lewis, K.K. 1995. "Are foreign exchange intervention and monetary policy related, and does it really matter?" The Journal of Business, 68(2): 185´ 214.

MacKinnon, J. G. 1990. "Critical values for cointegration tests", UCSD Discussion Papers, 90(4).

McAleer, M. and C. Watkins. 2004. "Econometric modelling of non-ferrous metal prices". Journal of Economic Survey, 18(5): 651´ 701.

Pamu, E.M. 2011. "Does the copper price explain the deviation of the real exchange rate from the purchasing power parity equilibrium in Zambia?" Issues on the Zambian Economy, 1(6): 38´ 44.

Rogoff, K. 1996. "The purchasing power parity puzzle". Journal of Economic Literature, 34: 647´ 68.

Sansó, A., V. Arago and J.L. Carrion. 2004. "Testing for changes in the unconditional variance of financial time series". Revista De Economia Financiera, 4: 32´ 53.

Tsay, R. S. 2002. Analysis of Financial Time Series, New York: John Wiley and Sons.

Weeks, J. 2013. "Short-run determinants of the nominal kwacha: Implications for exchange policy". Study Commissioned by the International Growth Centre at the London School of Economics in Partnership with Oxford University. Mimeo.

Wu, Y. 2013. "What explains movements in the peso/dollar exchange rate". IMF Working Paper No. 171/13.

Appendixes

Appendix I

Real Copper Price and Selected Macroeconomic Indicators in Zambia (1994-2012)

	% change real copper price	% change nominal kwacha /US$	% change base money	CAB % GDP	% change FX reserves	% change in FX supply to the market[4]	Inflation rate (%)	Fiscal revenue (excl. grants) % GDP	Overall Fiscal balance (excl. grants) % GDP	Household final consumption expenditure, % GDP	Govt final consumption expenditure, % GDP
1994	15.6	25.9		-3.2	39.4		54.6	20.9	-7.9	73.1	13.1
1995	-1.7	36.1	61.8	-8.4	-21.5		34.9	20.0	-4.3	72.4	15.4
1996	-17.5	35.3	25.9	-8.8	0.2		43.1	18.9	-3.9	76.4	18.3
1997	-3.0	10.4	8.8	-4.7	12.7		24.4	18.4	-2.4	71.8	17.5
1998	-15.8	72.3	31.0	-17.6	-71.2		24.5	18.2	-6.9	75.5	15.8
1999	17.2	13.2	28.6	-12.3	-33.9	13.2	26.8	19.1	-4.0	81.4	12.9
2000	-10.2	64.1	53.3	-20.4	492.0	-11.9	26.0	19.0	-7.8	87.0	9.5
2001	-13.4	-15.0	45.8	-20.2	-56.6	15.6	21.4	20.0	-4.7	87.2	10.1
2002	1.7	19.7	-3.9	-17.9	320.6	16.6	22.2	17.8	-4.1	79.4	11.9
2003	24.2	-5.2	50.6	-15.3	-41.7	42.4	21.4	17.3	1.1	73.6	13.9
2004	14.5	4.3	11.9	-8.2	18.0	13.0	18.0	18.0	2.1	60.1	17.2
2005	32.0	-28.6	33.8	-8.4	33.6	15.7	18.3	17.6	1.2	59.9	18.5
2006	70.1	27.9	20.1	1.3	62.3	39.1	9.0	17.0	-7.3	50.9	18.6
2007	9.3	-8.3	43.3	-6.1	51.9	15.0	10.7	17.4	-4.8	58.4	17.9
2008	-54.8	25.3	8.1	-7.1	-0.1	50.8	12.5	18.4	-6.3	63.6	17.4
2009	123.8	-3.0	33.8	4.2	75.6	-13.3	13.4	15.6	-5.5	58.1	18.0
2010	-29.7	2.7	51.6	7.1	7.6	28.9	8.5	17.4	-4.2	49.2	16.4
2011	12.3	0.9	-22.6	3.7	18.5	3.3	6.4	19.3	-4.3	45.4	20.6
2012	-11.8	6.5	51.5	0.0	29.5	37.0	7.3	18.2	-1.0	48.6	18.2

Source: World Development Index; Bank of Zambia Statistics Fortnightly Bulletin; and Author Computations.

