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Copper prices and financial markets in Zambia

Xolani Ndlovu and Eric Schaling*

Wits Business School, University of the Witwatersrand, 2 St David's Place, Parktown, Wits 2050, Johannesburg, South Africa

* Corresponding Author: Tel: +27 11 717 3660, Email: eric.schaling@wits.ac.za

Abstract

Resource-dependent economies in Sub-Saharan Africa are vulnerable to external shocks in the international commodity markets. In this paper, we investigate the financial markets channel through which these shocks are transmitted to the Zambian economy. Using a Vector Error Correction Model (VECM), we show that copper prices and financial market variables share a long-run equilibrium relationship. Short-term interest rates are shown to be the major channel through which shocks in the copper market are transmitted to the economy, bearing the burden of correcting the system to equilibrium. We provide policy recommendations to manage the vulnerability of financial markets (and macro-economy) to short and long-run shocks to the international copper prices.

Keywords: Zambia; VECM; Cointegration; Granger causality; Copper prices; Financial markets.

1. Introduction

The impact of copper prices on the Zambian economy has been a subject of considerable research in the development economics literature in the past three decades. Research themes include a general interest in the impact of commodity prices on small developing economies (McBean, 1966, Coppock, 1962, Nziramasanga and Obidegwu, 1980); investigation of the resource curse and Dutch disease narratives (Crain, 2010); mismanagement of mineral dependence (Auty, 1991); impact of copper prices on the exchange rate (Cashin *et al*, 2002, Bova, 2009, Mungule 2004, Chipili, 2010, Weeks *et al*., 2007, IMF 2009), and more recently, the commodity based industrialisation narrative (Weeks and Mungule, 2013, Morris and Fessehaie, 2014).

It is not difficult to see why economists and policy makers in Zambia are concerned with the behaviour of international copper prices versus various economic variables and indicators. Copper and cobalt account for 78 percent of the country's exports and are clearly the major source of foreign currency earnings (Central Statistics Office, 2015). The near collapse of the sector in the late 90s which was a result of a combination of low copper prices and mismanagement of copper revenues by the Government has been followed by rejuvenation in the past decade. The dynamics of the international copper market therefore raise concerns for policy makers in three areas of macro-economic management namely, fiscal policy, monetary policy and exchange rate policy (Weeks and Mungule, 2013).

Other issues of concern about Zambia have centred on issues of the country's comparative advantage. The abundance of copper raises questions around the associated "dependence" problem on copper. The World Bank (2001) raised concerns that countries that have this problem may have their growth stagnate in future as they cannot join the new economy of knowledge and technology. Other issues have centred around the harmful effects that the volatility of copper prices in the international markets may have on the local economic cycle and the Dutch disease (Meller and Simpasa, 2011).

In April 2005, Zambia reached the completion point for the Highly Indebted Poor Countries (HIPC) initiative. Weeks and Mungule (2013) observe that the Zambian Kwacha started appreciating after it became public news that the country had qualified for debt cancellation and this trend continued thereafter. This period coincided with a strong recovery of copper prices and significant inflows into the Zambian capital markets. The economic reforms of the 1990s had given birth to the Lusaka Stock Exchange (LUSE) in 1994. Thus, in addition to the traditional money markets, the economy had an alternative investment destination in the equities exchange. This paper investigates the short-run and long-run association between copper prices and other financial market variables in Zambia, namely the nominal exchange rate, equity prices and short term interest rates in a cointegrating vector error correction model with a focus on the post debt cancelation period, 2004 to 2014.

In spite of the wide interest in the impact of copper prices on the Zambian economy, we were unable to find previous research (theoretical and empirical) that considers the simultaneous interactions of copper prices and financial market variables considered in this study. This paper attempts to fill this gap. We employ a Vector Error Correction (VECM) framework that treats all variables in the model as a priori endogenous. This approach imposes a minimal set of theoretical restrictions on the model being tested thereby allowing a close to pure statistical analysis of the variables under consideration. Further, the VECM framework overcomes Sim's (1980) critique that some exogeneity assumptions for some variables in simultaneous equation models are not backed by fully developed theories. The framework allows the variables in the system to interact with themselves and with each other without having to impose a theoretical structure, except that the relationships are assumed to be linear. In addition, we analyse impulse response functions and forecast error variance decompositions.

Now we briefly outline the results of the paper. We find that all the variables in the model are integrated I(1) processes; the Johansen cointegration method indicates one cointegrating relationship among the variables. The VECM error correction estimates suggest the adjustment of the system back to long run equilibrium is borne by corrections to the short term interest rates. In the short run, exchange rates and equity prices appear weakly exogenous to the system – a result confirmed by our out-of-sample analysis. Further, we show that changes in copper prices lead changes in the other financial market prices in the short-run. In the long-run, the relationship between copper prices and short-term rates appears strong and significant. The model passes tests of misspecification and structural stability.

The results are likely to be of interest to policy makers and financial market participants who need to understand the nexus between copper prices and financial markets in Zambia. The remainder of the paper is organised as follows. The next section considers a brief review of relevant literature. Section 3 discusses the links between commodity prices and financial markets. In Section 4 we provide description of data and outline the empirical model. Estimation results are presented in Section 5 and Section 6 concludes.

2. Literature overview

Literature is replete with studies that focus on co-movements of commodity prices among themselves and also with macro-economic variables. There is some consensus in literature on the relative importance of commodity prices to the world economy. Commodity prices affect the level of stability of export earnings by developing countries, the cost of inputs to production in industrialized countries, the allocation of world capital flows and rates of national economic growth (Muhanji and Ojah, 2011). Policy makers are concerned with the links between commodity prices and macro-financial goals (whether they be net exporters or importers of primary commodities).[1] Financial market players, such as portfolio managers and traders are also concerned with the substitutability of commodities and financial market securities and therefore design of effective hedging strategies in times of uncertainty. There has been interest too in the commodity price cycles and design of counter-cyclical strategies for countries that depend on the export of specialised primary commodities for their export earnings (see Venables, 2016 for a recent review).

Our study is closely linked with strand of literature that connects commodity prices with macro-financial variables in developing commodity exporting countries. A considerable number of studies on commodity exporting countries analyse dependencies between commodity prices and individual macro financial variables such as exchange rates, equity prices and inflation (see Bhar and Hammoudeh, 2011 for a survey of literature). Some use an aggregated commodity price index as opposed to a single commodity price. The contribution of our study is two-fold. First we consider the behaviour of a single export commodity that contributes significantly to the export revenues of a developing open economy in sub Saharan Africa. Secondly, we analyse dependencies of the financial market variables and commodity prices in a multivariate set-up that allows us to uncover relationships among the financial market variables themselves.

