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MODELLING AND FORECASTING METAL PRICES: EVIDENCE FROM DEVELOPING AFRICAN ECONOMIES

By

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Abstract

Developing Africa has been heavily dependent on primary commodities for decades as these countries are rich in mineral resources and often tend to export that and little else. However, commodities are highly susceptible to volatility and their effects on these economies are enormous. This paper investigates the extent to which the GARCH and EGARCH models can accurately be employed to model and forecast metal prices. Also, a p-dimensional VECM is formulated in establishing the extent to which the metals are co-integrated. Seven metals - Aluminium, Copper, Gold, Lead, Nickel, Platinum and Zinc have been employed for the purpose of this study. The models yielded satisfactory prediction results, albeit mixed findings in terms of the superiority of the models. Nonetheless, we conclude that the results are sufficient in aiding African economies in deriving appropriate policies and trading strategies so as to capitalise on export revenues, resulting in increased GDP and overall economic growth and development of their countries.

Key Words: volatility, GARCH, EGARCH, VECM forecast, metal prices

Declaration

I, Vetjevera Mercy Handura hereby declare that this research report submitted for the degree of Master of Management in Finance and Investment (MMFI), at the University of the Witswatersrand Business School is my own unaided work, except where otherwise indicated and acknowledged. This thesis has not, either in part or whole been previously submitted to any other institution of higher learning for any degree or diploma.

Vetjevera Mercy Handura 29 August 2017

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Table of Contents

Chapter 1: Introduction 9

1.1 Introduction 9

1.2 Background & Context 9

1.3 Behavioural characteristics of Metals 13

1.4 Research Problem 14

1.5 Research Objectives and Research Questions 15

1.6 Significance of study 16

1.7 Data and Methodology 16

1.8 Conclusion 17

Chapter 2: Literature Review 18

2.1 Introduction 18

2.2 Commodity price volatility 18

2.3 Causes of the volatility 20

2.4 Other behavioural Characteristics of Commodity prices 22

2.5 Effects of volatility and other behavioural characteristics of commodity prices 24

2.6 Possible solutions to the problems 28

2.7 Empirical methodologies and results 29

2.8 Conclusion 32

Chapter 3: Data and Methodology 33

3.1 Introduction 33

3.2 The Data 33

3.3 Econometric Methodology 34

3.3.1. Test for stationarity 34

3.3.2. Test for Co-integration 35

3.3.3. Models for Forecasting 37

3.4 Conclusion 39

Chapter 4: Estimation and Interpretation of the Results 40

4.1 Introduction 40

4.2 Test for stationarity results 40

4.3 Johansen Test Results 41

4.4 Models for forecasting 44

4.5 Conclusion 48

Chapter 5: Conclusion 49

5.1 Introduction 49

5.2 Literature Review 49

5.3 Data and Methodology 50

5.4 Estimation and Interpretation of the Results 50

5.5 Overall Conclusions 52

6. References 54

Appendix I: Metals exported by African countries 60

Appendix II: Historical prices of the metals 60

Appendix III: Historical returns of the metals 62

Appendix IV: Descriptive Statistics 64

Appendix V: Critical Values for DF Tests 64

Appendix VI: VECM Estimation Results 65

Appendix VII: GARCH Forecast Graphs 69

Appendix VIII: EGARCH Forecast Graphs 72

List of Tables

Table 1: Metal Price Stationarity Results 40

Table 2: Metal Return Stationarity Results 41

Table 3: Johansen Test Results 42

Table 4: GARCH(1,1) Model Results 44

Table 5: GARCH(1,1) Model Diagnostic Results 45

Table 6: EGARCH(1,1) Model Results 45

Table 7: EGARCH(1,1) Model Diagnostics Results 46

Table 8: Forecasting Results 47

Table 9: Metals exported by African countries 60

Table 10: Descriptive Statistics 64

Table 11: Critical Values for DF tests (Fuller, 1976) 64

Table 12: VECM Output 65

Table 13: Short Run and Long Run Causality Model 67

Table 14: Wald Test Results Summary 68

List of Figures

Figure 1: Graphs depicting metal historical prices..... 60

Figure 2: Graphs depicting metal historical returns 62

Figure 3: Residual Diagnostics extracts of the VECM..... 68

Chapter 1: Introduction

1.1 Introduction

The dynamics of African economies with regards to economic wealth and realisation of it through the vast resources available to most of these developing countries beckons the need for the study and research into how these resources or commodities can contribute towards Gross Domestic Product (GDP) and national wealth. Not all African countries are realising the true wealth and benefits from their commodities and it is therefore important to delve deep into the issues on how the value from these commodities as well as the return from these commodities can be realised.

In looking at economic factors of significance, research shows that developing African countries are significantly affected by economic booms and busts caused by fluctuations in exchange rates, interest rates and commodity prices (Sy, 2016). The focus of this research aims to deepen understanding and appreciation of the extent to which commodity price fluctuations affect developing African economies by modelling and forecasting metal commodity prices. The modelling and forecasting of metal commodity prices will prove important and relevant given the vast mineral wealth and dependency of mineral wealth by various African countries.

1.2 Background & Context

Fluctuations in commodity prices have continued to have dynamic effects on global economic activity for decades as trends in commodity prices has greatly influenced the economic growth of many economies. This has been exacerbated by additional economic factors such as the performance of other currencies such as the Chinese Yuan. A classic scenario can be drawn from the devaluation of the Chinese Yuan in

August of 2015 that sent shock waves in global markets (Telesur, 2015). China has also been busy restructuring its economy with a move towards a more consumption based economy and less reliance on commodity – intensive investment (Lagarde, 2015). This move by China in its economy has in turn affected many metal exporting economies as China has always been the main destination for their commodities.

Taking these contemporary developments in the global economy into account, the extent to which fluctuations in metal commodity prices affect developing economies will be the subject matter of this research. A large portion of developing economies' GDP comes from commodity related activities as these activities remain an essential source of employment, income and government revenues (UNCTAD, 2013). The majority of these African economies have been characterized by the World Bank as low income economies, with total goods exports made up by more than half of the commodities (Bersch, 2012). They tend to rely mainly on one or two primary commodities thus making them more susceptible to adverse movements in commodity prices. Case examples would be Nigeria and Angola as both are heavily dependent on oil exports. Crude oil comprises 90 percent of Angola's total exports, while both oil and natural gas constitute 91 percent of Nigeria's total exports (Trading Economics, 2016). With the decline in oil prices, both Nigeria and Angola have seen adverse effects on their economies to extents such that Nigeria devalued the Naira while Angola approached the International Monetary Fund (IMF) for an economic programme, possibly supported by financial assistance (Offshore, 2016). These responsive measures and reactionary actions by Nigeria and Angola give credence to the need for research into commodity prices in other developing African countries.

In further assessing the relevance and impact of other commodities in other developing countries in Africa: Copper makes up over 60 percent of Zambia's total exports while Mozambique's exports of Aluminium comprises the top ten of the world's total production. Of the metals studied in this paper,

South Africa exports Zinc, lead and it is the world's largest exporter of Platinum and the fourth largest of Gold. Congo is also another African country rich in commodities and derives about 95 percent of its export earnings from extractive industries (Reuters, 2016). Congo also exports Gold, Zinc and Copper. Many of the other developing countries on the continent rely on exports of one or two other metal commodities which tend to be a much smaller portion of the total world production (Trading Economics, 2016). Table 9 in Appendix I summarises the metals which are exported by African countries.

During price booms, these countries are normally inclined to significant improvement in fiscal revenues, thereby allowing them to increase current and capital government expenditures (UNCTAD, 2013). Foreign exchange earnings also increase and so do foreign capital inflows and thus an improvement in these countries' balance of payments. Nonetheless, it is worth noting that higher metal prices during price booms can result in a situation known as the Dutch disease, whereby the higher prices precipitate a sharp inflow of foreign currency thus causing an appreciation of the local currency. This makes the country's other products less competitive in the export market, negatively impacting the economy (Hodge, 2012).

Jacobson & Parker (2014) further denote that booms tend to create substantial short term economic benefits and long term hardships such as joblessness and lower incomes. This is affirmed by UNCTAD (2013) which considers economic growth driven by primary commodity production and exportation to be quite limited while Frankel (2011) theorised that the effects of the resource curse remains evident and prevalent in many commodity rich countries on the continent. This curse hypothesises that countries rich in natural resources such as minerals and fuels tend to have less economic growth than those that don't.

The reversal of the upward trend in metal prices remains a further reminder of the challenges faced by developing countries dependent on one or few metal commodities. Price slumps have the effects of translating into lower commodity terms of trade which is a representation of the value of a country's exports relative to imports (Mendoza, 1995). Additionally, lower prices put pressures on current account balances, fiscal accounts and eventually lead to slower economic growth (Davis & Tilton, 2002).

i) Base metals

As of 2014 when metal prices started plummeting, the market for base metals remained oversupplied albeit production cuts by some producers and a few supply interruptions. Low prices seem to be persistent together with the uncertainty over demand given current global economic conditions. The supply of zinc has been tightened due to the closure of large mines in 2015 such as Century in Australia and Lisheen in Ireland; and Glencore's overall production cuts (World Bank Group, 2016). Glencore is the world's largest commodity trading company with a total addressable market share of over 30 percent in various metals such as Zinc, Nickel, Cobalt, Lead, Aluminium and Copper (The Telegraph, 2011).

The lower metal prices have weakened economic growth in Congo, as some mines have suspended operations and thousands of jobs have been lost (Reuters, 2016). In Zambia, the lower copper prices, decreased exports and reduced foreign direct investments (FDI) weakening the economy as a whole (The World Bank, 2016). This further resulted in significant depreciation of the Zambian Kwacha against the United States (US) Dollar, with losses in value of about 50 percent over a period of just one year (York, 2015).

All factors analysed together, sluggish demand for base metals persists during periods of lower metal prices due to subdued economic growth as metal prices tend to be strongly related to global industrial production (UNCTAD, 2015). The Lead market contracted considerably due to the uncertainty in demand given China's e-bike market and growth of electric vehicles (World Bank Group, 2016). However, Aluminium demand often trends slightly higher than that of other base metals, in the wake of lower commodity prices due to its many uses, favourable properties and substitution attractiveness.

ii) Precious metals

Precious metals have a tendency to hold their own much better than base metals during economic headwinds. This is in part due to the fact that Gold has always been considered a safe haven for investors, especially when the US Dollar is under pressure. When the Dollar is uptrend, there tends to be a downside trend in the Gold market (Jesiolowski & Chow, 2015). Demand in India and China, the largest consumers of Gold has also been weak, and so too was supply, that trended much lower due to declined investments, reduced costs and depreciated producer currencies (World Bank Group, 2016).

1.3 Behavioural characteristics of Metals

The majority of the problems addressed in the previous section are brought about by the volatility of commodity prices, which is considered one of the key behavioural characteristics of metal prices. The short term fluctuations and long term trends in commodity prices are key determinants of exchange rates, prices, national income and the balance of payments (Cabrales, Castro, & Joya, 2014) for these economies.

According to Myers (1994) prices of primary commodities are characterised by high volatilities, stochastic trends and excess kurtosis. Co-movements in commodity prices (a situation where different commodity prices move together much more closely than would be expected as a result of commodity market spill over) and time varying volatility (the temporal instability in the variance of commodity prices over time) have also been found to further characterise commodity prices (Myers, 1994). The graphs in Appendix II represent the daily prices of the seven metals from January 2005 to March 2016 and clearly depicting how volatile these metals are.

The extent to which the metal price volatility affects a specific country's macroeconomic variables depends on the volume and product composition of the metal in the country's trade (UNCTAD, 2013). The higher the volume and product composition, the more susceptible the country will be to metal price volatility. With the exception of Zambia's copper production and South Africa's platinum production, most of the continent's production of metals tends to be smaller volumes of the total world production. Nonetheless their composition tends to be a much larger portion of their individual country's trade exports. Hence, African countries are prone to the vulnerability in metal commodity price movements.

1.4 Research Problem

It is worth observing the extent of metal price volatility and its effects on developing African economies heavily dependent on them. Metals have been studied to a much lesser degree in comparison to soft and energy commodities. Also, very little studies have focussed on the actual modelling and forecasting of metal commodities in the context of developing African economies.

To that extent, the research problem to be addressed within the ambit of this thesis reads as follows: Metal price volatility and developing African economies' over dependence on these commodities is detrimental to the sustainable economic growth and stability of these economies. Specific attention is drawn to this research problem in the anticipation that the modelling and forecasting of the metals commodity prices will aid economic agents in developing economies better align policies from expected future commodity prices.

1.5 Research Objectives and Research Questions

The objective of this study is to gain an understanding of metal commodity price behaviour. The research seeks to employ an empirical study of metal prices with specific emphasis on volatility as it affects developing African countries. Given that 'volatility is unobservable and must be estimated,' (Watkins & McAleer, 2001: p.1) time-series techniques will be used in the modelling and forecasting of the metal prices. This is in the expectation that trends and patterns will be derived from the empirical study that will enable African economies to better manage their risks and align their policies accordingly. Inter alia, the study attempts to address the following questions:

- To what extent can the different Generalised Autoregressive Conditional Heteroscedasticity (GARCH) models accurately model and forecast metal price volatility?
- Can metal price forecasting and predictions yield results that can aid agents in developing economies with decision making as they strategize for the future?

1.6 Significance of study

The study will contribute to the literature on metal prices that is currently very limited. Additionally, significance also evolves from the anticipation that the findings will contribute to the understanding and appreciation of metal price behaviour which is expected to aid economic agents in developing countries with their policies. The behavioural study of the metal prices further aims to emphasise the extent of the commodity price volatilities.

1.7 Data and Methodology

The study will make use of the daily spot prices of the precious metals (Gold and Platinum) and the daily futures prices of the base metals (Aluminium, Copper, Lead, Nickel and Zinc) from January 2005 to April 2016. This is in part due to the fact that 'models that incorporate futures prices generally yield superior forecasts over horizons of one year or longer' (Bowman & Husain, 2004: p.3). However, spot prices were adopted for the precious metals as these metals are not as actively traded in the futures market as the base metals. The base metal prices have been extracted from the London Metal Exchange (LME) while the precious metal prices have been obtained from the Commodity Exchange (COMEX), both via Bloomberg. The period (2005 to 2016) has been specifically chosen as the research aims to study and understand metal prices pre and post the 2008 to 2009 global crisis, beyond the 2011 commodity boom up to and inclusive of the recent global economic slowdown.