Appendix II

Brief Outline of the BP Method

The underlying model in the BP method is formulated as follows. A linear regression with m breaks ($m+1$ regimes) is specified as

$$y_t = x_t'\beta + z_t'\delta_j + u_t \qquad (t = T_{j-1}+1,....,T_j)$$

such that $j = 1,...,m+1$; y_t is the observed dependent variable at time t in this case copper price; $x_t(p\times 1)$ and $z_t(q\times 1)$ are vectors of covariates; β and δ_j $(j = 1,...,m+1)$ are vectors of coefficients; and u_t is the error term at time t. The break dates or points $(T_1,...,T_m)$ are treated as unknown whereby $T_0 = 0$ and $T_{m+1} = T$. The unknown regression coefficients and break points are estimated using a sample of T observations on y_t, x_t and z_t.

The linear regression can be treated as a partial structural change model if the entire sample is used and β is not subject to shifts. Otherwise the linear regression becomes a pure structural change model when $p = 0$ as all the coefficients are subject to change. For each $m-partition$ $(T_1,\cdots,T_m)$ denoted (T_j), the associated least squares estimate of β and δ_j are obtained by minimizing the sum of squared residuals $S_T(T_1,...,T_m)$ and the estimated break points $(\hat{T}_1,...,\hat{T}_m)$ are such that $(\hat{T}_1,...,\hat{T}_m)$ = $\text{argmin}_{T_1,...,T_m} S_T(T_1,...,T_m)$, with the minimization taken over all partitions $(T_1,\cdots,T_m)$ such that $T_i - T_{i-1} \geq q$.

The maximum number of structural breaks (m) allowed by the BP method in any data series is 10 with five options available to the researcher to choose from: $m = 2$, $m = 3$, $m = 5$, $m = 8$ and m = 10. The choice of m is guided by the assumptions about the errors in data and sample size such that the value of the trimming parameter (´) expressed in percentage for the construction of test statistics used to determine the number of multiple breaks present in a series can be set in relation to the number of observation T. Five options for ε are available: ε =0.05, 0.10, 0.15, 0.20 and 0.25 with the corresponding m = 10, 8, 5, 3 and 2. Accordingly, the minimum distance between two consecutive breaks h is computed or set arbitrarily by the researcher.

The three test statistics used are $\sup F_T(k;q)$; double maximum ($D_{\max}$) split into $UD_{max}\,F_T(M, q)$ and $WD_{max}\,F_T(M, q)$ where the former gives an equal weight while the latter gives weights to individual tests in such a way that the marginal p values are equal across the values of M bound; $\sup F_T(\ell+1|\ell)$ and the sequential procedure. Critical values for each test are available in Bai and Perron (1998) at 1%, 2.5%, 5% and 10% significance levels.

The BP method also generates confidence intervals at different significance levels indicating the range of dates within which the detected break date falls. The null hypothesis for all the tests is that the series has no structural breaks, i.e., $m = 0$

However, the alternative differs across the tests. In the case of $\sup F_T(k;q)$, the alternative is a fixed number of breaks, i.e., $m = k$ while $D_{\max}$ tests the null against the alternative of unknown number of breaks. A single change in the series is the alternative for $\sup F_T(\ell+1|\ell)$. Three information criteria supplement the decision regarding the number of structural breaks present in data series. These are the Bayesian Information Criterion (BIC), modified Schwarz criterion (LWZ) and the Bai and Perron (1998) criterion based on sequential application of the $\sup F_T(\ell+1/\ell)$ test.

The BP method is employed against the commonly used cumulative sum of square (CUSUM) type tests by Inclán and Tiao (1994) and Sansó et al. (2004) because it uses a more efficient algorithm based on dynamic programming principle in detecting sequentially multiple breaks in data series. A linear regression model is used and global minimizers of the sum of squared residuals estimated by least squares obtained. Break dates in the mean/variance of data series are detected one at a time conditional on the breaks that have already been located. Further, assumptions about the data error structure (serial correlation and/or heterogeneity in data or errors across regimes or segments) are dealt with definitively by allowing for a common and different distribution structure. Conversely, the iterated cumulative sum of square (ICSS) algorithm in unconditional variance by Inclán and Tiao (1994) makes restrictive assumption about the distribution of the disturbance (i.e., iid which does not always hold especially in financial time series data) and suffers from size distortion as it does not consider the fourth moment properties of the disturbances and conditional heteroscedasticity. Sansó et al. (2004) address the weaknesses of the Inclán and Tiao (1994) test by relaxing the iid assumption and allows for persistence in the series. However, both Inclán and Tiao (1994) and Sansó et al. (2004) tests are conducted on unconditional variance series while the BP method is more encompassing as the test is conducted on the mean and conditional as well as unconditional variance.

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