The link between the exchange rate and commodity prices is widely researched in the literature. This is not surprising given that until recently, financial markets have been underdeveloped or reliable data has not been available especially in

[1] This strand of literature is also connected to the "resource curse" literature such as Sachs and Warner (1999, 2001); Gylfason *et al*. (1999) and the Dutch disease (Corden and Neary 1982; Torvik, 2001).

sub-Saharan Africa. Cashin *et al* (2004) find evidence of co-movement between commodity prices and real exchange rates of a number of developing commodity exporters. For some small exporters of primary commodities who depend on exports of a single or several commodities for foreign currency earnings, volatility in the price of commodities has a direct impact on the balance of payments. For example, Hegerty (2013, 2014) finds that shocks to commodity prices exert pressure on the real exchange rates of Western African countries and Latin America respectively. Bova (2009) finds that the volatility of the copper price and the exchange rate are related in an EGARCH framework. Further, in a multivariate structural model, Weeks and Mungule (2013) find that the source of exchange rate instability is capital account movements which are moderated by foreign exchange holdings of the Bank of Zambia. The main source of foreign exchange reserves is export revenues from copper. Other leading papers in this strand of literature include Chen and Rogoff (2003), Clements and Fry (2008), Swift (2004) and more recently Issa *et al*. (2008), Chen *et al*. (2010) and Cayen *et al*. (2010).

Another body of related literature links commodity prices and equity prices. In a structural VAR model Chaban (2009) analyses the relationships among the nominal prices of natural resources, nominal returns on equity and nominal exchange rates of three OECD countries: Australia, Canada and New Zealand. The author finds that the portfolio-rebalancing channel of Hau and Rey (2006) is weaker in these countries because commodity prices' flexibility plays a special role in the transmission of shocks by linking equity markets across countries and reducing the need for portfolio rebalancing.[2] A positive supply shock such as increased productivity in the U.S. that affects U.S. equity returns positively is transmitted to commodity-exporting countries through commodity prices.[3]

[2] In the portfolio rebalance model, Hay and Rey (2006) provide theoretical micro foundations of the relationship between equity markets and exchange rates. Their model assumes that foreign exchange risk is unhedged; that domestic investors hold a portfolio of domestic and foreign equities and that domestic investors hold equity and foreign exchange risk as a bundle. A portfolio is allowed to deviate due to exogenous shocks such as shocks in equity markets. For example if foreign equities outperform domestic stocks, the share of foreign equities increases in the portfolio, exposing that portfolio to increased exchange rate risk. To rebalance the portfolio risk, domestic portfolio managers find it optimal to withdraw a portion of the foreign equity, in so doing appreciating the domestic currency via increased demand of local currency from inflows from sale of foreign equities. The model therefore implies that stronger equity markets are associated with weaker exchange rates due to the portfolio rebalancing motive.

[3] Increased demand for industrial raw materials in the US increases demand for commodities leading to inflation of commodity prices. Booming commodity prices in USD drive domestic equity returns of commodity exporting countries up and through increased capital inflows appreciate commodity currencies. It is potentially interesting to find out what relationships exist between developing stock exchanges in Africa and major export commodity prices.

Correlations between the stock market and commodity markets have been explored extensively in the literature. For example, Lombardi and Ravazzolo (2016) report that correlations between commodity markets and stock markets have increased significantly post 2008, a result that is robust to different correlation specifications. This result is at odds with the proposition of using commodities as a hedge for stock markets because of the actual or perceived negative correlation between the two variables (e.g. Gorton and Rouwenhorst 2006). Other scholars document the effect of increased participation by speculators. Büyüşahin and Robe (2012) report that correlation between the two markets has increased due to increased activity of speculators. Chang *et al*. (2011) find evidence of volatility spill overs between oil and equity prices. Choi and Hammoudeh (2010) suggest that commodity traders concurrently look at both stock and commodity markets fluctuations to infer the trend of each market.

Christiano, Eichenbaum, and Evans (1996) argue that commodity prices are set in continuous auction markets with efficient information, and thus they can be early indicators of macroeconomic activity and can be used in monetary Vector Auto Regression (VAR) models. This argument is followed by Browne and Cronin (2010) and Akram (2009). Using quarterly data in a five-variable VAR model for oil prices, food price index, metals, Akram (2009) finds that oil prices and industrial raw material prices display overshooting behaviour in response to interest rate shocks. Further, he finds that negative shocks to the world economy leads to lower interest rates and commodity prices. The validity of this result suggests that a similar investigation in the context of small commodity exporters in Africa will be fruitful. Related to this body of literature are studies on inflation hedging using commodity prices (for example Ciner *et al*., 2013; Batten *et al*., 2014; Hammoudeh *et al*., 2015) and the relationship between commodity prices and conduct of monetary policy (for example Hegerty, 2016; Hove *et al*., 2015; Mallick and Soussa, 2013; Ntantamis and Zhou, 2015).

As noted by Kablan *et a*l (2016), with a few exceptions like Hegerty, 2016; Mallick and Soussa, 2013, most of the studies have given attention to developed economies and periphery countries have been ignored. Our study seeks to fill this gap.

Our study follows the work of Bhar and Hammoudeh (2011) who examine dynamic interrelations among individual industrial commodity prices and commodity-sensitive macro financial variables in a regime switching model. They employ four multivariate Markov Switching (MS) models to examine the relationships between copper, oil, gold and silver and three financial variables namely short term interest rates, exchange rates and the world equity index. In all the four MS-models the authors find that relationships between each of the commodity price series and financial market variables in their sample were regime dependent and that macro-financial variables transmit more information to commodity prices than the other way round. Their study provides a useful framework that can be adapted to analyse the dynamic relationships specific to Zambia.

3. Commodity prices and financial markets

Theoretical links between commodity prices and macro-financial variables are well documented in literature. We provide here a brief discussion of theoretical channels through which commodity price shocks can be transmitted to financial markets.

The linkage between exchange rates and commodity prices is discussed widely in the economics literature (see Clements and Fry, 2008, Chen and Rogoff, 2003, and Ndlovu, 2011) for a comprehensive review of literature on the relationship between commodity prices and commodity currencies). The literature discusses two channels namely the trade in goods channel and the "portfolio balance" class of models.

Under the trades in goods channel, consider a small open commodity exporting economy with tradable and non-tradable goods sectors. An increase in the price of the exported commodity in world markets would affect the demand for non-traded goods through its effect on wages – a channel similar to the well documented Balassa-Samuelson effect.[4] Assuming that prices of non-tradable goods are sticky, the exchange rate instead of prices would have to adjust to preserve efficient resource allocation. Thus, a positive terms of trade shock such as a boom in commodity markets eventually leads to an appreciation of the exchange rate in an environment of nominal price rigidities in the non-tradable sector.

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[4] The Balassa-Samuelson effect owes its name to two economists Balassa (1964) and Samuelson (1964). The model posits that faster productivity in tradable versus non-tradable goods in a given economy compared to international counterparties would eventually raise the price level and therefore the real exchange rate. The model assumes that labour is an important factor of production and is fully mobile across the tradable and no-tradable goods sectors. A rise in productivity of tradable goods will raise wages in the tradable sector. Since labour is assumed to be perfectly mobile across the two sectors, the wages in the non-tradable sector would also rise. Producers in the non-tradable sector would have to raise prices to match higher labour costs since the rise in wages is not matched by increased productivity.