With regard to the excess co-movement behavioural characteristic of commodity prices, the study will conduct a test of co-integration amongst the metals. This will be done using the Johansen test for co-integration. The GARCH models will then be used for the actual modelling and forecasting of the metal prices.

1.8 Conclusion

In summary, this chapter served to introduce the research topic and provide a brief background to the study in which the overdependence of African developing countries on metal commodity was detailed out together with the effects of such overdependence on these commodity rich economies. Furthermore, the behavioural characteristics of the metals as well as a statement of the research problem, subsequent to the research objectives and research questions were also outlined.

The remainder of the research is organised as follows. The next chapter contains a review of the relevant literature, with particular emphasis as it affects the developing African economies. Chapter three will provide an account of the data employed and a detailed description of the research methodology. Here the Johansen test, the GARCH and EGARCH empirical methods will all be fully diffused and explained. Chapter four will outline the empirical results of the study and render the relevant interpretations. The last chapter will summarise the key findings and conclude accordingly.

Chapter 2: Literature Review

2.1 Introduction

Extensive work has been done on commodity price behaviour for many years, particularly on soft and energy commodities and to a much lesser degree on hard commodities. Baffes & Haniotis (2010) assert that the 2008 price boom has also renewed interests in the long term behaviour and determinants of commodity prices. So does Halperin (2010) who stressed that the boom-bust and then boom again 'ignited research and public discourse on commodity prices' (p.12). Likewise, Kinda, Mlachila, & Ouedraogo (2016) posit that interests in commodity markets and their impact on economies has been revived by the recent decline in commodity prices, especially oil prices. There seems to be uniformity amongst the various studies that commodity markets are highly volatile, while the other aspects of their behavioural characteristics remain contentious.

2.2 Commodity price volatility

The volatility of commodity markets has been one of concern for policy makers, producers and consumers for many years. Dash, Solanki, & Shobana (2012) conducted a study on energy, hard and soft commodity prices and found them to be characterised by substantial volatility. So did earlier work by Cashin & McDermott (2002) and later by Issler, Rodrigues, & Burjack (2014), Moreira (2014) and many others. Kroner, Kneafsey, & Classens (1993) stated that measured volatility has been as low as 15 percent and at times higher than 50 percent. They further affirmed that commodity price volatility has exceeded that in exchange rates and interest rates in many periods while Myers (1994) emphasised that primary commodities are generally more volatile than manufactured consumer goods.

Yet, as volatile as commodities are, developing African economies have a heavy dependence on them. Cabrales *et al*.(2014) upheld that on the supply side, many developing countries are highly dependent on commodity exports income and so did Page & Hewitt (2001) who emphasised the developing economies' over reliance on one or few primary commodities. Deaton (1999) firmly asserted that most African economies export primary commodities and little else. This was also confirmed by Deaton & Laroque (1992) who stated that less developed countries depend heavily on the exports of a small number of primary commodities. Hence, their study on 13 commodities so as to determine the empirical behaviour of commodity prices in comparison to theory. The researchers made use of a simple expectation's competitive storage model in which the behaviour of prices from one year to the next was found to conform to theory predictions about conditional expectations and conditional variances. Furthermore, the study raised the importance of the formulation of economic policy for these less developed economies.

Kinda *et al*. (2016) employed a sample of 71 commodity exporting economies from emerging and developing countries so as to investigate the impact of commodity price shocks on financial sector fragility. This paper theorised that negative shocks to commodity prices tend to weaken the financial sector and to a larger extent the economy as a whole. Particularly in countries that do not have a diversified export base, such as developing African countries. To that extent, the work by Kinda *et al*. (2016) contributes to this study in that it emphasises the adverse effects of the overreliance on primary commodities and puts forward the importance of economic diversification and macro-prudential policies.

Likewise, Bleaney & Greenaway (2000) also stressed sub-Saharan countries' heavy dependence on primary commodities exports, following their empirical study on a panel data of 14 sub-Saharan African countries from 1980 to 1995. The researchers estimated investment and growth equations on the level

and volatility of the terms of trade and real effective exchange rates, thereby highlighting the negative correlation between specialisation in primary commodity exports and growth. Similarly, Deaton and Miller (1995) had maintained the existence of correlation, although at the time between commodity prices and economic growth in Africa. This arose following their study which aimed to address whether macroeconomic results ought to be attributed to the inherent difficulty of predicting commodity price fluctuations or rather the sub-standard political arrangements and fiscal policies in sub-Saharan Africa. Additionally, the research aimed to understand the extent of sub-Saharan Africa's ability to deal with commodity price variability by using an extended vector autoregression (VARX) model. GDP and its componenets were each regressed on their own lags and on the lagged values of an index of international commodity prices (Deaton and Miller, 1995). 32 sub-Saharan countries and 21 commodities from the region were sampled accordingly. This study established that commodity prices are instrumental variables for economic growth in sub-Saharan Africa, but however could not find a direct link between political arrangements and commodity prices.

Deaton and Miller (1995), like many other researchers stressed that African countries are heavily dependent on a small concentration of primary commodity exports and this is the general consensus of the literature. Grilli & Yang (1988), Dehn (2000), Reyes (2012) and Tiawara (2015) are all examples of such studies. The list is however not exhaustive.

2.3 Causes of the volatility

As much as the various studies confirm unequivocally the volatility within the commodity markets, the causes of this volatility are not as apparent. Kroner *et al*. (1993) state that disturbances in demand and supply are the causes of the large price variations and so does Byrne, Fazio, & Fiess (2010) who uphold that 'global demand and supply shocks are key determinants of the variability of commodity prices.' On

the other hand, Deaton & Laroque (1996) emphasised that demand shocks alone were a more probable source of price fluctuations especially in the short run. Jacks, O'Rourke, & Williamson (2009) argued that speculative positions due to a large influx of new traders into oil and other commodity futures markets tend to cause a run up in prices, which is also believed to have an underlying effect on the variability of commodity prices. This was also established by Pindyck (2002) who found that some portions of commodity price volatility was due to speculative noise trading and herding behaviour as opposed to mere market fundamentals. According to Labys (2005) commodity markets are also subject to shocks or trends ranging from natural catastrophes, political or military interventions to structural market changes, that all tend to have an underlying effect on commodity price variation. The author also makes mention of uncertainity as a considerable factor that pervades the commodities market, thereby causing price variation. Again, speculation results in this uncertainity in the market and so too does political interventions, structural breaks, time-varying price elasticities and links to business cylces (Labys, 2005).

Furthermore, Frankel (1986) theorised that monetary policy has an impact on commodity price fluctuations and this was confirmed by Cabrales *et al*. (2014) who conducted an empirical study on oil, Coal, Gold and Nickel. Additionally, the researchers also assert that since commodities are priced in US Dollars, fluctuations in the US Dollar exchange rates and shocks on the US monetary policy also causes volatility in the commodity markets. However, Sjaastad and Scacciavillani (1996) stressed that fluctuations in the exchange rates of major currencies, and not just the US Dollar contributed to the instability of world prices, that of Gold in particular. The work by Batten, Ciner, and Lucey (2010) established the volatility of precious metals to be sensitive to other macroeconomic factors such as business cycles, monetary environment and financial market sentiments, albeit at differring degrees.

According to Assa, Dabbous, and Gospodinov (2013) movements in commodity prices and increased volatlity within the market is largely attributed to the Chinese demands of commodities and that of other emerging markets as well. Also, the researchers assert that massive capital inflows into commodity markets from institutional investors, portfolio managers and speculators tend to cause volatility within the markets. This was in agreement with Labys and Maizels (1990) who thoerised that financial resources flows, including that of speculative funds from capital markets contributed to volatility within the commodity markets and thereby resulting in global economic instability.

The literature remains vast and widespread as to the causes of volatility within commodity markets, with such causes differing from study to study as per the findings of the various researchers. This study has faired sufficiently well in addressing such causes, and it would be rather impossible to address all such causes given time constraints.

2.4 Other behavioural Characteristics of Commodity prices

According to the Prebisch-Singer hypothesis of 1950, the price of primary commodities decreases over time relative to manufactured goods (Cashin and Mcdermott, 2002). However, this hypothesis has received moderate to no support over the years, as Cashin and Mcdermott (2002) themselves had difficulty in proving it, stating that the hypothesis remains controversial and unresolved. Harvey *et al*. (2010) found conflicting results as 11 major commodities out of 25 they tested support that the Prebisch-Singer hypothesis is a relevant phenomenon for commodity prices while the other 14 did not. Arezki *et al.* (2013: p.1) also obtained mixed results for the hypothesis but with the 'majority of the tested series showing negative trends'. However, Cuddington, Ludema, & Jayasuriya (2002) were bold enough to state that a long-run downward trend in real commodity prices is rather elusive.

Metal price variation was found to be theoretically and empirically positively correlated to industrial-production variation by Issler *et al.* (2014). This is in contrast to Moreira (2014) who established that commodity prices were not necessarily correlated with any specific economic activity given that they were formed in international markets. Also, the commodity market is characterised by excess co-movement amongst different unrelated commodity prices as asserted by Pindyck & Okimoto (1990), Myers (1994) and Ohashi & Okimoto (2016). Additionally, Cabrales *et al*. (2014) confirm this notion by stating that commodity markets are characterised by spreading shocks between markets. These shocks, especially adverse commodity price shocks have been determined by Kinda *et al.* (2016) to be the root cause of increased financial sector fragility. This was established after the researchers conducted tests focussed on various measures of commodity price shocks, sub categories of commodities and the occurrence, duration, intensity and instability of the price shocks in reaching their conclusions.

Cashin and Mcdermott (2002) established that price variation is large, relative to trend, while Deaton and Laroque (1992) theorised that commodity prices were often dominated by long periods of doldrums punctuated by sharp upwards spikes. A study on commodity prices and growth in Africa conducted by Deaton (1999) concluded that over the long run, the real prices of primary commodities produced by African countries were either trendless or trended gently downwards. Nonetheless, with the exception of the 2008 to 2009 global crisis and the recent global economic slowdown, 'commodity prices have increased sharply over the last decade' (Adler & Sosa, 2011: p.5).

The aforementioned makes it rather challenging in establishing stylised facts about commodity price cycles. Moreover, the literature on commodity price cycles is very limited. Reinhart & Wickham (1994, p.16) put forth that shocks which drive commodity price cycles exhibited 'differing degrees of persistence across commodities,' while Cashin and Mcdermott (2002) emphasised that large long lived booms and

slumps in cycles made it rather highly unlikely in indicating any major changes in long run prices. Cuddington & Jerreit (2008) examined super cycles in real metal prices, stating that they were driven by industrialization and urbanisation in the Chinese economy. The paper further highlights that those earlier super cycles were driven by similar developments in the United States, Europe and Japan. Currently, the expectation would therefore be one of collapse of these super cycles given the recent slowdown of the Chinese economy and its move towards a more consumer based economy and an overall decline in metal demand. However, would this really be the case considering that past literature could not unambiguously agree on the stylised facts on metal price cycles?

2.5 Effects of volatility and other behavioural characteristics of commodity prices

The uncertainties that accompany these price cycles and volatility make trading and hedging strategies difficult particularly for developing countries (Dash *et al*.; 2012). Commodity price volatility represents risk in storable commodity markets as uncertainty exists for producers in terms of revenues generated and consumers in terms of costs incurred (Watkins and McAleer, 2001). Deaton and Laroque (1992) also assert that such volatility poses key problems of both macroeconomic and microeconomic policy for countries whose export earnings and Gross National Product (GNP) are dependent on commodities. Cashin and Mcdermott (2002) uphold this difficulty posed on macroeconomic policy by volatility owing to developing economies over-dependence on commodities.

Moreira's (2014) study on commodities established that the higher the volatility in commodities prices, the lower the GDP level of a country and the higher the inflationary expectations. Additionally Jacks *et al.* (2009) detailed that volatility 'impairs future growth prospects, especially in countries with imperfect capital markets' (p.3). Nevertheless, Bleaney and Greenaway (2008) state that theory is somewhat

ambiguous on the effects of trends and volatility of the terms of trade on growth and investment, albeit their own findings established that volatility in the terms of trade has a negative impact on growth.

The continents growth has also been hampered by the slowing down of the Chinese economy (Wortsall, 2015) which is the biggest trading partner with most of the metal exporters on the continent. This over exposure to China has also been particularly problematic as China has been rebalancing its economy. Bugnacki (2015) affirms that China's commodity purchases from Africa declined 40 to 60 percent since 2014. Kambou (2015) confirms this, stating that the slower than expected growth in China weighs on the continents' demand for commodities further driving prices down and thereby leading to a significant decline in export revenues of many countries.

This downturn in commodity prices result in other socio-political problems beyond economics in the exporting countries: strikes evolve, mines close down and retrenchments become imminent (Wilson & England, 2015). Bigg (2015) further affirms that these results in other problems such as higher unemployment rates and increased poverty levels. Bersch (2012) asserts that this could in turn exert political pressure on governments as they balance mitigating fiscal policies against possible negative impact on public finances. Furthermore, the author affirms that global commodity price shocks tend to create strong inflation, as food prices which makes up about 50 percent of the developing countries' consumption basket is highly correlated with other commodity prices.

The continent is also faced with other difficulties during price booms, better referred to as boom problems. Deaton (1999) posit that 'rising commodity prices will not solve Africa's poverty' (p.33). This, according to the researcher is owing to the poor investment considerations and quality of governance on the continent. Additionally, Kinda *et al.* (2016) were other researchers who emphasised the poor quality

of governance, weak fiscal space, lack of sovereign wealth fund, non-implementation of macro-prudential polices and the lack of a diversified export base to be other factors resulting from the developing countries' over dependence on primary commodities. The literature has extensively referred to these problems emanating from the overabundance in primary commodities as the resource curse.

Stevens, Lahn, & Kooroshy (2015) established that the resource curse constrained growth, fed corruption and fuelled conflict. Hodge (2012) further theorised that the resource curse was inclusive of a broader range of political and socio-economic factors, argued to hinder the development and growth in resource rich countries. Additionally, the natural resource wealth is also believed to inhibit the development of democracy (Frankel, 2011). Davis (2009) also concluded that the resource curse was as a result of depletion effects, trade policy, institutional failure, terms of trade movements and export revenue volatility. Nevertheless, this researcher further affirms that, while there may be a resource curse, there certainly was a resource disappointment as well. Hodge (2012) adds on to this notion stating that there is nothing inherently growth-inhibiting in mineral booms, but however it is the resource allocation thereof that is. Instead of referring to the commodity abundance as a resource curse, Frankel (2011) theorised that is was best to view it as a double-edged sword, equally beneficial and costly to those economies. The findings of researchers such as Deaton and Laroque (1992), Page and Hewitt (2001), Cabrales *et al*. (2014) and many others tend to accentuate the negative impact of commodities on over-reliant economies.