Under the portfolio balance model, the exchange rate is treated as a function of demand and supply of national assets; domestic and foreign assets are treated as perfect substitutes. For a commodity exporting economy, a boom in the price of the exported commodities in international markets would typically lead to an excess supply of dollars and accumulation of foreign reserves, increasing pressure in the relative demand of their domestic currencies. To equilibrate the demand for the domestic currency, the price of the domestic currency would have to appreciate in terms of the foreign currency.

The link between commodity prices and stock markets comes from the input costs and activities of financial investors. A positive shock in the price of strategic commodities like oil for example can be expected to feed into the production costs (through the spill-over of higher energy costs, see Lombardi *et al*., 2012) in a net oil importing economy. Assuming that prices are sticky in the goods market to accommodate the oil shock, an increase in the price of a key production input would most likely negatively affect investor expectations of future earnings and therefore stock market prices. While correlations between commodity prices and stock markets has not been strong until the 2008 financial crisis (Lombardi and Ravazzolo, 2016), increased financialisation of commodity markets justify another link between the two asset markets. Gao and Süss (2015) report that 80 percent of all investors in commodity markets are financial investors. Investment in commodities provides an alternative to stock markets. Cassassus and Higuera (2011) provide evidence that oil prices are good predictors of equity prices. In a recent study, Lombardi and Ravazzolo, (2016) shed more light to this link. The authors indicate that joint modelling of the evolution of prices in the two asset markets is valuable from an asset allocation point of view.

The connection between commodity prices and interest rates (a monetary policy variable) is well developed in literature. Frankel (2008) presents three theoretical channels through which interests rates can interact with prices of storable commodities. The first link relates to the activities of financial speculators in commodity markets. All things being equal, low real interest rates are likely to encourage speculators to shift from treasury bills investments towards financial markets for commodities.[5] The second link comes from the extraction decision of commodity producers. To arrive at the decision to extract the commodity "now or later", a producer has to consider a number of factors including cost of storage, risk and opportunity cost of holding commodity inventories. An

5 See also Gao and Süss (2015) for a discussion on the financialisation of commodities.

environment of high real interest rates is likely to encourage producers to extract the commodities now (which are non-interest earning), liquidate them and earn high interest from the proceeds of the sale. Thus high interest rates are likely to increase supply of commodities and exert downward pressure on their prices. The third link comes from the cost of carrying inventories. For a primary commodity producer or processor of the raw materials, the decision to carry inventory is likely going to be affected by costs of storage including real interest rates. If the interest rates are high, it is likely that everyone would like to hold lower inventories, thus lowering demand and commodity prices, ceteris paribus. These theoretical links have been tested in the literature (see Frankel, 2008; Gruber and Vigfusson, 2012, Akram, 2009). In commodity exporting countries, policy makers may introduce countercyclical measures against commodity price declines resulting in increased interest rate volatility (Hegerty, 2016).

The foregoing discussion on the relationship between commodity prices, interest and exchange rates suggests that interest rates and exchange rates would move in opposite directions in response to a commodity price shock. The relationship departs from one implied by the traditional workhorse open macroeconomic models such as the Mundell-Fleming (MF) model (see Mundell 1962, 1963, Fleming 1962, Dornbusch 1976, Frankel and Rose 1995, Taylor 2002). The MF model, based on the assumptions of perfect capital mobility and interest rate parity implies that interest rates and nominal exchange rate move in the same direction. According to Makin (2013), the traditional open macro-economic models "neglect" the commodity currency phenomenon. In a commodity exporting economy with a "commodity currency", prolonged commodity price booms which result in persistent appreciation of the exchange rate result in fall in national output as production is disrupted elsewhere in the economy. For this reason, an optimal monetary policy response should be one that limits the appreciation of the exchange rate, that is, a contractionary policy stance. We now test these conjectured links for Zambia.

4. Data and econometric methodology

4.1. Data description and measurement

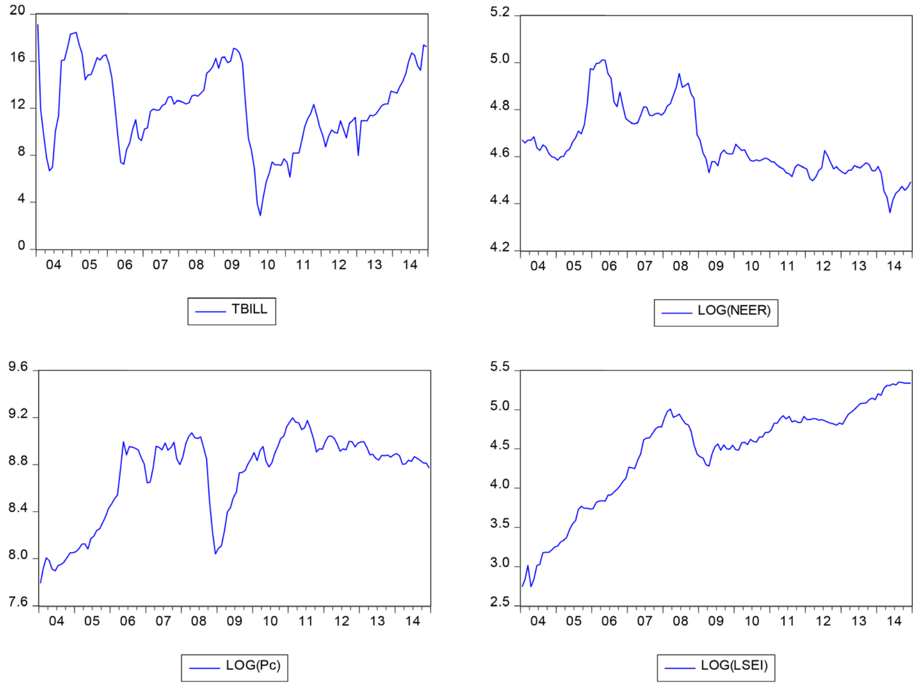
The study uses monthly data for the sample period January 2004 to December 2014 for copper prices (p_c) and three financial market variables namely, the Zambian Kwacha exchange rate (*NEER*), the three month Treasury bill rate (*TBILL*) and the Lusaka Stock Exchange Index (*LSEI)*. Copper is an industrial metal traded on the London Mercantile Exchange (LME) and constitutes nearly 70 percent of Zambia's exports with main destinations being Switzerland (61.1percent) and China (25.6 percent). The monthly average spot price is used in this study. The data series was extracted from the IMF database and is measured in USD/Metric tonne. The Zambian Kwacha exchange rate is measured as the Nominal Effective Exchange Rate Index (NEER, 2010=100) published by the IMF. The nominal effective exchange rate (NEER) of the Zambian Kwacha is calculated as the geometric weighted average of a basket of bilateral nominal exchange rates taking into account Zambia's largest international trade partners. An increase in the index (above 100) indicates appreciation of the Zambian Kwacha relative to the United States dollar. Nominal variables are preferred in order to capture the asset price bubbles in the data. The equity index is the Lusaka Stock Exchange main board index. The index (2010 = 100) was extracted from the CEIC database and measures the monthly average value of the equities index. The measure of short term interest rate is the three month Treasury bill rate published by the Bank of Zambia measured in percent, per annum. We use the 91-day Treasury bill rate as a proxy for monetary policy and inflation (Bhar and Hammoudeh, 2011). The 91 day Treasury bill rate implicitly reflects the stance of monetary policy in Zambia (see Fundanga 2009). To enable us to interpret the estimated coefficients as elasticities, all the data series with the exception of the Treasury bill rate are transformed into natural logarithms.

Table 1: Data Descriptive Statistics

	Copper Price	**Equity Index**	**T-bill Rate**	**Exchange Rate**
Mean	6458.852	102.3998	12.07818	106.1978
Median	7049.975	104.4350	12.09000	100.6750
Maximum	9880.940	210.6600	19.13000	150.2000
Minimum	2421.480	15.58000	2.880000	78.45000
Std. Dev.	1957.593	52.09897	3.483411	16.23384
Skewness	-0.638385	0.137204	-0.151572	1.042146
Kurtosis	2.250421	2.341993	2.389626	3.308976
Jarque-Bera	12.05604	2.795501	2.554492	24.41855
Observations	132	132	132	132

The descriptive statistics are presented in Table 1. The statistics clearly show that copper prices and financial market variables in Zambia exhibit high kurtosis, suggesting extreme market movements in either direction (gains or losses).

FIGURE 1: PLOTS OF COPPER PRICES AND FINANCIAL MARKET VARIABLES



The data plots in Figure 1 show the relevant financial time series against the copper price. The series are possibly non-stationary and cointegrated. We carry out the Augmented Dickey Fuller (Dickey and Fuller, 1981) test for stationarity and the Phillips-Perron (Phillips and Perron, 1988) tests for a unit root. The appropriate lag lengths for the estimations are chosen based on the log likelihood (LR) criterion, preferred by Sims (1980).

4.2. The Econometric procedure

We employ the Johansen Maximum Likelihood procedure to investigate the short-run and long run relationships among copper prices and the financial market variables. Johansen (1995) shows that relationships among non-stationary time series variables that are cointegrated of rank r can represented as a multivariate Vector Error Correction model (VECM). An unrestricted VAR model of order p with $(k \, x \, 1)$ endogenous variables all integrated of order one, forced by a vector of $(k \, x \, 1)$ independent Gaussian errors can be formulated as a VECM of the form:

$$\Delta y_t = \mathbf{\Pi} y_{t-1} + \sum_{i=1}^{p-1} \mathbf{\Gamma}_i \Delta y_{t-i} + \gamma D_t + e_t \qquad (1)$$

Where y_t is a (k x 1) vector of dependent (endogenous) variables; D_t is a vector containing constants and dummies; Π is a (kxk) matrix, decomposed as $\alpha\beta^l$ with matrices α and β, dimensioned (kxr) capturing the speed of adjustments and long-run relations respectively; r_i (i = 1, ..., p - 1) are (kxk) parameter matrices capturing the short run dynamics among the variables and e_t is a (k x 1) vector of disturbances, has mean 0 and covariance matrix Ω and is independent, identically distributed (i.i.d.) over time.

If the matrix Π in equation (1) has rank $0 \leq r < k$ where r is the number of linearly independent cointegrating vectors, then there exists a linear combination of y_t that is stationary.

Substituting $\alpha\beta^l$ into (1), the VECM can be re-written as:

$$\Delta y_t = \boldsymbol{\alpha\beta}' y_{t-1} + \sum_{i=1}^{p-1} \boldsymbol{\Gamma}_i \Delta y_{t-i} + \gamma D_t + e_t \qquad (2)$$

The Johansen (1995) estimation approach enables us to conduct hypotheses tests on the cointegrating matrix β and the loading matrix α using standard asymptotic chi-squared tests.

In the VECM framework the characteristics of the data series determine the exact specification of the model. This framework has been the workhorse of time series econometrics since Sim's (1980) seminal article. The approach treats all variables in the model as a priori endogenous. This procedure has at least two distinct advantages. First, the framework imposes a minimal set of theoretical restrictions on the model being tested thereby allowing close to pure statistical analysis of variables under consideration. Second, the VECM framework overcomes Sim's (1980) critique that some exogeneity assumptions for some variables in simultaneous equation models are not backed by fully developed theories. Theoretical models developed using industrialised economies assumptions often perform dismally when tested using developing economies data. To answer the questions of this study, we argue that the VECM framework is suitable for analysing dependencies among financial assets and copper prices in Zambia as it allows the variables in the system to interact with themselves and with each other without having to impose a theoretical structure, except that the relationships are assumed to be linear.

We use the trace and maximum Eigen value statistics to determine the rank (r) of the cointegrating matrix Π. The two tests can be written in terms of Eigen values (λ_i) (see Johansen 1995 for details). For a sample size (T):

$$\lambda_{trace}[\mathcal{H}_1(r)|\mathcal{H}_0] = -T\sum_{i=r+1}^{p}\ln(1-\hat{\lambda}_i) \quad (3)$$

Where $\hat{\lambda}_i$ is the estimated eigenvalue and the null hypothesis is λ_i, so only the first r eigenvalues are non-zero.

$$\lambda_{max}[\mathcal{H}_1(r+1)|\mathcal{H}_1(r)] = -T\ln(1-\hat{\lambda}_i) \quad (4)$$

For $r = 0,1,2 \ldots, p - 2, p - 1$. The null is that there exists r cointegrating vectors against the alternative of $r + 1$ vectors.

For the short-run dynamics, we conduct Granger (1969) causality tests. While the existence of cointegration among the variables can be interpreted as long-run causality, the cointegrating relation does not indicate direction of causality.[6] A VECM derived from long-run cointegrating vectors can be used to test Granger causality and therefore whether an endogenous variable can be treated as exogenous (that is, determined outside the system) within a sample period in the short-run (Masih and Masih, 1996).

In addition to the foregoing "within-sample" analysis, we conduct "out-of-sample" analysis of the four variables using Impulse Response Functions (IFR) and Forecast Error Variance Decompositions (FEVDs). If the model has been correctly specified, impulse response functions and forecast error variance decompositions have well-known interpretations. The IRFs show the effect of a shock on one variable on the other variables in the system while forecast error variance decompositions indicates the proportion of movement in a variable due to its "own" shocks versus shocks from the other variables in the system. This analysis is conducted over a 24 month period.

We verify our model for potential misspecification by testing for autocorrelation, homoscedasticity and normality of residuals. To test for the stability of the model we follow Lütkepohl (2005) and Hamilton (1994) in testing the roots of the characteristic polynomial of the VECM.

5. Empirical results

The ADF and Philips Perron test results indicate that all the variables are $I(1)$ processes (Table 2). We added the Stock and Watson (1989) test to justify inclusion (or exclusion) of a drift term and/or deterministic trend in our model. The results indicate that the level data series have a constant term but

[6] See Granger *et al*, 2000.

no deterministic trend. We therefore include only a drift term in our model on levels and assume no drift nor time trend in first differences. Cointegration tests are carried out using the Johansen (1995) procedure.