Considering Frankel's (2011) double-edged sword theorem, capital flows to African developing countries, be it in the form of portfolio flows or FDI can be equally beneficial and costly to these economies. These inflows tend to increase during commodity price booms. This is as affirmed by Rangasamy & Mihaljek (2011) who detailed that 'the surge in commodity prices has supported large FDI inflows to the extractive sector in many African countries' (p.72). Spatafora & Tytell (2012) denote that historically, portfolio equity

flows have responded markedly to commodity price booms in comparison to FDI. Conversely, according to the researchers, the 2011 commodity price boom saw FDI increase much faster than in the past. Additionally, the study by Deaton and Miller (1995) put forth the philosophy that during price booms, especially when commodity prices are rising more rapidly than the interest rates on international loans, developing countries tend to service debt through fresh borrowings.

Capital flows can be beneficial and 'aid economic growth and development when used productively and at sustainable levels' (Muhanji & Ojah, 2011: p.1). However, Muhanji and Ojah (2011) put forth that African countries still have the notoriety of being characterised by unsustainable external debt levels. Bevan, Collier and Gunning (1989, 1990 and 1991) in Deaton and Miller (1995) theorised that African governments tend to invest far in excess of their savings and that such investments are usually of poor quality with low returns. According to the authors, during periods of rising prices, governments also tend to increase current expenditures in a way that is difficult to reverse when booms turn to slumps, thus destabilising their economies even further.

Interestingly, Kinda *et al.* (2016) also found African countries to acquire more public debt, but however, during periods of lower commodity prices and negative shocks. This in turn resulted in increased bank costs, non-performing loans and foreign currency denominated debts as foreign reserves tend to be highly correlated with commodity prices especially for the net exporting developing countries. Nevertheless, Bastourre, Carrera and Ibarlucia (2012) denote that regardless of the potential beneficial effects of capital inflows, they tend to exacerbate the volatility and pro-cyclicality of receiving economies, simultaneously sharply impacting the real exchange rates.

2.6 Possible solutions to the problems

Due to this volatility, the uncertainties and problems it brings about, past empirical work intended to predict commodity price behaviours by forecasting and modelling them with the expectations of addressing some of the above mentioned problems. According to Halperin (2010) uncertainty remains rather complicated to manage in comparison to volatility and can be reduced by having accurate forecasts of future commodity payoffs. Additionally, the researcher denotes that volatility can in turn be effectively managed by entering into futures markets. Derivatives such as futures and options can be employed to hedge against the price risks in commodity markets. However, one requires knowledge and understanding of the underlying time series in order to apply strategies for hedging and pricing of options and other derivatives.

Bernanke in his 2008 speech highlighted the importance of forecasting commodity price changes and understanding the factors that drive those changes for policy. Similarly, Deaton (1999) theorised that sensible development and macroeconomic policy rules for commodity exporting countries must be grounded in an understanding of the behaviour of commodity prices. From which the developing countries should adopt policies that promote sound economic growth and good governance so as to ensure the effective use of natural resource windfalls (Kinda *et al.*, 2016). Additionally, the researchers encourage sound fiscal policies characterised by low debt levels, macro-prudential policies to limit or mitigate systematic risks as well as import substitution policies, whereby countries diversify their production and possibly export base as well. Bugnacki (2015) confirms this, prompting African countries to start exploring means of diversifying their economies by considering intra-regional trades amongst each other, investment infrastructure and entrepreneurship.

However, for a continent that is rich in commodities with a heavy reliance on them, it will take several years before the aforementioned diversification measures can really add to the GDP figures. Additionally, the development of improved institutions to effectively manage the natural resources (Frankel, 2011) can also be difficult. Hence, in the short to medium term, more emphasis should be placed on the modelling and forecasting of commodity prices. Halperin (2010) also asserts that in the meantime greater information through better forecasting is essential to the wellbeing of these countries as they work towards improved resource management.

2.7 Empirical methodologies and results

The work of Kroner *et al*. (1993) and Bowman and Husain (2004) both presented three differing alternatives to forecasting commodity prices. The former highlighted the Implied Standard Deviation (ISD) method which uses option prices to measure expectations of future volatility; time series forecasting method which involves modelling of variances and lastly a combined model method which entails combining the two aforementioned methods. The latter, posited the judgmental forecasts methods, which was based on quantitative and qualitative analysis of various factors; statistical models forecasts, which relied exclusively on historical price information and a systematic forecast approach that incorporated all available information. That being historical price data and futures prices.

Nonetheless, the literature suggests that the time series forecasting method has been established as the empirical conventional method of forecasting commodity prices as it has been employed countless times by researchers in the past. Deaton and Laroque (1992),Myers (1994), Kroner *et al*. (1993), Watkins and McAleer (2001), Kellard and Wohar (2002), Dash *et al.* (2012), Issler *et al.* (2014), Moreira (2014), Cabrales

et al. (2014)and Ohashi and Okimoto (2016) are all examples of researchers who conducted time series methods of modelling and or forecasting commodity prices (this list is however not exhaustive).

Dooley and Lenihan (2005) conducted a study on lead and zinc prices whereby two time series forecasting techniques, namely: forecasting cash prices using lagged forward prices and ARIMA forecasting of cash prices were employed. The researchers believed that exporting countries would welcome any means by which price instability and unpredictability can be minimised, and forecasting future prices is one such measure. The study established, albeit not conclusively that the ARIMA model was slightly better at forecasting the metals, given that zinc could not provide definitive evidence to suggest that one model was superior to the other, while lead could. Both models however remain useful for forecasting in the mining industry vis-à-vis planning processes.

Chkili, Hammoudeh and Nguyen (2014) modelled and forecasted the conditional volatility and market risk of crude oil, natural gas, Gold and Silver by employing four Linear GARCH models (GARCH, IGARACH, EGARCH and Risk metrics) and three nonlinear models (FIGARCH, FIAGARCH and HYGARCH). The study established that the FIAGARCH model was best suited for estimating the Value-at Risk (VAR) forecasts for both short and long trading positions. Like Chkili *et al.* (2014), Issler *et al.* (2014), also conducted a study whereby a variety of models (linear, non-linear, single equation and multivariate) were used in forecasting the prices and returns of six metal commodities. The researchers followed through with a forecast-combination approach which they found to outperform the individual model forecasts, including the random-walk model. They further concluded that the best forecasting results in terms of Root Mean Square Error (RMSE) were achieved by the average forecast (AF), bias-corrected average forecast (BCAF)

and the weighted average forecast (WAF). The forecast-combination models are also believed to achieve optimality by eliminating individual model forecast errors (Issler *et al.*, 2014).

Forecasting commodity prices is not without challenges. Commodity futures prices are often criticised for being uninformative for forecasting purposes as they tend to do no better than a random walk (Alquist & Killian, 2010). Cashin and Mcdermott (2002) also considered their forecasting difficult as they were often accompanied by large unpredictable movements that could have persistent effects. Hence, realised prices commonly deviated from forecasted prices by substantial amounts (Kroner *et al*., 1993). In addition Bowman and Husain (2004) stressed that forecasting commodity prices with reasonable accuracy is complicated by their considerable variability while Kellard and Wohar (2002) maintained that shock persistence made modelling commodity prices as stochastic trends rather challenging.

The work by various researchers therefore attempted to model commodity prices using more sophisticated models such as the various GARCH models, given their ability to capture volatility clustering and stochastic trends. The GARCH model is however not without shortcomings of its own. Non-negativity conditions may be violated, the model cannot always account for leverage effects and it tends to enforce a symmetric response of volatility to positive and negative shocks (Brookes, 2014). Watkins and McAleer (2001) also theorise that the model does not predict outlying observations very well, while Engle (2001) asserts that the ARCH/GARCH models have ignored information on the direction of the returns. To the extent that such challenges occur, the GARCH model can be extended to other GARCH family models such as the EGARCH, GJR and or the GARCH-M models where applicable.

2.8 Conclusion

There seems to be mixed findings on the behavioural characteristics of commodities. Nevertheless, with an appropriate understanding of the behaviour of commodity prices, developing markets might better be able to harness problems brought about by commodity price volatilities, behaviours and over dependence on them. The empirical evidence suggests that various researchers have adopted differing methods in an attempt to model and forecast commodity prices. Nevertheless, this paper follows through and focuses mainly on the GARCH and EGARCH models, presented in the next chapter.

Chapter 3: Data and Methodology

3.1 Introduction

This chapter aims to analyse the data to be employed in the empirical study as well as establish the econometric methodology to be utilised in exploring the dynamics of the metal price behaviours and for forecasting.

3.2 The Data

A first glance of the data is denoted in Appendix II, where the time-variations of the metal prices are plotted. We observe that the prices show a great deal of fluctuations. The effects of the 2007 – 2008 financial crises are evident in the commodities markets as is reflected by the slump in 2008. This is as a result of transmission mechanisms from one market to the next. The effects on Gold are less in comparison to the other metals, most likely due to the fact that gold is considered a safe haven especially in times of financial distress. Post 2010, the metals prices have been on a descending trajectory although still reflecting major volatilities as depicted by the seven graphs.

Next, we calculate the continuously metal price returns by taking the natural logarithms of the prices, as follows:

$$y_t = \ln\left(\frac{p_t}{p_{t-1}}\right) * 100 = \ln p_t - \ln p_{t-1} \quad (1)$$

where y_t is the log returns and p_t is commodity price at time t.

The evolution of the commodity returns is depicted in Appendix III, followed by the descriptive statistics of all seven commodities in table 10 under Appendix IV. The commodity returns portray immense clustering of volatility, hence the need for the GARCH models as they have the ability to capture volatility clustering which is a common feature of financial series (Brooks, 2014). The daily average returns of the metals range from -0.016 to 0.031, with nickel being the lowest and gold the highest respectively. Expectantly, gold reported the lowest standard deviation of 1.2234, followed by platinum with 1.4188 and then aluminium of the base metals with 1.4457. Meantime, nickel has the highest standard deviation of 2.3445. All the returns are negatively skewed and therefore large negative returns are to be observed from the series, whilst their distributions are all not normal given a coefficient of kurtosis higher than three for all the metals.

3.3 Econometric Methodology

3.3.1. Test for stationarity

Firstly, we observe the univariate characteristics of the data by testing for stationarity properties within the metal price data set. A non-stationary series would have unit root, thereby exhibiting previous values of the error term that will have non-declining effects on the current value of y_t as time progresses (Brookes, 2014). According to Brookes (2014) non-stationary data can lead to spurious regressions whereby one non-stationary time series is regressed on another non-stationary time series, with the results possibly indicating a significant relationship while there is none. Dooley & Lenihan (2005) asserted that spurious regressions have a high R^2 and t-statistics that seem significant, while in actual fact the results have no economic value.

Stationarity is most desirable in time series data analysis, and Dooley & Lenihan (2005) make reference to the necessity of conducting a test for stationarity given that the Classical Liner Regression Model (CLRM)

requires that all variables are stationary. The Augmented Dickey Fuller (ADF) test is employed accordingly, as follows:

$$\Delta y_t = \psi y_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta y_{t-1} + u_t \quad (2)$$

where α is a random walk with a drift, u_t is the error term and the test is conducted on ψ using critical values as denoted in table 11 in Appendix V. The hypothesis to determine whether the series has unit root or not is represented as:

$$\begin{array}{ll} H_0 : y_t \sim I(1) & (\text{Series is non} - \text{stationary}) \\ H_1 : y_t \sim I(0) & (\text{Series is stationary}) \end{array}$$

In the event that the metal prices are non-stationary, we conduct the ADF test again, but this time on the returns that were arrived at from equation (1) where we took log differences on the metal prices.

3.3.2. Test for Co-integration

Various studies have highlighted spill over effects within commodity markets and further emphasised their susceptibility to co-move excessively. Co-integration is a 'concept whereby time series data have a fixed relationship in the long run' (Brookes, 2014: p. 682).

A simplistic test for co-integration is the Engle-granger (1987) test. Nevertheless, this study opted for the Johansen test due to short comings with the Engle-Granger test. According to Brookes (2014) the Engle-Granger test identifies only one co-integrating relation, while there can be more than one co-integrating relationship. Also the literature further suggests that it is not possible to perform any hypothesis tests on the actual co-integrating relationship in step one of the Engel-Granger test. The test further results in variables being treated as asymmetric with one being the dependent and the other the independent variable (Brookes, 2014).

The Johansen test has therefore been established within the literature to be a more superior test for co-integration than the Engle-Granger (1987) test, as it tends to have more desirable statistical properties (Sjo, 2008). Additionally, given that we are testing the long run relationship amongst seven metals, the Johansen test seems to be more a statistically sound test for this purpose.

Having performed the unit root test on the metals prices, we establish the Johansen's test by expressing a p-dimensional Vector Error Correction Model (VECM) as follows:

$$\Delta y_t = \sum_i^{k-1} \Gamma_i \Delta y_{t-1} + \Pi y_{t-1} + \mu + u_t, \qquad t = 1, \dots, T \tag{3}$$

where Δ is the first difference operator, y_t is the set of integrated $I(1)$ variables to be tested, μ is a drift parameter and Π can be interpreted as a long-run coefficient matrix. We employ Johansen and Juselius (1990) maximum likelihood method, whereby we test whether the coefficient matrix Π contains long-run information for the variables under study (Bakhat & Wurzburg, 2013). The hypothesis of the test is given by:

$$\begin{array}{lll} H_0 : r = 0 & vs & H_1 : 0 < r \leq g \\ H_0 : r = 1 & vs & H_1 : 1 < r \leq g \\ H_0 : r = 2 & vs & H_1 : 2 < r \leq g \end{array}$$

where r is the number of co-integrating vectors under the null hypothesis. A failure to reject $H_0 : r = 0$ would conclude that there are no co-integrating vectors and the test would essentially be completed. However, should this null ($H_0 : r = 0$) be rejected, the null that there is 1, 2, 3 etc. co-integrating vectors will then be tested until the null is no longer rejected (Brookes, 2014).

In event that the variables are found to be co-integrated, we build a VECM whereby the short run and long run relationships between the metals can further be modelled simultaneously. A single equation VECM which can also be employed for multivariate equations is defined by:

$$\Delta y_t = \alpha \varepsilon_{t-1} + y\Delta x_t + u_t \quad (4)$$

where ε_t can be expressed as

$$\varepsilon_t = y_t - \beta x_t \quad (5)$$

being the error term from the regression of y_t on x_t and β the co-integrating vector (Xu, 2012).

3.3.3. Models for Forecasting

i) GARCH Model

This section follows through with the univariate GARCH model. This model was developed independently by Bollerslev (1986) and Taylor (1986)' (Brookes, 2014) and it is an enhancement of the 1982 ARCH model by Engle. In both models, variances are modelled as an Autoregressive Moving Average (ARMA) process (Kroner *et al*., 1993). The GARCH model has gained popularity over the years, given its ability to allow for the inclusion of a lagged dependent variable (Watkins and McAleer, 2001). This essentially allows for conditional variance to be dependent on its own previous lags (Brooks, 2014). Also, Du (2012) affirms that the GARCH model displays better capability of financial time series analysis in empirical studies.

The simple GARCH$(1,1)$ model will be adopted for the purpose of this study given that the literature suggests it is sufficient in capturing volatility clustering and that higher order models are rarely required (Brooks, 2014). Thus a simple GARCH$(1,1)$ model can be denoted by:

$$y_t = u + \phi y_{t-1} + u_t \qquad u_t \sim N(0, \sigma_t^2) \quad (6)$$

where σ_t^2 can be expressed as

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta \sigma_{t-1}^2 \quad (7)$$

being the conditional variance, α_0 is the regression constant; α_1 can represent the persistence of shock returns, u the long run mean return of the metal and β the persistence of volatility shocks (Dash *et al*., 2012). For the GARCH process to exist, the conditional variance must be positive, so that $\alpha_0 > 0, \alpha_1 \geq 0, \beta_1 \geq 0$. This model is considered to be parsimonious, avoids over-fitting and consequently less likely to breach the non-negativity constraints (Gujarati, 2004).

ii) EGARCH model

Next we estimate the Exponential GARCH model that was suggested by Nelson (1991) following the ARCH/GARCH models' inability to provide information on the direction of the returns (Engle, 2001). Engle (2001) further established that there is convincing evidence that the direction of the returns does affect volatility and not just the magnitude as suggested by the ARCH/GARCH models. This model also assumes that the negativity and positivity of the unanticipated excess returns does not determine the conditional variance (Rossi, 2004). According to Lama *et al*. (2015) the EGARCH model was developed to allow for the asymmetric effects between positive and negative shocks on the conditional variance of future observations. Hence, our study further adopts the EGARCH model and expresses it by specifying the logarithm of the conditional variance as follows:

$$\ln(\sigma_t^2) = \omega + \beta \ln(\sigma_{t-1}^2) + \gamma \frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \alpha \left[\frac{|u_{t-1}|}{\sqrt{\sigma_{t-1}^2}} - \sqrt{\frac{2}{\pi}} \right] \quad (8)$$

where parameters ω, β and α are not restricted to being non-negative.

Given that the expression is exponential, instead of quadratic the forecasts of the conditional variance are therefore guaranteed to be non-negative (Lama *et al*., 2015). This is an attractive feature of the EGARCH model in comparison to the GARCH model, given that the GARCH could breach the non-negativity constraints although the probablity of that occuring are very low.

3.4 Conclusion

This chapter served to provide a detailed account of the data employed in the study. We made reference to the stylised facts of the metals and analysed some of the descriptive statistics of the data, which are all presented in Appendix IV. The ADF test was then employed in establishing whether the data series has unit root or not by testing for stationarity.

Next, the chapter outlined the methodology employed in the study, with the test for co-integration among the metals being carried out first. Here, the Johansen test was outlined, followed by a single equation VECM should the metals be co-integrated. Thereafter, the chapter established the GARCH and EGARCH models that will be used in the actual modelling and forecasting of the metals. Chapter four, will next analyse the data and interpret the results accordingly.

Chapter 4: Estimation and Interpretation of the Results

4.1 Introduction

In this chapter we estimate, interpret and analyse the results from the methodology as outlined in the previous chapter. First we examine the results from the unit root test, followed by an analyses of the results from the Johansen Test for co-integration and then finally an estimation and interpretation of the results from both the GARCH and EGARCH models.

4.2 Test for stationarity results

The results for stationarity as per equation (2) are presented below. First the ADF test results for the metals prices are summarised in table 1 below and we make reference to table 11 in Appendix V denoting the DF critical values.

Table 1: Metal Price Stationarity Results

Variable	Coefficient	T-Statistic	ADF Critical Value at 5%
Aluminum	-0.003	-1.978	-2.86
Copper	-0.003	-2.069	-2.86
Gold	-0.001	-1.614	-2.86
Lead	-0.003	-2.335	-2.86
Nickel	-0.002	-1.351	-2.86
Platinum	-0.002	-1.981	-2.86
Zinc	-0.003	-2.206	-2.86

The t-statistic of all the metal prices is greater than the ADF critical values at the 5 percent level of significance. We therefore fail to reject the null hypothesis, thereby concluding that all metals price series are non-stationary.

Having taken log differences on the metal price series, the ADF test results on the metals returns reveals that they are all stationary, given that their t-statistic is less than the ADF critical values, as denoted in the table below. We therefore, reject the null hypothesis at the 5 percent level of significance, indicating that all the return series contain no unit roots.

Table 2: Metal Return Stationarity Results

Variable	Coefficient	T-Statistic	ADF Critical Value at 5%
Aluminum	-1.052	-55.648	-2.86
Copper	-1.082	-57.278	-2.86
Gold	-1.008	-53.263	-2.86
Lead	-0.940	-49.942	-2.86
Nickel	-1.002	-53.302	-2.86
Platinum	-0.931	-49.194	-2.86
Zinc	-1.027	-54.110	-2.86

4.3 Johansen Test Results

Having ensured that all metals are non-stationary on levels, a Johansen test for co-integration is then carried out and an extract of the test results are presented in table 3 on the next page.

An examination of the Trace statistic depicts that the t-statistic exceeds the critical values under the first two hypothesised number of co-integrating equations and those p-values are also lower than 5 percent. We therefore, reject the null at the 5 percent level of significance. Essentially, the null that there is no co-integrating vectors and that there is at most 1 co-integrating vectors is rejected. From at most 2 to 6 co-

integrating equations, the Trace statistic is lower than the critical values and the p-values are all greater than 5 percent and we therefore fail to reject the null of no co-integrating equations or vectors amongst the variables. Thus the Trace test indicates 2 co-integrating equations at the 5 percent level of significance.

Table 3: Johansen Test Results

Test	Unrestricted Co-integration Rank (Trace)			Unrestricted Co-integration Rank (Maximum Eigenvalue)		
Hypothesised nr of CE(s)	T-Statistic	Critical Value	P-Value	T-Statistic	Critical Value	P-Value
None *	727.2447*	125.6154	0.0001	626.747*	46.23142	0.0001
At most 1 *	100.4977*	95.75366	0.0226	35.83951	40.07757	0.1391
At most 2	64.65819	69.81889	0.1205	26.66978	33.87687	0.2814
At most 3	37.98841	47.85613	0.3025	21.98100	27.58434	0.2213
At most 4	16.00741	29.79707	0.7117	12.60417	21.13162	0.4893
At most 5	3.403241	15.49471	0.9456	2.120351	14.26460	0.9877
At most 6	1.282890	3.841466	0.2574	1.282890	3.841466	0.2574

The Maximum Eigenvalue test, depicts that the Max-Eigen Statistic exceeds the critical value under the first hypothesised number of co-integrating equations and that p-value is also less than 5 percent. We therefore reject the null that there is no co-integrating vectors at the 5 percent level of significance. However from at most 1 to 6 co-integrating equations, the Maximum Eigen statistics is lower than the critical values and the p-values are all greater than 5 percent and we therefore fail to reject the null of no co-integrating equations or vectors amongst the variables. The Max-eigenvalue test indicates that there is 1 co-integrating equation at the 5 percent level of significance. Given the Trace test and the Maximum Eigenvalue test results, the overall Johansen test result therefore indicates that the metals are co-integrated and that there is a long run association amongst them.

Having established this co-integration and long run association amongst the metals, their relationship is further modelled by way of a VECM. The Trace test established that there are 2 co-integrating equations, while the Maximum Eigenvalue test only established 1 co-integrating equation. This study therefore proceeds with an unrestricted VECM using 1 co-integrating equation. This model is normalised on gold and all the estimation results from the VECM are presented in Appendix VI. Table 12 under that Appendix presents the output results from the VECM and we observe that the coefficients of the error correction term of Aluminium, Copper, Lead, Nickel and Platinum are all significant. They will thus, have significant effects in bringing the model back to equilibrium should the variables diverge too much from each other. The coefficients of the co-integrating vector β can be presented as follows:

$$Gold = -74.60528\,\text{Aluminium}_t - 53.72054\text{Copper}_t + 13.29225\text{Lead}_t - 0.295895\text{Nickel}_t + 279.2473\text{Platinum}_t + 88.29025\text{Zinc}_t - 70658.68$$

Table 13 under Appendix VI depicts the short run and long run causality model of the metals. First, we analyse the long run causality effects amongst the metals. The coefficient of the co-integrated model (C1), essentially the speed of adjustment towards the long run equilibrium is positive and insignificant. Thus, there is no long run causality from all the metals towards gold. Next, the Wald test is employed to determine the short run causality and joint significance of the metals. A summary of the test results are presented in table 14 of the same Appendix. The results indicate a short run causality between the two precious metals, and no short run causality from all the base metals to Gold, except for copper. This was arrived at given that the probability of the Chi-square test statistic of all the metals was greater than 5 percent, except for Copper and Platinum.

Lastly, figure 3 of Appendix VI shows extracts of the residual diagnostics tests for the VECM. The model is free from serial correlation amongst its residuals. Thus, the VECM presented in this study is satisfactory and it can be accepted, even though the residuals of the error term are not normally distributed.

4.4 Models for forecasting

i) GARCH Model

The GARCH$(1,1)$ models for the seven metals yielded results as depicted below.

Table 4: GARCH$(1,1)$ *Model Results*

	Aluminium	Copper	Gold	Lead	Nickel	Platinum	Zinc
u	-0.000461	0.018541	0.029968	0.012624	-0.00134	0.018218	0.028439
α_0	0.019384	0.022663	0.018239	0.006445	0.055412	0.027278	0.005116
α_1	0.950486	0.931836	0.935029	0.968355	0.933289	0.904977	0.968613
β	0.039951	0.061660	0.052785	0.030582	0.056684	0.081923	0.030687
$\alpha_1 + \beta$	0.990437	0.993496	0.987814	0.965611	0.989973	0.986900	0.999300
p-values	0.9839	0.4832	0.1059	0.6609	0.9699	0.3711	0.3011

The long run mean return of all the metals is positive, except for Aluminium and Nickel. Interestingly, those two metals did not record the highest volatility, as generally the expectation is that metals with the highest volatility would have lowest long run mean return. Platinum recorded the highest volatility. The persistence of returns shocks and persistence of volatility are significant factors in determining the commodities' returns given that their p-values is less than 5 percent for all the metals. The volatility reported is well below 10 percent for the all metals. $\alpha_1 + \beta$ is close to unity for all the metals, therefore implying that shocks to the conditional variance will be highly persistent (Brooks, 2014) and the metals' returns volatility are significantly responsive to shocks. Overall the GARCH results from the seven metals are all statistically insignificant given p-values of greater than 5 percent.

The residual diagnostics outcome of the seven GARCH models are summarised in table 5 on page 45. Aluminium, Copper and Zinc GARCH models all had no serial correlation amongst their residuals and those models also did not have any ARCH effect within their residuals. All the other metals reported serial correlation and ARCH effect within their models, whilst the Jarque-Bera test revealed that the residuals of all seven models were not normally distributed.

Table 5: GARCH$(1,1)$ *Model Diagnostic Results*

Commodity	**Serial Correlation** No, P-value >5%	**ARCH Effect** No, P-value >5%	**Normality Test** Yes, P-value >5%
Aluminum	No	No	No
Copper	No	No	No
Gold	Yes	Yes	No
Lead	Yes	Yes	No
Nickel	Yes	Yes	No
Platinum	Yes	Yes	No
Zinc	No	No	No

ii) EGARCH Model

Next the results for the EGARCH$(1,1)$ models for the seven metals are presented in the table 6 below.

Table 6: EGARCH$(1,1)$ *Model Results*

	Aluminium	Copper	Gold	Lead	Nickel	Platinum	Zinc
u	0.006531	0.007611	0.034757	0.026719	-0.015964	0.019373	0.026195
ω	-0.056014	-0.092303	-0.088956	-0.054878	-0.062628	-0.122108	-0.056027
α	0.080163	0.136299	0.127354	0.07632	0.101169	0.170422	0.078293
β	0.003236	-0.042915	-0.003599	-0.003343	-0.002650	0.002341	-0.006996
γ	0.991709	0.989247	0.984437	0.997322	0.991016	0.984945	0.997050
p-values	0.7755	0.7622	0.0599	0.3729	0.6643	0.3261	0.3587

Nickel is the only metal that reported negative long run mean returns. The persistence of the volatility of all the metals except for Aluminium is significant and negative, thus indicating that there is negative correlation between the past return and future volatility of the returns. The constant variance that corresponds to the long-run average, persistence of shock returns and the standard normal variable are all significant factors in determining the commodities' returns given that their p-values are all less than 5 percent for all the metals. As with the GARCH model, the EGARCH results from the seven metals also provide statistically insignificant results given p-values of greater than 5 percent.