Table 2: Tests for Root Unit

Variable	**ADF TEST STATISTIC**		**PHILIPS PERRON TEST**	
Levels	**Constant with trend**	**Constant without trend**	**Constant with trend**	**Constant without trend**
Copper Prices				
-2.4895	-2.4710	-2.2758	-2.5553	
Exchange rate (NEER)	-2.5891	-2.7831	-2.3652	-2.5082
Interest Rate (TBILL)	-2.0926	-2.1040	-2.8905	-2.9835
Equity Index (LSEI)	-2.5572	-2.4925	2.4944	-2.1538
First Differences				
$\Delta(Pc)$	-7.2606	-7.2158	-7.2246	-7.2276
$\Delta(NEER)$	-9.2398	-9.1613	-9.4167	-9.3651
$\Delta(TBILL)$	-8.5749	-8.6262	-8.5375	-8.5895
$\Delta\ (LSEI)$	-9.2035	-8.8437	-9.6176	-9.3489

Notes: The Critical values for rejection are -4.0296, -3.4444 and -3.1471 at a significant level of 1percent, 5 percent and 10 percent respectively for models with a constant and linear trend and -3.4812, -2.8830, -2.5787 at a significant level of 1percent, 5 percent and 10 percent respectively for models without a linear trend. The optimal lag for the ADF test was chosen based on the Schwartz Information Criterion and the truncation parameter for the PP test was selected using the Newey-West truncation method.

For our dataset, the Log Likelihood (LR) information criteria indicates the optimum lag as $p = 4$. The diagnostic tests for autocorrelation, heteroscedasticity and normality of residuals are provided in Table 3. The results indicate that the model is robust to autocorrelation and ARCH effects. The residuals are however non-normal. We proceed with inference on our model based on Lütkepohl (2011) who notes that normality in the distribution of residuals is a desirable but not a necessary condition for the validity of many of the statistical procedures related to VECM and VARs.[7]

[7] See also Sun, Ford and Dickson, 2010

TABLE 3: DIAGNOSTIC TESTS

	LM-Stat(8)	ARCH (χ^2)	Normality	Skewness	Excess Kurtosis
Panel A: Single Equation tests					
T-bill	1.084453	0.869141	22.8046	0.016999	5.0675
	[0.3797]	[0.6055]	[0.00000]	[0.01000]	
Copper Price	1.222295	1.339229	66.0665	-0.72901	6.20325
	[0.2932]	[0.2494]	[0.0000]	[0.01558]	
Equity Index	1.011573	0.742874	7.74849	0.021284	4.17778
	[0.4319]	[0.7448]	[0.0274]	[0.05881]	
Exchange Rate	0.667850	1.350809	29.0447	0.30506	5.25218
	[0.7187]	[0.1801]	[0.0000]	[0.0005]	
Panel B: Model tests					
	10.70181	260	76.60280	4.887590	71.71521
	[0.8275]	[0.3225]	[0.0000]	[0.2990]	[0.0000]

Notes: Standard errors in [ ]

The results of the Johansen (1995) test for cointegration are displayed in Table 4. Both the trace and maximum eigenvalue statistics are significant and reject the null hypothesis of no cointegration at the 5 percent level of significance and indicate the presence of at most one cointegrating vector.

TABLE 4: JOHANSEN TEST FOR COINTEGRATION

Hypothesized No. of CE(s)	Trace Statistic	Maximum Eigenvalue Statistic	Critical Values (5 %)	
			Trace	Maximum Eigenvalue
	64.81452***	41.37122	47.85613***	27.58434
	23.44330	14.19212	29.79707	21.13162
	9.251184	7.212844	15.49471	14.26460
	2.038340	2.038340	3.841466	3.841466

Notes: *** denotes significance at 5% level

5.1. Short-run Dynamics

Granger Causality/Block Exogeneity Wald tests are presented in Table 5. While the tests indicate presence of and direction of Granger causality, they do not provide information on the strength of the causal chain among variables. The Wald tests can be interpreted as "within-sample" tests as they do not indicate the variables' exogeneity or endogeneity outside the sample period (Masih and Masih, 1996).

The short run dynamics indicate that changes in copper prices precede changes in the three financial market variables. Among the financial market variables themselves, equity prices Granger cause short term interest rates. This result reflects the superiority of information efficiency of copper market over the other financial markets in Zambia. Copper is transacted in highly efficient auction markets and its price reflects demand and supply shocks rapidly. For a country that depends heavily on copper for foreign currency, price signals in the copper market are leading indicators of future direction of balance of payments and impact on the wider macro-economy in the short run.

In the literature, the short-run link between copper and the exchange rate has been found by Bova (2009) in an EGARCH framework. The author highlights that the volatility in the copper market which are traded in high-speed international markets is related to volatility of the exchange rate in the short run. With respect to equity prices, a positive shock to copper prices reflects an improvement in the future dollar incomes of copper exporters and the government (via rents like tax and royalties). For a copper dependent economy, investors such as fund managers and speculators can be expected to adjust their expectations of future incomes of companies and therefore bid for their shares thereby inflating equity prices. The asset-price argument can be extended to the yields on Treasury bills. Our results indicate that changes in equity prices precede changes in the money market rates – we surmise that this mechanism operates via the asset substitution mechanism. Short term interest rates seem to "react" to changes in the equities market. For a portfolio manager with a choice of only two assets namely equities and interest bearing instruments (quite plausible for Zambia); money market rates have to adjust to a change in the equity prices to maintain the same asset weights in a given portfolio.

Short term interest rates appear to be unrelated to the exchange rate in the short-run. This result indicates that monetary policy is ineffective in moderating exchange rate volatility in the short run.

Table 5: Granger Causality Tests

	Independent Variable			
	Δ(ln_cu)	Δ (ln_luse)	Δ (tbill)	Δ (ln_zmw)
Dependent variable		χ^2 Statistic		
(ln_cu)	-	3.406959	2.209016	1.629127
(ln_luse)	6.185004***	-	3.426831	0.226010
(ln_tbill)	3.788591***	5.484564*	-	4.788026
(ln_zmw)	5.947009**	0.046215	0.419357	-

Notes: *, ** and *** indicate significance at 10%, 5% and 1% respectively. A significant χ^2 Statistic implies that the independent variable Granger causes the dependent variable.

5.2. The Long-run dynamics

The presence of at least one cointegrating vector implies that the vector can be generically identified in the long-run through a normalisation process (Boswijk, 1996, Hunter and Ali, 2014). While literature generally regards normalisation as innocuous, Bowswijk (1996) suggests that empirical normalisation requires that further rank conditions be satisfied. Burke and Hunter (2005) suggest that any identification procedure should preclude normalisation on variables that are either long-run excluded or weakly exogenous to the system.[8] We follow this reasoning in this paper and therefore, before imposing and identification restrictions, we test the variables in our model for long run exclusion (LE) and weak exogeneity (WE).