Table 7: EGARCH$(1,1)$ *Model Diagnostics Results*

	Serial Correlation No, P-value >5%	**ARCH Effect** No, P-value >5%	**Normality Test** Yes, P-value >5%
Aluminum	No	No	No
Copper	No	No	No
Gold	Yes	Yes	No
Lead	Yes	Yes	No
Nickel	Yes	Yes	No
Platinum	Yes	Yes	No
Zinc	No	No	No

The residual diagnostics outcome of the seven EGARCH models are summarised in the table 7 above. As with the residual diagnostics tests of the GARCH models, Aluminium, Copper and Zinc EGARCH models also all had no serial correlation amongst their residuals as well as no ARCH effect within their residuals. All the other metals reported serial correlation and ARCH effect within their models, whilst the Jarque-Bera test also revealed that the residuals of all seven models were not normally distributed as was the case with the GARCH model.

iii) GARCH and EGARCH Forecasting

The data set has a total of 2954 observations per metal series, and the last 1128 are utilised as our holdout sample, thus making our out of sample forecast period being from 1st April 2012 to 29 April 2016. A one-step ahead forecast of the volatility is employed, and all forecast graphs for both the univariate GARCH and EGARCH models are given in Appendices VII and VIII. The forecasting ability of both models is determined on the basis of the Root Mean Square Error (RMSE) and the Mean Absolute Error (MAE). The RMSE is considered the most popular measure of forecast accuracy. Overall, the smaller the forecasting errors, the less the forecasted results deviate from the actuals and the more accurate the forecasting models are. The forecasting results are denoted in table 8 below.

Table 8: Forecasting Results

	GARCH$(1,1)$		**EGARCH**$(1,1)$	
Commodity	**RMSE**	**MAE**	**RMSE**	**MAE**
Aluminium	1.089051	0.850260	1.089392	0.851266
Copper	1.201706	0.879803	1.194741	0.869889
Gold	1.029546	0.718394	1.032779	0.723212
Lead	1.318279	1.016207	1.320092	1.018141
Nickel	1.688044	1.267959	1.688139	1.268110
Platinum	1.166618	0.895050	1.166528	0.894944
Zinc	1.286313	0.967197	1.285894	0.966554

The EGARCH models for Copper, Platinum and Zinc reported lower RMSE and MAE than the GARCH models for the same metals. These empirical results therefore conform to theory that the EGARCH model tends to be a superior model than the GARCH model in capturing asymmetric volatility. Interestingly, for

all the other metals (Aluminium, Gold, Lead and Nickel) the GARCH model outperformed the EGARCH model in terms of RMSE and MAE.

All the models reported a Thiel's Inequality Coefficient of less than one, indicating that the models estimated are superior to the benchmarks, whilst the bias proportion of all the models is very small, negligible in fact, thereby meaning that the forecasts are free from bias.

4.5 Conclusion

In this chapter we established that all the metals' price series have unit root, whereas the ADF test on the metals' returns revealed that the series were all stationary. The Johansen test demonstrated co-integration amongst the metals and that there is a long run relationship amongst them. Hence, the study further followed thru with building a VECM so as to model the joint relationship amongst the metals. This model revealed that there is no long run causality amongst the metals. Interestingly, Copper and Platinum revealed short run causality towards Gold, while all the other metals indicated no short run causality towards Gold.

Next the GARCH and EGARCH models were estimated and their results interpreted accordingly. The dynamics of commodity returns volatility have been established to be highly responsive to shocks. Of importance, was the forecasting results that seemed rather incongruous. Three of the metals demonstrated results that support theory that EGARCH model is superior to the GARCH model, while the other four did not. Nonetheless, the forecasts themselves can be considered adequate given that the RMSE and MAE were very low and not to mention close to negligible bias proportion.

The next chapter will summarise the key findings and provide overall concluding remarks.

Chapter 5: Conclusion

5.1 Introduction

The paper put forth an extensive background to metals exported by developing African countries. The importance of the metals to these countries and their economies cannot be stressed enough. The study further delved into the behavioural characteristics of the metals, and from that deduced that amongst others, metal price volatility tends to have significant effects on metal prices. Consequently affecting macroeconomic variables such as the GDP of these countries and their overall economic development, given their over-reliance on primary commodities. The literature suggests that attempts to predict commodity price behaviours by modelling and forecasting them aimed to address problems brought about by commodity price volatility. This paper followed through the same, by making use of the GARCH models in modelling and forecasting commodities.

The concluding remarks regarding the literature review; data and methodology; the estimation and interpretation of the results and the extents to which our findings conform to previous literature, as well as the overall concluding remarks are presented in this chapter.

5.2 Literature Review

The literature is vast and widespread on commodities, however to a much lesser degree on metals, especially in the context of developing African economies. Adequate reference has however been made to studies covering commodities other than metals only, as well as in regions other than developing Africa. We satisfy ourselves that the literature reviewed in this paper was sufficient in assisting with the

understanding of metals price behaviour. The various studies employed differing methodologies in studying commodity behaviour and forecasting them. The findings were mixed. Albeit, consensus seems to be that commodities are highly volatile and unpredictable. This paper is a contribution to the literature on metals, particularly in the context of developing African economies that is currently very limited.

5.3 Data and Methodology

The stylised facts of the data were analysed and the clustered volatility of the series became more evident upon taking the log differences of the metal prices. The metals' return series were then found to be stationary, which was not the case with the metals' price series. The ADF test was employed in establishing this. Next, the Johansen test was employed, and the presence of co-integration amongst the variables warranted the use of Error Correction modelling. We successfully established seven separate GARCH and EGARCH models for each of the metals, in order to establish the behavioural characteristics of the metals and forecast them. Thereby, establishing the extent to which the different GARCH models can accurately model and forecast metal volatility. The paper has fared adequately well in addressing that.

5.4 Estimation and Interpretation of the Results

The results from the Johansen test conform to the vast theory that there is excess co-movement and spill over effects in commodity markets. The metals were found to be co-integrated and to have a long run relationship. This agrees to the findings by Pindyck & Okimoto (1990), Myers (1994), Ohashi & Okimoto (2016) and Cabrales *et al*. (2014). This further prompted the formulation of a VECM, whereby the long run and short run causality effects amongst the metals were further investigated. The results were mixed, albeit most revealing that there is no long run and short run causality amongst the metals, with the exception of platinum and copper in the short run. The lack of long run and short run causality effects

amongst the metals would seem plausible, as the price of Gold is not necessarily dependent on or caused by the other metals. However, the VECM merely served to model and investigate the extent of the short run and long run relationships amongst the metals simultaneously.

It is worth noting that this study considers the co-integrating relationship from the Johansen test to be positive. The graphs in Appendix II reflects the time variations of the metal prices and from them it is apparent that booms and slumps tend to occur at similar points in time for the seven metals, albeit at differing degrees. Also, we deduce that our study, just as those of Cashin and Mcdermott (2002) and Cuddington *et al.* (2002) cannot confirm unequivocally the Prebisch-Singer hypothesis of 1950 that prices of primary commodities decreases over time. However, we can conclude that metal prices are in fact cyclical and related to economic activities and cycles.

The findings from the GARCH and EGARCH models seem sufficient in capturing the volatility clustering of the metals. From both models, we establish that the persistence of returns shocks, the persistence of volatility, the constant variance that corresponds to the long-run average and the standard normal variance are all significant factors in determining the metals' returns. We establish that there is negative correlation between the past return and future volatility of the returns in six of the seven metals under the EGARCH Model. This model is considered superior to the GARCH model, because of its ability to capture asymmetric volatility. However, our findings can only confirm the superiority of the EGARCH to the GARCH model in three of the metals, namely Copper, Platinum and Zinc. The other four do not conform to theory. Nonetheless, we are confident that the forecasting models can sufficiently be employed by economic agents in developing countries to model and forecast their commodities and thereby help with decision making. The incredibly low RMSE and MAE of both models for all the metals,

the negligible bias proportion and the reported Theil's Inequality Coefficient, indicate good fitted forecast models.

5.5 Overall Conclusions

Economic agents in developing countries can deduce a lot from the behavioural characteristics of the metals established in this paper. An increase or decrease in the price of one metal, be it due to favourable or unfavourable market conditions in that specific metal market can be an indication that spill over effects are bound to occur. This is due to the co-integrating and long run relationships established amongst the metals. Economic agents can then alter their policies accordingly. This study also resolved that commodity prices are cyclical and related to economic activities and cycles. Therefore major changes in economic activities or cycles should be an indication to review current policies and trading strategies. For example, increased investor confidence in US markets will result in a strengthening USD and this can be considered as an opportunity to expand exports given that metal prices are priced in USD.

Furthermore, the forecasting of metals, can assist in predicting future values that the metal prices are expected to take. That said, economic agents can then either restrict or expand metal exports in the anticipation of the expected commodity prices, and thereby being a means of realising the true benefits and value from their commodities, resultantly, increasing the countries' GDP. For example an upward trend in metal prices can be an indication for the exporters to restrict production and exports now and sell them in the future at higher prices. However, we are cognisant of the fact that commodity prices cannot be modelled and forecasted in isolation. For true value to be derived from the forecasting decisions, it would be worth also modelling and forecasting the related currency, the USD in particular.

The GARCH family models have been hailed throughout the literature as superior modelling and forecasting models for time series data, and our study served to establish the extent to which they can accurately model and forecast commodity prices. The predictions results yielded were also satisfactory. Thus, we are confident that the research questions stated in this paper have been well addressed and resolve that developing economies can make use of GARCH family models to model and forecast metal prices. Therefrom deriving appropriate policies, be it macro-economic or fiscal policies as well as trading strategies, so as to capitalise on export revenues, resulting in increased GDP and overall economic growth and development in their countries.

Some limitations are worth considering for this paper. Firstly, time was a constraint and it limited the scope and depth of this research. The period covered, January 2005 to April 2016 includes the aftermath of the global financial crisis, which resulted in what some researchers have termed “unusual” volatility and this may have affected the results of this study. Also, the sample size selected is very small, only seven metals and the study only made use of the GARCH and EGARCH models. Additionally, the metals were modelled and forecasted alone without considering other variables such as related currencies. There was no specification of an economic fundamental that drives metal commodity prices as well. Therefore, there is vast scope to extend this study in terms of the period to be covered, the number of commodities to be included; the addition and specification of other economic variables such as a related currency, as well as the application of other GARCH family models.

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Appendix I: Metals exported by African countries

Table 9: Metals exported by African countries

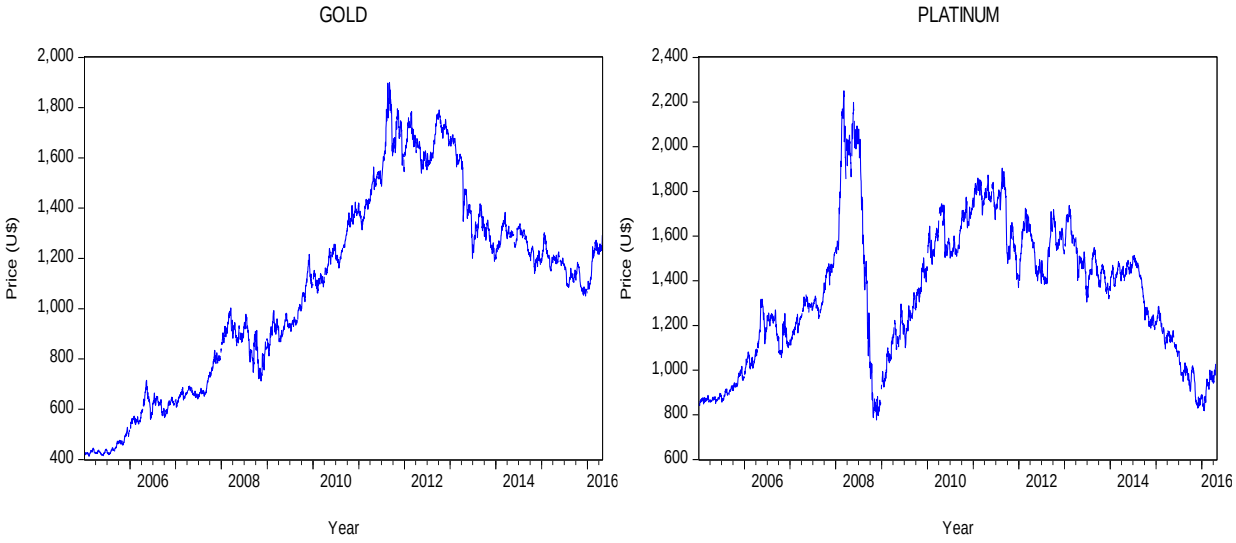
Metal Exports by African Countries

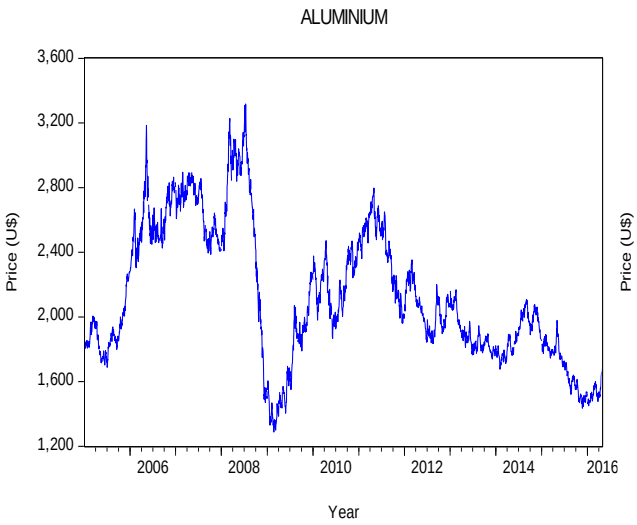
Metal	Country	Metal	Country
Gold	Burkina Faso Chad Cameroon Congo Ivory Coast Ghana Guinea Liberia Mali Mauritania Niger Senegal South Africa Sudan Tanzania Zimbabwe Ethiopia Namibia	**Platinium**	South Africa Zimbabwe
		Copper	Zambia Congo Mauritania Uganda Botswana Namibia South Africa
		Aluminim	Cameroon Ghana Mozambique
		Lead	Namibia South Africa
		Zinc	Burkina Faso Congo Namibia South Africa
		Nickel	Botswana Zimbabwe

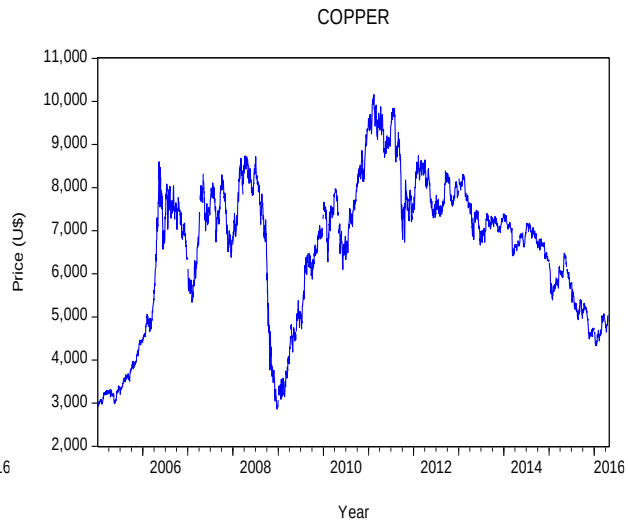
Source, author with information from Trading Economics & US Geological Survey Mineral Resources Program