The LE tests are conducted by imposing a zero restriction on the elements of the long-run matrix β. If this hypothesis cannot be rejected at the 5 percent level, the cointegrating vector cannot be normalised on this variable. The WE tests are carried out by imposing zero restrictions on the elements of the adjustment matrix α. Failure to reject the zero restriction null implies that the variable is weakly exogenous to the system, that is, it drives the system instead of adjusting to it. The results of the LE and WE tests are presented in Table 6.

[8] In our case where we have a single cointegrating vector, normalization implies rendering the model to be related to a particular dependent variable. It makes sense that the dependent variable be endogenous to the system, that is, it cannot be excluded from the system in the short and long run.

Table 6: Long-run Exclusion (LE) and Weak Exogeneity (WE) Tests

	Log(Copper price)	**Log(Equity Index)**	**T-bill**	**Log(Exchange rate)**
Panel A: LE Tests $\chi^2(1)$	23.42969	13.84564	26.00574	4.247505
p-value	0.000001***	0.000198**	0.000000***	0.039308**
Panel B: WE Tests $\chi^2(1)$	5.884499	0.068700	17.11949	2.111350
p-value	0.095275*	0.793239	0.000035***	0.146210

Notes: *, ** and *** indicate significance at 10%, 5% and 1% respectively

From Table 6 Panel A, it is clear that all four variables cannot be excluded from the long-run equation as they are statistically different from zero. From Panel B however, with the exception of the copper price and the short term interest rate, the proposition that equity prices and the exchange rate are weakly exogenous cannot be rejected. This result implies that the long-run equation cannot be normalised on the exchange rate nor equity prices. Therefore the cointegrating vector is normalised on the short term interest rate as follows (with standard errors in ( ) and t-statistics in [ ]):

$$\begin{array}{lllll} TBILL = & -16.451(p_c)^{***} & +6.830(NEER)^{**} & +6.558\,(LSEI)^{***} & +94.484 \\ & (1.83811) & (2.72417) & (1.13293) & \\ & [\,8.94973] & [-2.50724] & [-5.78840] & \end{array} \quad (5)$$

Notes: *, ** and *** indicate significance at 10%, 5% and 1% respectively.

By inspection of equation (5), we observe that all the long run parameters are statistically significant at 5 percent level or better. In the long run, short term interest rates are associated with movements of -17 percent, 6.8 percent and 6.6 percent to a 1 percent change in the copper price, exchange rate and equity prices respectively. Moreover, the short run adjustment parameters indicate that the short term rate is the "slave" of the system, that is, it bears the burden of short run endogenous adjustment to bring back the system to its long-run equilibrium.

This result is important as it reflects the importance of the conduct of monetary policy in bringing the system to long run equilibrium in Zambia.[9] While the

[9] Until 2012, the Bank of Zambia (BoZ) pursued a Monetary Aggregate Targeting (MAT) framework - reserve money was the operating target while broad money was the intermediate target, aimed at controlling inflation, the ultimate target. To achieve these objectives, the BoZ conducted Open Market Operations (OMOs) and regular auctions of Government securities. In April 2012, the policy was changed to interest rate targeting – a policy rate based on the overnight interbank rate was introduced. Although the policy rate has been set based on the

ultimate monetary policy target is inflation in Zambia, the BoZ has paid attention to exchange rate volatility in recent years. The BoZ estimates the country's marginal propensity to import at over 40 percent implying a remarkable pass-through rate of the exchange rate changes to the general price level. The actions of the BoZ in achieving exchange rate stability through monetary policy explain why the money market rate is the "forcing" variable of the exchange rate to the long run trend.

This specific mechanism, (discussed by Weeks and Mungule, 2013) functions through the actions of domestic branches of international banks. By increasing the yield on domestic government securities through open market operations, for example, the BoZ narrows the spread between Kwacha and dollar denominated securities. The domestic branches of international banks tend to shift from dollar denominated assets in favour of domestic securities markets, thus appreciating the domestic exchange rate. This mechanism works the same way (by lowering yield on domestic bonds) in the event that the BoZ wants to achieve a depreciation of the exchange rate.[10]

5.3. Out-of-sample analysis

In our out-of-sample analysis, we consider impulse response functions and forecast error variance decompositions. The stability checks in Table 3 do not indicate that the model is misspecified. Therefore IRFs and FEVDs are valid and have known interpretations.

5.3.1. Impulse response functions

Our discussion of the impulse response functions (IRFs) centres on the responses of the financial market variables to shocks in the copper price, their own shocks and shocks to the other financial market prices. The results are displayed in Figure 2.

The response of the money market rates to a positive innovation in the copper price is a contemporaneous fall and appears permanent. This result confirms the findings from the in-sample long run equation. The players in the Zambian market must pay attention to the price of copper as unexpected positive shocks

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[9] interbank rate, bank lending rates have been shown to track closely the 91-day Treasury bill rate (Simpasa *et al* 2014).

[10] It is not difficult to see why the Central Bank will be concerned about the effect of a volatile exchange rate in Zambia. Weeks and Mungule (2013) argues that interventions in the exchange rate markets "socialises hedging" foreign exchange risks in a market with relatively shallow hedging products and dominated by a few market participants.

tend to be followed by lower interest rates.[11] Following an appreciation of the exchange rate, short term interest rates tend to rise contemporaneously before reverting to steady state in the third month. The interest rates then fall before correcting to steady state on the ninth month. This result indicates the tendency of the BoZ to lower yields on Kwacha denominated debt instruments to moderate the volatility of the exchange rate through the actions of domestic branches of international banks discussed earlier. A positive shock to the short-term interest rate is followed by a contemporaneous rise that stays constant for about four months before it falls gradually for another six months. Following a positive shock in the equity prices, the short-term interest rate falls contemporaneously before rising with a lag of two months, peaking on the sixth month before correcting steadily to the fourteenth month. This result is consistent with short-term Granger causality result. The "reaction" of the money market rates to a positive shock in the equities price most likely reflects the inefficiencies in the Zambian financial markets – one would expect a faster response in the developed financial markets.