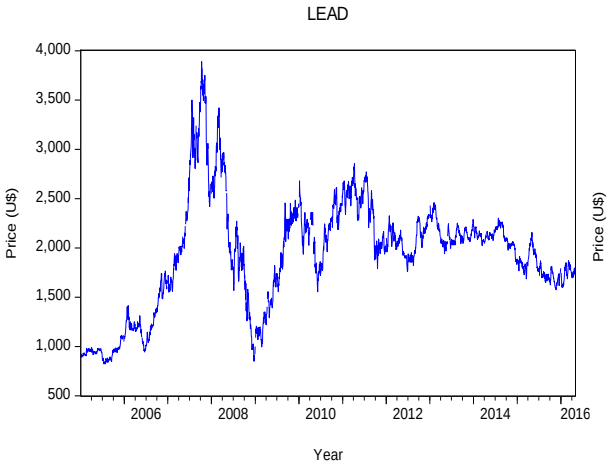
Appendix II: Historical prices of the metals

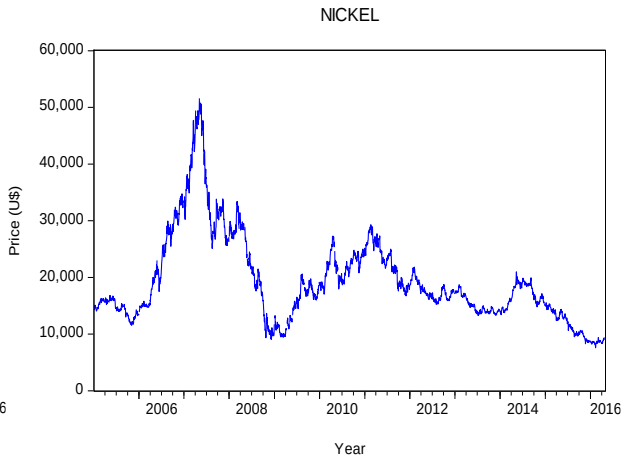
Figure 1: Graphs depicting metal historical prices

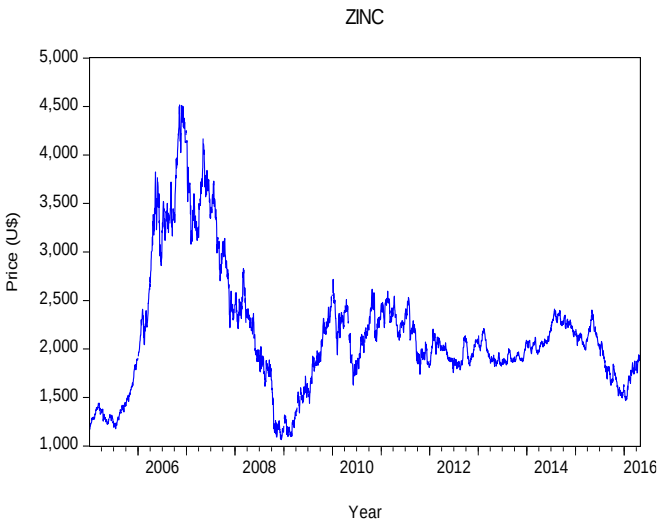



ALUMINIUM
Price (U$)
3,600
3,200
2,800
2,400
2,000
1,600
1,200
2006
2008
2010
2012
2014
2016
Year


COPPER
Price (U$)
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
2006
2008
2010
2012
2014
2016
Year

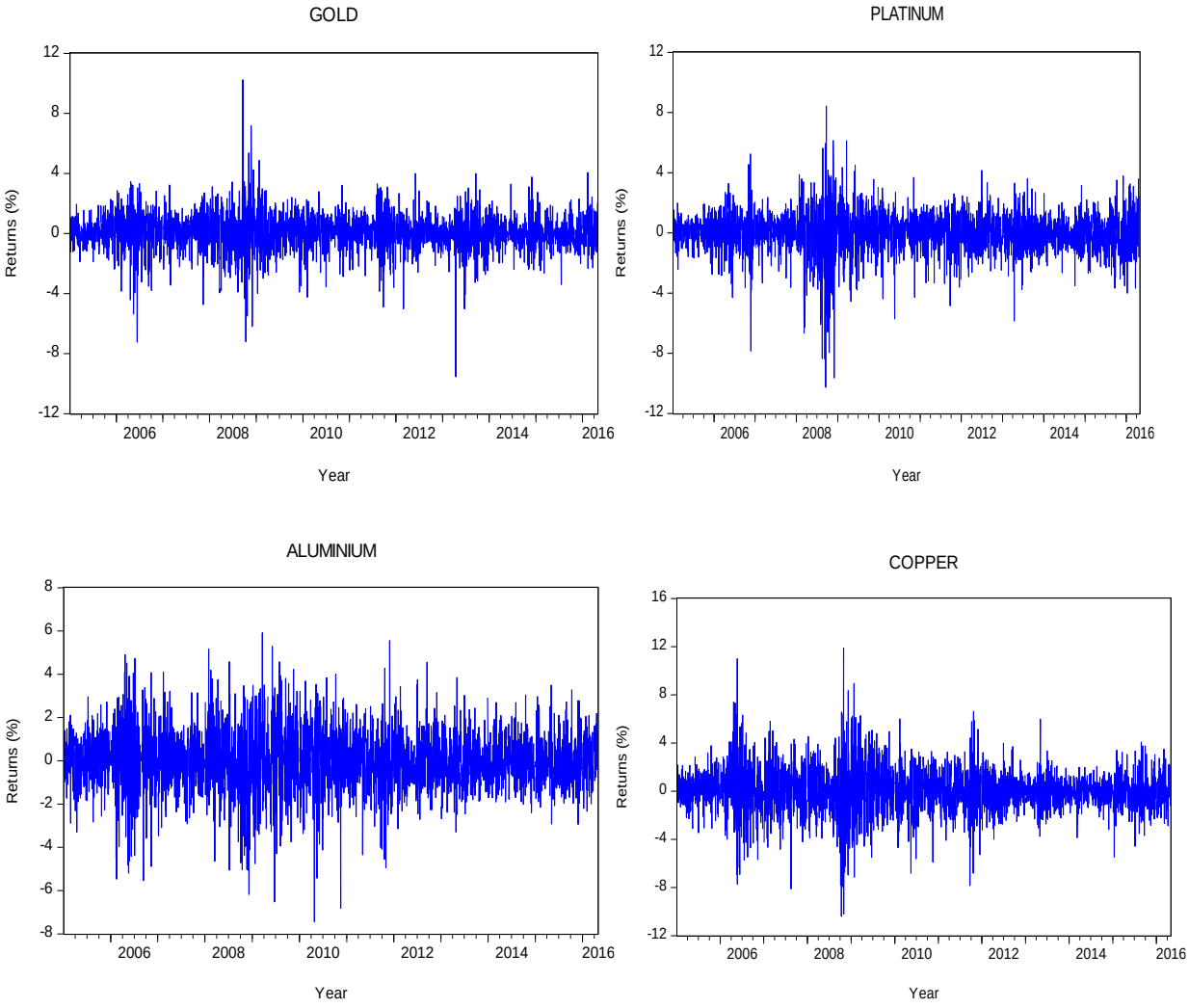

LEAD
Price (U$)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
2006
2008
2010
2012
2014
2016
Year

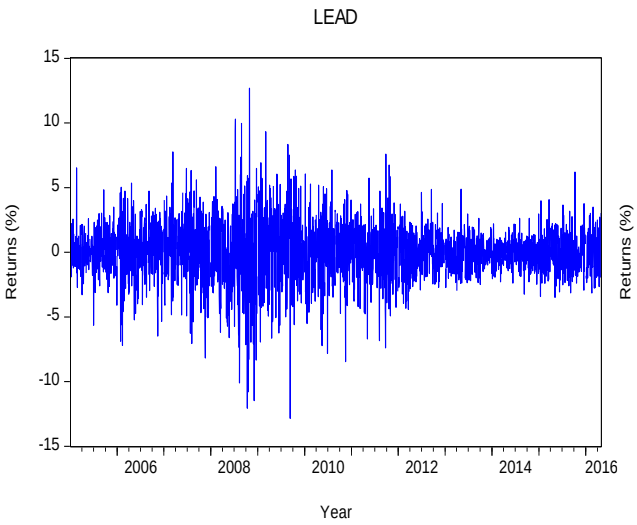

NICKEL
Price (U$)
60,000
50,000
40,000
30,000
20,000
10,000
0
2006
2008
2010
2012
2014
2016
Year

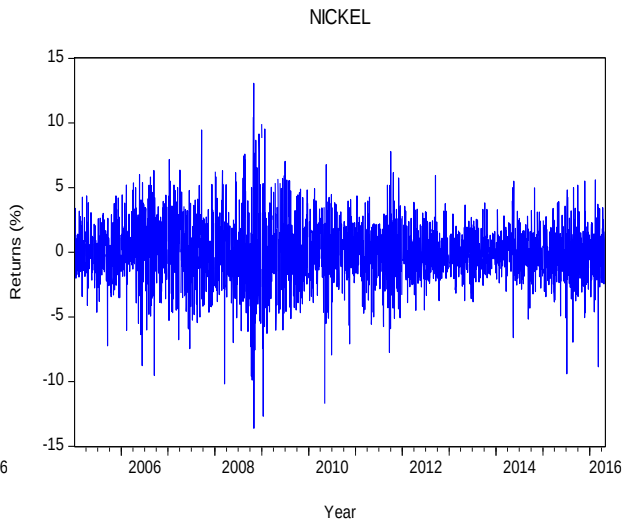

ZINC
Price (U$)
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
2006
2008
2010
2012
2014
2016
Year

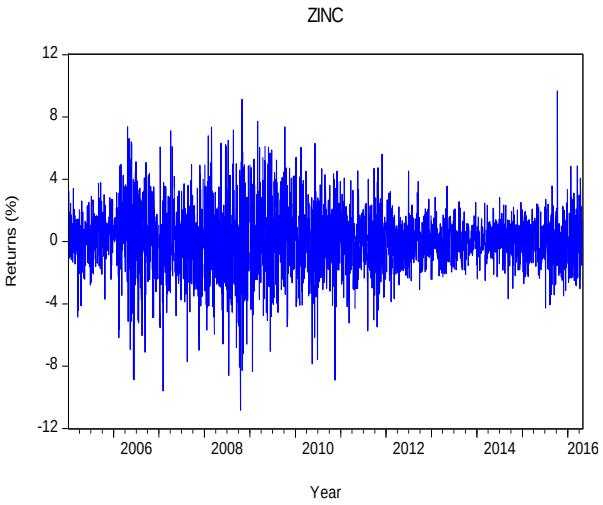
Appendix III: Historical returns of the metals

Figure 2: Graphs depicting metal historical returns




LEAD
Returns (%)
15
10
5
0
-5
-10
-15
2006
2008
2010
2012
2014
2016
Year


NICKEL
Returns (%)
15
10
5
0
-5
-10
-15
2006
2008
2010
2012
2014
2016
Year


ZINC
Returns (%)
12
8
4
0
-4
-8
-12
2006
2008
2010
2012
2014
2016
Year

Appendix IV: Descriptive Statistics

Table 10: Descriptive Statistics

	ALUMINIUM	COPPER	GOLD	LEAD	NICKEL	PLATINUM	ZINC
Mean	-0.001235	0.016658	0.030946	0.013945	-0.015801	-0.002489	0.015233
Median	0.000000	0.000000	0.049815	0.022576	0.000000	0.056964	0.000000
Maximum	5.913052	11.88048	10.24258	12.67517	13.06031	8.426472	9.656369
Minimum	-7.437372	-10.40026	-9.548214	-12.84951	-13.60482	-10.25854	-10.83222
Std. Dev.	1.445670	1.854415	1.223401	2.199861	2.344526	1.418754	2.084668
Skewness	-0.161236	-0.041808	-0.376267	-0.208795	-0.090393	-0.674970	-0.149173
Kurtosis	4.536751	6.681516	8.712715	5.983046	5.559539	8.207225	5.050484
Jarque-Bera	291.6590	1604.101	3927.451	1073.253	778.8232	3423.068	507.8846
Sum	-3.505321	47.29306	87.85671	39.59011	-44.86001	-7.064876	43.24767
Sum Sq. Dev.	5931.310	9759.470	4247.664	13734.18	15599.93	5712.504	12333.49
Observations	2839	2839	2839	2839	2839	2839	2839

Appendix V: Critical Values for DF Tests

Table 11: Critical Values for DF tests (Fuller, 1976)

Significance Level	**10%**	**5%**	**1%**
CV for Constant but no trend	-2.57	-2.86	-3.43
CV for Constant and trend	-3.12	-3.41	-3.96

Source: Brookes 2014, p 362.

Appendix VI: VECM Estimation Results

Table 12: VECM Output

Vector Error Correction Estimates
Sample (adjusted): 1/07/2005 4/29/2016
Included observations: 2733 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
GOLD_SPOT(-1)	1.000000
ALUMINIUM(-1)	74.60528 (21.9991) [3.39129]
COPPER(-1)	53.72054 (8.45488) [6.35379]
LEAD(-1)	-13.29225 (13.6466) [-0.97403]
NICKEL(-1)	0.295895 (1.33484) [0.22167]
PLATINUM_SPOT(-1)	-279.2473 (43.2383) [-6.45834]
ZINC(-1)	-88.29025 (16.5260) [-5.34250]
C	70658.68

Error Correction:	D(GOLD_SPOT)	D(ALUMINIUM)	D(COPPER)	D(LEAD)	D(NICKEL)	D(PLATINUM_SPOT)	D(ZINC)
CointEq1	7.85E-06 (7.4E-06) [1.06337]	-5.97E-05 (1.7E-05) [-3.46129]	-0.000172 (6.4E-05) [-2.68037]	-7.95E-07 (2.4E-05) [-0.03352]	-0.000362 (0.00027) [-1.34996]	-1.10E-05 (1.0E-05) [-1.05807]	3.81E-05 (2.6E-05) [1.44835]
D(GOLD_SPOT(-1))	-0.021365 (0.02472) [-0.86417]	0.086931 (0.05776) [1.50500]	0.159638 (0.21471) [0.74351]	0.038248 (0.07939) [0.48176]	0.495976 (0.89728) [0.55275]	-0.064896 (0.03495) [-1.85706]	0.101287 (0.08812) [1.14940]
D(GOLD_SPOT(-2))	0.013104 (0.02463) [0.53212]	0.063801 (0.05753) [1.10893]	0.195431 (0.21387) [0.91380]	0.164923 (0.07908) [2.08554]	1.651532 (0.89375) [1.84786]	0.036110 (0.03481) [1.03739]	0.086024 (0.08777) [0.98005]
D(ALUMINIUM(-1))	-0.013291 (0.01245) [-1.06771]	-0.038910 (0.02908) [-1.33791]	-0.450347 (0.10811) [-4.16581]	-0.108617 (0.03997) [-2.71724]	-1.206169 (0.45178) [-2.66983]	-0.013495 (0.01760) [-0.76695]	-0.112739 (0.04437) [-2.54096]

D(ALUMINIUM(-2))	0.004328	-0.007736	0.203596	0.019560	0.999329	-0.014946	0.051168
	(0.01241)	(0.02900)	(0.10781)	(0.03986)	(0.45053)	(0.01755)	(0.04425)
	[0.34863]	[-0.26674]	[1.88852]	[0.49069]	[2.21813]	[-0.85179]	[1.15645]
D(COPPER(-1))	-0.000111	-0.013195	-0.018279	-0.004243	-0.042803	0.001423	-0.017817
	(0.00387)	(0.00903)	(0.03357)	(0.01241)	(0.14029)	(0.00546)	(0.01378)
	[-0.02875]	[-1.46115]	[-0.54451]	[-0.34183]	[-0.30511]	[0.26039]	[-1.29318]
D(COPPER(-2))	2.10E-05	-0.009519	-0.043466	-0.004383	0.105340	0.001350	-0.021808
	(0.00382)	(0.00893)	(0.03321)	(0.01228)	(0.13878)	(0.00541)	(0.01363)
	[0.00549]	[-1.06544]	[-1.30883]	[-0.35690]	[0.75902]	[0.24979]	[-1.60004]
D(LEAD(-1))	-0.000327	-0.004177	0.069804	0.123385	-0.539754	0.005167	0.022001
	(0.00820)	(0.01915)	(0.07119)	(0.02632)	(0.29750)	(0.01159)	(0.02922)
	[-0.03990]	[-0.21811]	[0.98056]	[4.68740]	[-1.81430]	[0.44593]	[0.75302]
D(LEAD(-2))	0.000444	0.016319	0.016100	0.006974	0.139151	0.015554	0.066002
	(0.00817)	(0.01909)	(0.07096)	(0.02624)	(0.29655)	(0.01155)	(0.02912)
	[0.05435]	[0.85483]	[0.22687]	[0.26580]	[0.46922]	[1.34667]	[2.26621]
D(NICKEL(-1))	-0.000108	0.001400	-0.002637	-0.002189	0.079231	0.000992	-0.000718
	(0.00067)	(0.00157)	(0.00582)	(0.00215)	(0.02434)	(0.00095)	(0.00239)
	[-0.16035]	[0.89362]	[-0.45282]	[-1.01663]	[3.25548]	[1.04698]	[-0.30022]
D(NICKEL(-2))	0.000470	-0.002755	-0.003929	-0.000506	-0.084338	-0.000850	-0.002465
	(0.00066)	(0.00155)	(0.00575)	(0.00213)	(0.02403)	(0.00094)	(0.00236)
	[0.70977]	[-1.78150]	[-0.68341]	[-0.23800]	[-3.51015]	[-0.90798]	[-1.04450]
D(PLATINUM_SPOT(-1))	0.036644	0.060295	0.135582	0.092581	0.608943	0.126364	0.003865
	(0.01886)	(0.04405)	(0.16375)	(0.06055)	(0.68434)	(0.02665)	(0.06721)
	[1.94338]	[1.36868]	[0.82796]	[1.52898]	[0.88983]	[4.74119]	[0.05750]
D(PLATINUM_SPOT(-2))	-0.033726	0.049986	0.074114	-0.087179	-1.234618	-0.043937	0.044310
	(0.01880)	(0.04393)	(0.16331)	(0.06038)	(0.68247)	(0.02658)	(0.06702)
	[-1.79356]	[1.13778]	[0.45383]	[-1.44373]	[-1.80905]	[-1.65304]	[0.66110]
D(ZINC(-1))	-0.002686	-0.029084	0.008867	-0.009503	0.128527	-0.008116	0.060513
	(0.00885)	(0.02069)	(0.07690)	(0.02843)	(0.32137)	(0.01252)	(0.03156)
	[-0.30333]	[-1.40586]	[0.11530]	[-0.33420]	[0.39994]	[-0.64846]	[1.91730]
D(ZINC(-2))	-0.004496	0.017324	-0.045750	-0.013082	-0.494129	-0.001352	-0.045425
	(0.00892)	(0.02083)	(0.07743)	(0.02863)	(0.32357)	(0.01260)	(0.03178)
	[-0.50432]	[0.83171]	[-0.59087]	[-0.45692]	[-1.52710]	[-0.10729]	[-1.42944]
C	0.210332	0.029468	0.956423	0.090711	-0.192870	-0.069306	0.191484
	(0.26124)	(0.61035)	(2.26880)	(0.83892)	(9.48141)	(0.36927)	(0.93116)
	[0.80512]	[0.04828]	[0.42155]	[0.10813]	[-0.02034]	[-0.18769]	[0.20564]
R-squared	0.004029	0.019684	0.018914	0.014088	0.016435	0.013742	0.010513
Adj. R-squared	-0.001470	0.014272	0.013497	0.008645	0.011005	0.008297	0.005051
Sum sq. resids	506183.8	2762999.	38177997	5219856.	6.67E+08	1011344.	6430896.
S.E. equation	13.64927	31.88934	118.5391	43.83131	495.3798	19.29321	48.65090
F-statistic	0.732700	3.636995	3.491968	2.588351	3.026681	2.523825	1.924572
Log likelihood	-11013.14	-13332.32	-16920.68	-14201.63	-20829.09	-11958.94	-14486.74
Akaike AIC	8.071086	9.768258	12.39420	10.40441	15.25436	8.763221	10.61306
Schwarz SC	8.105704	9.802876	12.42882	10.43903	15.28898	8.797839	10.64767
Mean dependent	0.210033	0.058178	1.054153	0.141603	0.590926	-0.078653	0.234175

S.D. dependent	13.63925	32.11936	119.3473	44.02201	498.1283	19.37375	48.77423

Determinant resid covariance (dof adj.)	3.39E+22
Determinant resid covariance	3.25E+22
Log likelihood	-97980.52
Akaike information criterion	71.78889
Schwarz criterion	72.04636

Table 13: Short Run and Long Run Causality Model

Dependent Variable: D(GOLD_SPOT)
Method: Least Squares
Date: 03/25/17 Time: 23:13
Sample (adjusted): 1/07/2005 4/29/2016
Included observations: 2733 after adjustments
D(GOLD_SPOT) = C(1)*(GOLD_SPOT(-1) + 74.605283169*ALUMINIUM(-1) + 53.7205426875*COPPER(-1) - 13.2922489241*LEAD(-1) + 0.295894902145*NICKEL(-1) - 279.2472745*PLATINUM_SPOT(-1) - 88.2902482989*ZINC(-1) + 70658.6847218) + C(2)*D(GOLD_SPOT(-1)) + C(3)*D(GOLD_SPOT(-2)) + C(4)*D(ALUMINIUM(-1)) + C(5) *D(ALUMINIUM(-2)) + C(6)*D(COPPER(-1)) + C(7)*D(COPPER(-2)) + C(8)*D(LEAD(-1)) + C(9)*D(LEAD(-2)) + C(10)*D(NICKEL(-1)) + C(11) *D(NICKEL(-2)) + C(12)*D(PLATINUM_SPOT(-1)) + C(13) *D(PLATINUM_SPOT(-2)) + C(14)*D(ZINC(-1)) + C(15)*D(ZINC(-2)) + C(16)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	7.85E-06	7.39E-06	1.063366	0.2877
C(2)	-0.021365	0.024723	-0.864168	0.3876
C(3)	0.013104	0.024626	0.532117	0.5947
C(4)	-0.013291	0.012448	-1.067712	0.2857
C(5)	0.004328	0.012413	0.348634	0.7274
C(6)	-0.000111	0.003865	-0.028751	0.9771
C(7)	2.10E-05	0.003824	0.005489	0.9956
C(8)	-0.000327	0.008197	-0.039899	0.9682
C(9)	0.000444	0.008171	0.054350	0.9567
C(10)	-0.000108	0.000671	-0.160355	0.8726
C(11)	0.000470	0.000662	0.709768	0.4779
C(12)	0.036644	0.018856	1.943378	0.0521
C(13)	-0.033726	0.018804	-1.793561	0.0730
C(14)	-0.002686	0.008855	-0.303332	0.7617
C(15)	-0.004496	0.008915	-0.504325	0.6141
C(16)	0.210332	0.261243	0.805120	0.4208

R-squared	0.004029	Mean dependent var	0.210033
Adjusted R-squared	-0.001470	S.D. dependent var	13.63925
S.E. of regression	13.64927	Akaike info criterion	8.071086
Sum squared resid	506183.8	Schwarz criterion	8.105704
Log likelihood	-11013.14	Hannan-Quinn criter.	8.083597
F-statistic	0.732700	Durbin-Watson stat	2.005181
Prob(F-statistic)	0.752981		

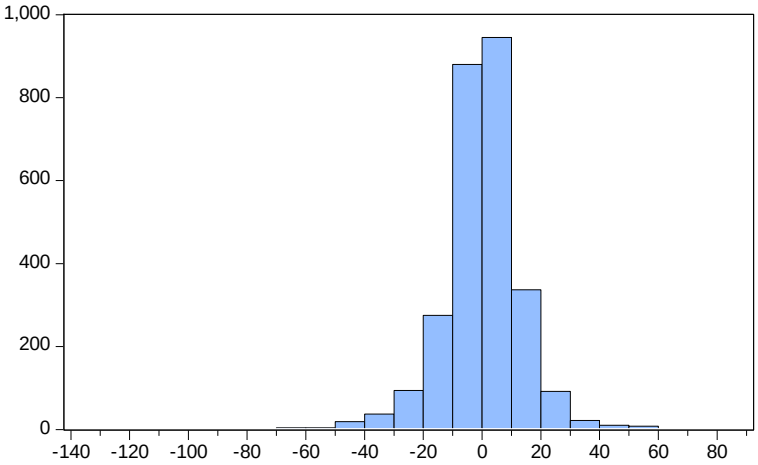
Table 14: Wald Test Results Summary

Chi-square	Test Statistic	Probability
Aluminium	1.234957	0.539300
Copper	0.000855	0.000855
Lead	0.004125	0.997900
Nickel	0.514761	0.773100
Platinum	6.498830	0.038800
Zinc	0.369867	0.831200

Figure 3: Residual Diagnostics extracts of the VECM

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.683259	Prob. F(2,2715)	0.1860
Obs*R-squared	3.384640	Prob. Chi-Square(2)	0.1841

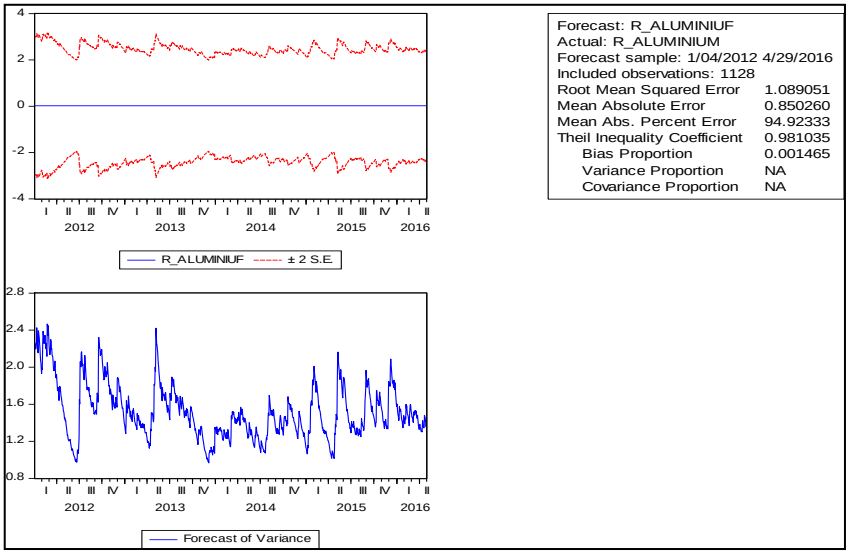


Series: Residuals
Sample 1/07/2005 4/29/2016
Observations 2733

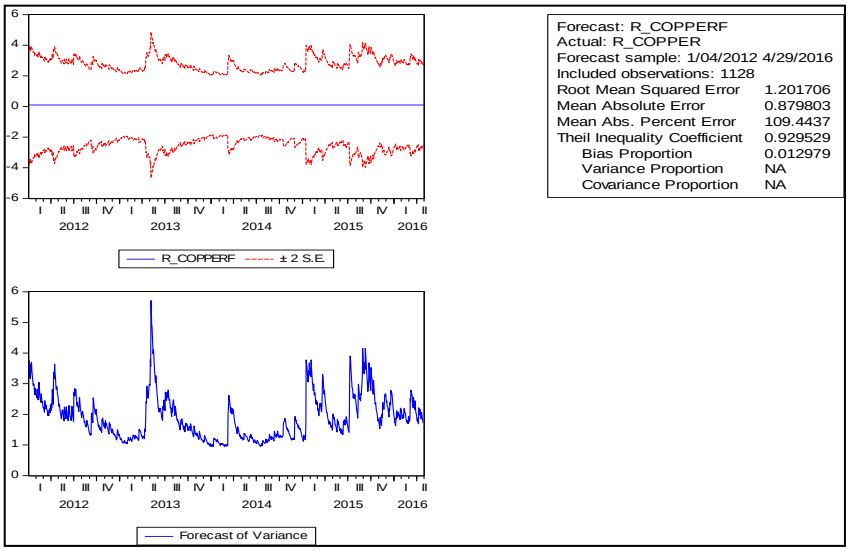
Mean	2.52e-16
Median	0.337000
Maximum	85.23996
Minimum	-136.0046
Std. Dev.	13.61174
Skewness	-0.737983
Kurtosis	10.90337
Jarque-Bera	7361.085
Probability	0.000000