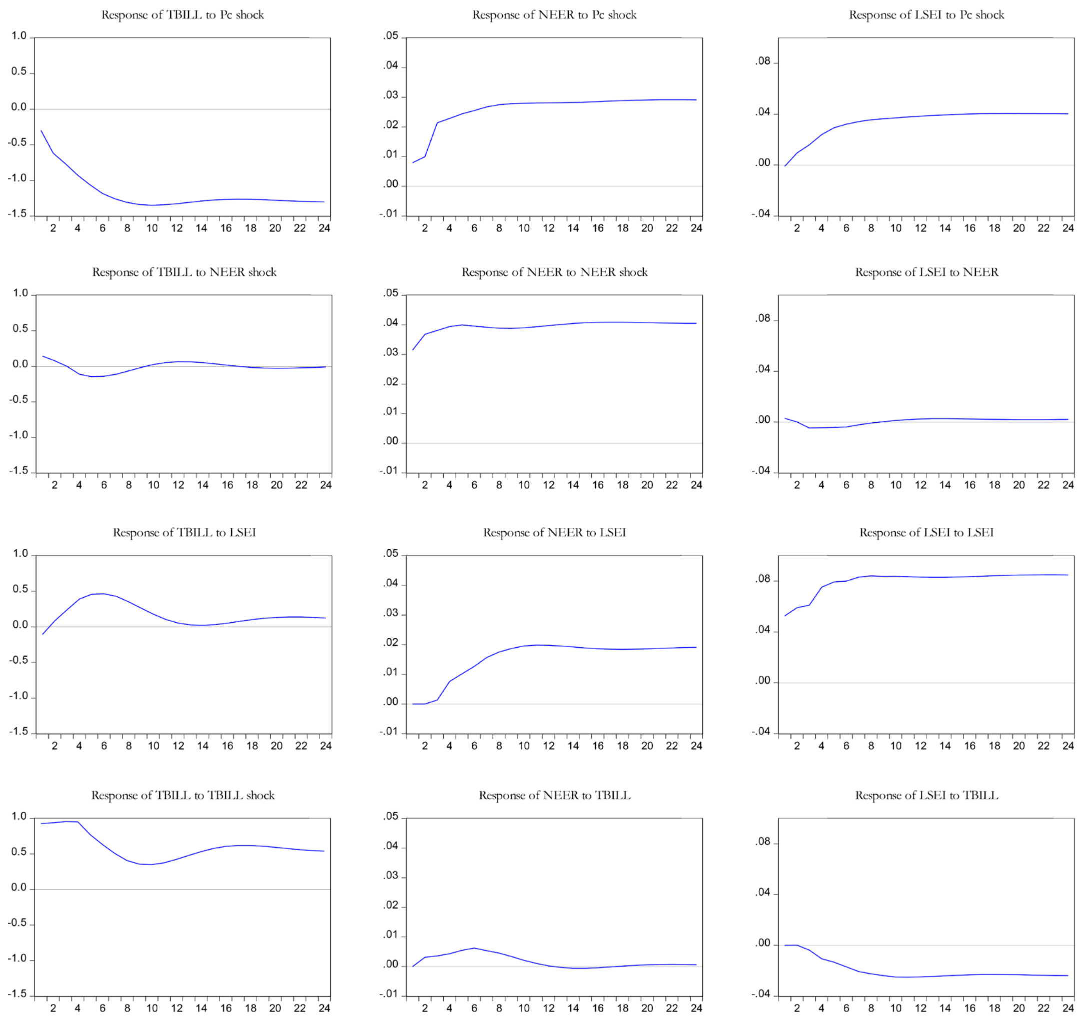
The response of the exchange rate to a shock in the interest rate seems transitory; appreciating the exchange rate with a one month lag and correcting steadily by the twelfth month. This result likely reflects leveraging activities by investors – high interest rates attract foreign portfolio flows into the money market, exerting upward pressure on the exchange rate (see Muhanga and Soteli, 2009). A positive shock in the copper price leads to a steady and permanent appreciation of the exchange over the two year period, possibly through its effects on the current account movements. This result supports the fairly conventional theoretical views of open economy macro-economics. A boom in the copper price improves the country's current account leading to an appreciation of the exchange rate (see Krugman 1983a). Equity market shocks appear to appreciate the exchange rate with a two months lag. This observation supports evidence of robust participation by foreigners on the Lusaka Stock Exchange.[12] The portfolio flows in turn increase the foreign exchange order flows on the Zambian Kwacha in the manner described by Hau and Rey (2006). By comparison however, while appreciation of the exchange rate places downward pressure on the equity prices (possibly by increasing the incentive for profit taking and locking in foreign

[11] Higher copper prices tend to be followed by appreciation of the exchange rate. The pass-through from the exchange rate tends to adjust inflation and interest rate expectations downwards. See https://www.lusakatimes.com/2015/11/03/bank-of-zambia-hikes-interest-rates-to-15-5-full-statement/

[12] Foreign participation on the stock exchange was 21 percent of total turnover in 2011 (http://www.luse.co.zm/wp-content/uploads/2012/08/Year-End-Statistics-2012.pdf)

exchange gains by foreign investors), the effect appears to be statistically indifferent from zero. Basher *et al* (2012) report a similar result using the trade weighted US index and an emerging market equity index.

Figure 2: Impulse Response Functions



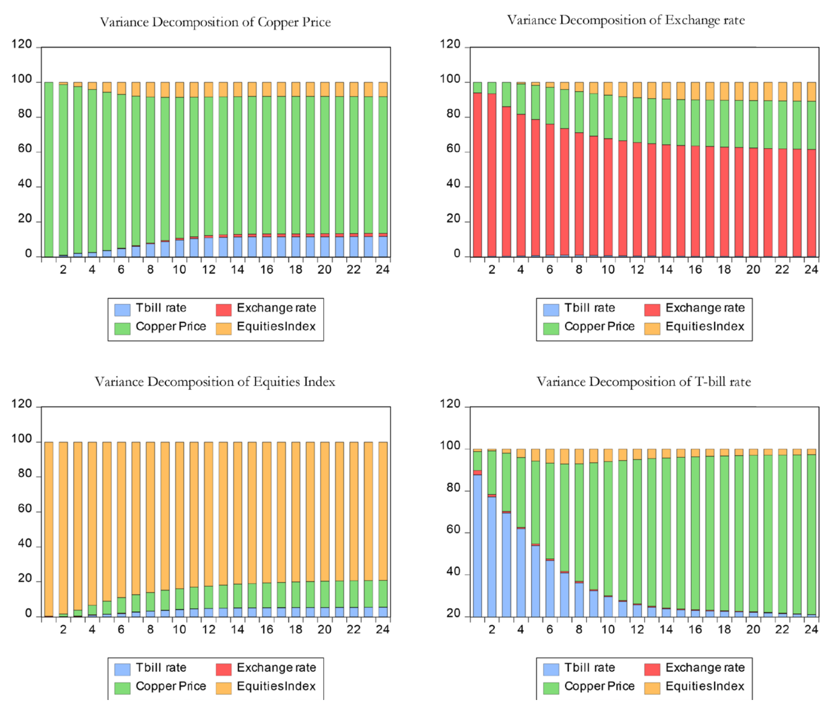
The reaction of the equity index to its own shock does not appear to correct over the experiment period. This result likely reflects inefficiencies in the stock exchange – one would expect shocks in efficient markets to correct rapidly. Stock market prices fall following a shock in the short term interest rates. Equity prices initially rise to a shock in the copper price and thereafter stay at the elevated level indicating the permanent effect of the shock and indicating that the two variables share a long-run equilibrium relationship.

5.3.2. Variance decomposition

Following the discussion of the impulse response functions, we now turn to the results of the variance decompositions. The forecast error variance decompositions are displayed in Figure 3 for the four variables in our study.

As can be seen from Figure 3, the exchange rate, equity prices and the copper price dominate the system in the short run, supporting our in-sample findings of weak exogeneity in the previous sub sections. By the sixth month for example, 75 percent, 88 percent and 89 percent of the variation in the exchange rate, copper price and equity index are explained by their own innovations respectively. By comparison however, the short term interest appears as the least weakly exogenous variable, supporting the proposition that the variable is a “slave” to the system responsible for correction to long-run equilibrium. The copper price dominates the short term rates in the long run – explaining 76 percent of the variation by the 24th month. Overall, the picture depicted by FEVDs supports the results of the IRFs on the influential role of the copper price in the determination of financial market prices in Zambia; the remote role played by the exchange rate in the equity price and interest rate equation and the long run bi-directional causality between the equities and money markets.

FIGURE 3: VARIANCE DECOMPOSITIONS



6. Conclusions and recommendations

We showed that there exists a stable long-run relationship between copper prices and financial market variables in Zambia in a Vector Error Correction Model (VECM). The correction to the long-run equilibrium is borne mainly by short term interest rates suggesting heavy reliance on monetary policy by the policy makers to steady financial markets in the event of exogenous shocks. In-sample short run Granger causality runs mainly, as expected from the copper prices to the financial markets although changes in the equities market lead changes in short term interest rates. The latter may reflect asset substitution activities of financial market players in Zambia – evidence that development of the equities an alternative investment class to the traditional Government securities. The out-of-sample analysis of impulse response functions and variance decomposition largely confirms our in-sample findings, emphasising the endogeneity of short term interest in the short and long run.

Our results raise at least two issues for policy in Zambia. First is the vulnerability of the financial markets (and the macro-economy) to the external shocks to the copper market and secondly the “over-reliance” on monetary policy to absorb the shocks from the copper market. While the country has had rich pickings from the financial market reforms of the 1990s (see Weeks and Mungule, 2013), it has to be borne in mind that the “commodity super-cycle” helped accentuate the period of remarkable economic growth in the last decade.[13] The threat is raised by commodity slump that started in 2014 (viewed by some scholars as the end of the commodity super-cycle, e.g. Goldberg, 2015; Bershidsky, 2015). Bauer and Mihalyi, (2015) list Zambia among the ten least prepared countries for the burst of the commodity super-cycle. Another relevant concern is how long the commodity price slumps will last. The previous commodity price super-cycles were on average between 15-28 years apart (see Le Billon and Good, 2015). In light of our findings we now make some policy recommendations for the Zambian authorities.

First, a set of counter-cyclical policies are required during periods of a commodity price boom. Reliance on tight monetary policy in the event of a commodity price downturn may have the unintended consequences of increasing domestic borrowing costs for the Government at a time when borrowing is

[13] Zambia's economy experienced strong growth in the last decade, with real GDP growth in 2005-13 more than 6 percent per year. See http://www.theodora.com/wfbcurrent/zambia/zambia_economy.html

required to finance a fiscal deficit.[14] Counter-cyclical measures include revenue and stabilisation funds and adoption of fiscal rules that avoid over-optimistic revenue forecasting and over-expenditure by Government (Frankel, 2011). Such reforms have been adopted in Chile for example.[15] Monetary authorities may consider anchoring policy on price indices tied to the main export prices rather than consumer price index (CPI).[16] Stabilisation funds and sovereign wealth funds built during commodity prices super cycles need to be considered (Varangis et al 1995). Stabilisation funds, built to smoothen revenue in the short-medium term typically involves the government depositing funds in an offshore account in periods of excess revenue for withdrawal when the commodity prices are below a pre-determined reference price (Bauer, 2014). Chile provides a case study with its Pension Reserve and Social and Economic Stabilization Fund.[17]

In the long-term the economic diversification agenda should be accelerated – with the upshot of broadening the portfolio of economic activities that reduces vulnerability of export revenues to copper. A well-developed non-resource based tradable sector may take advantage of Kwacha devaluation in periods of commodity price slumps to increase competitiveness in global markets (Le Billon and Good, 2015). Some practical tools that may be adopted to help the diversification agenda include implementing measured trade restrictions to support local manufacturing, improving access to financial markets and market liberalisation.[18] Other forms of diversification may include promotion of sectors with backward and forward linkages with the copper mining industry. Backward linkages involve use of local inputs and local suppliers by mining firms to promote growth of local industry. While such initiatives' success is mixed in low income countries, more flexible approaches such as raising the capability of local firms by mining companies are promising for the future (Sutton, 2014). Forward linkages, (sometimes known as beneficiation) involve further processing of the raw primary commodity for local use or export. Another policy alternative is to harvest copper revenues to invest in sectors that

[14] Zambia's marginal propensity to import is estimated at over 40 percent (see Weeks and Mungule, 2013). This means that an exchange rate deprecation of 10 percent could potentially lead to economy-wide price increases of over 40 percent.

[15] In Chile, a new structural budget rule requires that the copper price and estimated output be estimated by an independent panel of experts. The two variables of copper are the most important inputs into the state budget.

[16] See Frankel (2006) for a robust proposal for small commodity exporters to peg policy in the export price index.

[17] See http://www.swfinstitute.org/fund/chile.php

[18] Opening up financial markets and financial liberalisation enables producers access to international financial markets and alternative investments abroad.

are completely unrelated to copper mining, either through development banks of industrial policy (Venables, 2016). Malaysia offers an example of success of this policy (see Yusof, 2011).

Other policy choices for Zambia include strengthening the governance and transparency in the management of copper revenues. These improvements may include a formal program of raising citizen awareness on the implications of commodity price cycles and related revenue management decisions.[19] The authorities also need to improve management of the "resource for infrastructure" deals particularly with China.[20] Such deals accelerate the diversification program and help transform the sub-soil assets into surface assets at the price of foregoing concurrent consumption. These policy options while they come with their limitations are necessary to reduce the vulnerability of export revenues to the shocks in the copper market and by extension, over reliance on monetary policy as a response instrument to copper price shocks.

For financial market players, it is valuable to watch the copper price as a signal of the future direction of interest rates. Equity prices may also signal future direction of short-term interest rates.

Biographical Notes

Xolani Ndlovu is currently employed by the Old Mutual Group as Head of Foreign Exchange Trading in Harare. He holds a Master of Management in Finance and Investment degree from the University of the Witwatersrand, Johannesburg and is currently a PhD candidate with the same university. His research interests include international commodity markets, sub-Saharan financial markets and international finance.

Professor Eric Schaling holds the Jelle Zijlstra Chair in International Finance at Wits Business School, Johannesburg. Eric studied macroeconomics at the Faculty of Economic and Business Administration at Tilburg University in The Netherlands. After obtaining his doctorate there he joined the Monetary Analysis Division of the Bank of England. He has been a consultant to the IMF, the Federal Reserve Bank of St. Louis and the South African Presidency and was appointed Fellow at the Centre for Economic Research at Tilburg University, The Netherlands, in 2004.

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[19] As suggested by Venables (2016), Malaysia and Botswana have seen management of citizens expectations improve economic performance

[20] Halland *et al*, (2014) note that some of these deals are barter deals and form parts of bilateral trade agreements. Bräutigam and Gallagher (2014) estimate that, between 2000 and 2011, China committed $53 billion to Africa in funding of "resource for infrastructure" type deals.

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