Appendix VII: GARCH Forecast Graphs

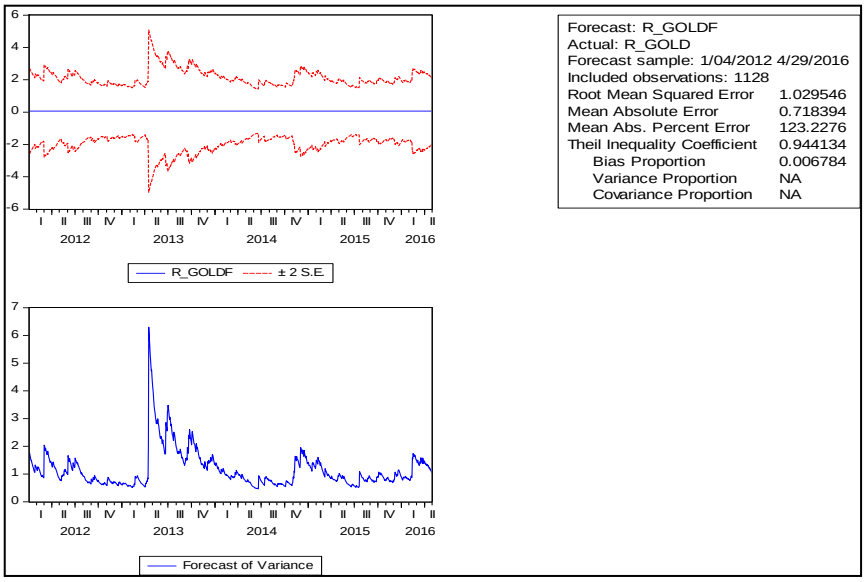
a) Aluminium



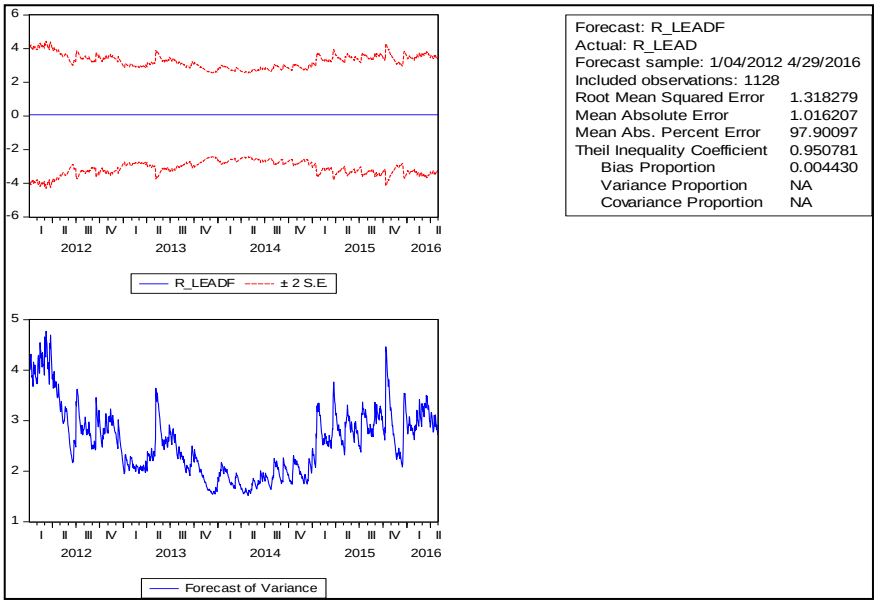
b) Copper



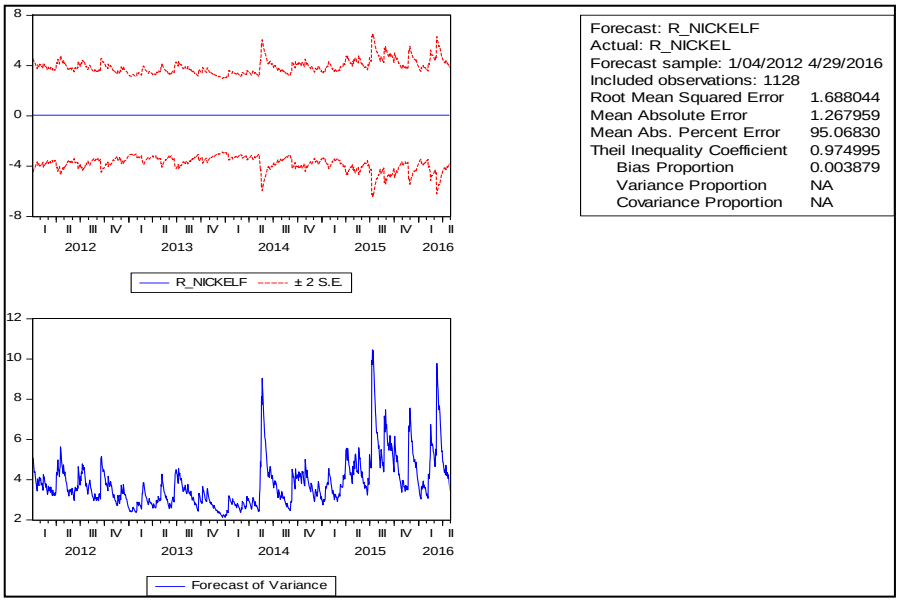
c) Gold


Forecast: R_GOLDF
Actual: R_GOLD
Forecast sample: 1/04/2012 4/29/2016
Included observations: 1128
Root Mean Squared Error 1.029546
Mean Absolute Error 0.718394
Mean Abs. Percent Error 123.2276
Theil Inequality Coefficient 0.944134
Bias Proportion 0.006784
Variance Proportion NA
Covariance Proportion NA
R_GOLDF ± 2 S.E.
Forecast of Variance
2012
2013
2014
2015
2016

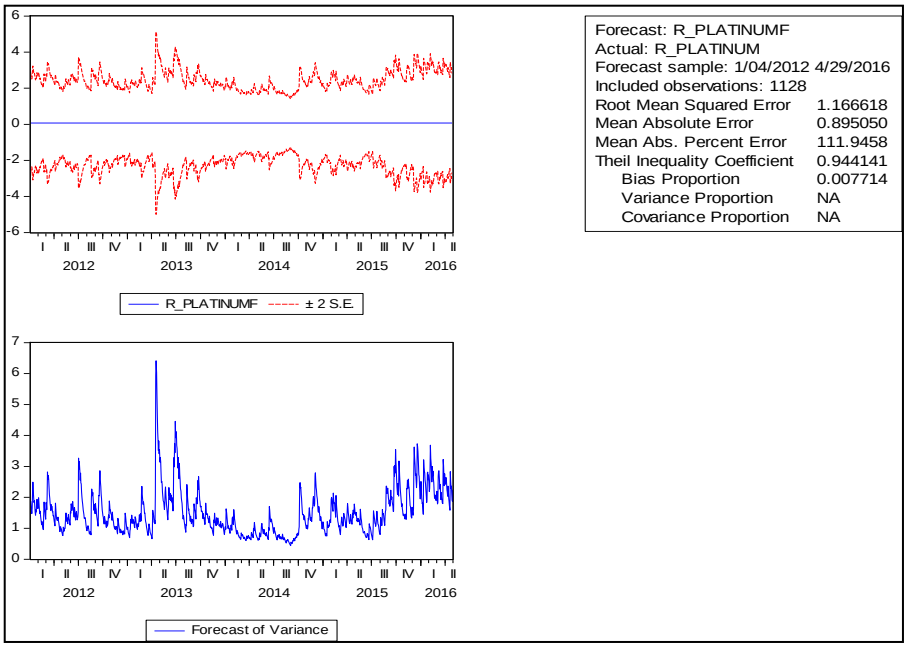
d) Lead


Forecast: R_LEADF
Actual: R_LEAD
Forecast sample: 1/04/2012 4/29/2016
Included observations: 1128
Root Mean Squared Error 1.318279
Mean Absolute Error 1.016207
Mean Abs. Percent Error 97.90097
Theil Inequality Coefficient 0.950781
Bias Proportion 0.004430
Variance Proportion NA
Covariance Proportion NA
R_LEADF ± 2 S.E.
Forecast of Variance
2012
2013
2014
2015
2016

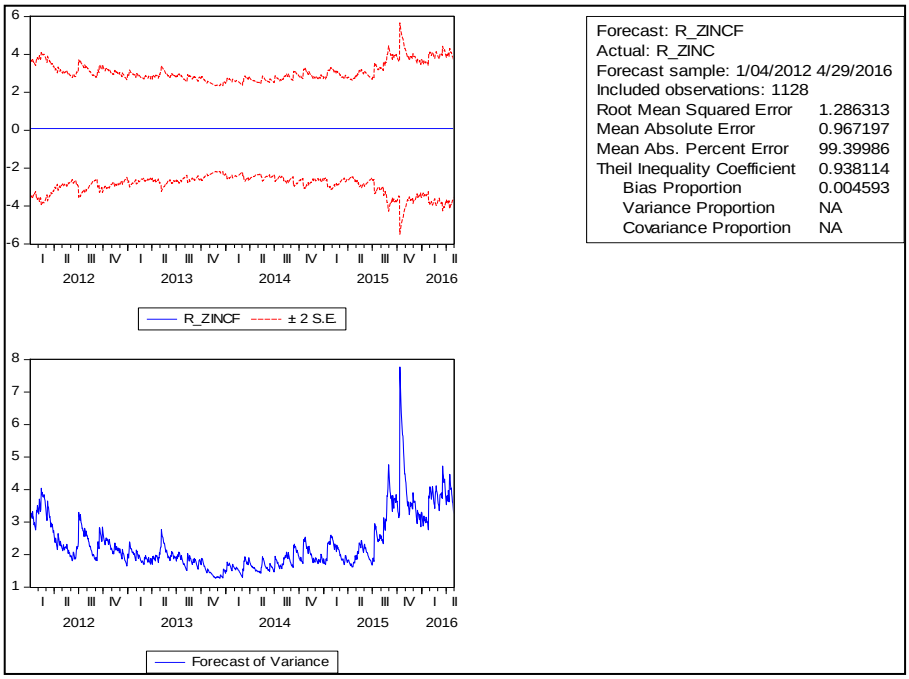
e) Nickel



f) Platinum

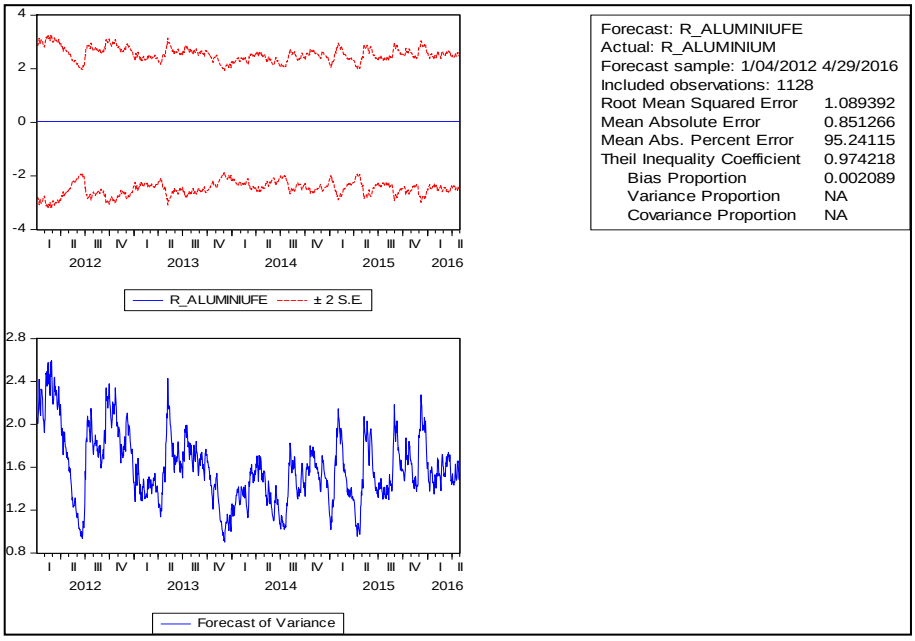


g) Zinc

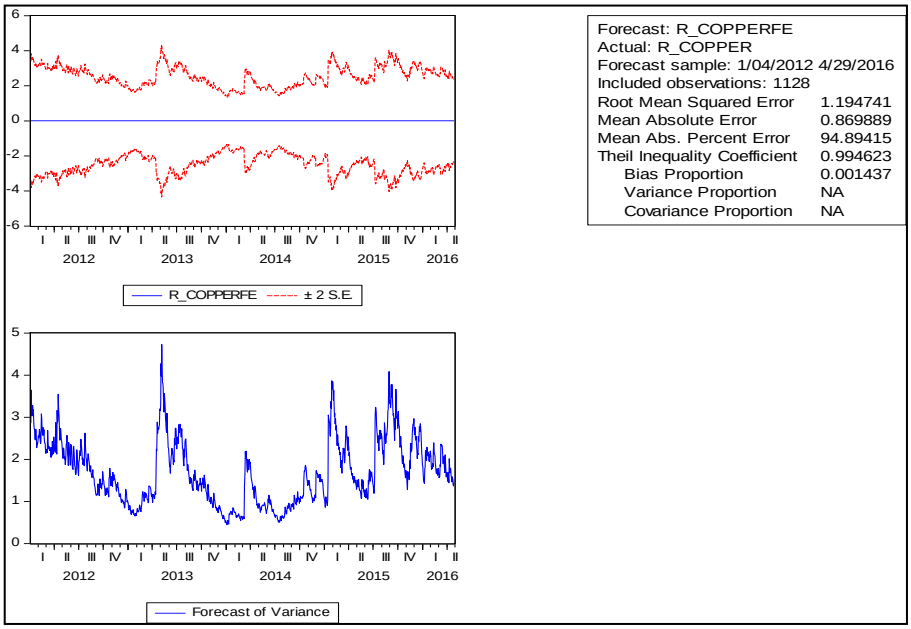


Appendix VIII: EGARCH Forecast Graphs

a) Aluminium



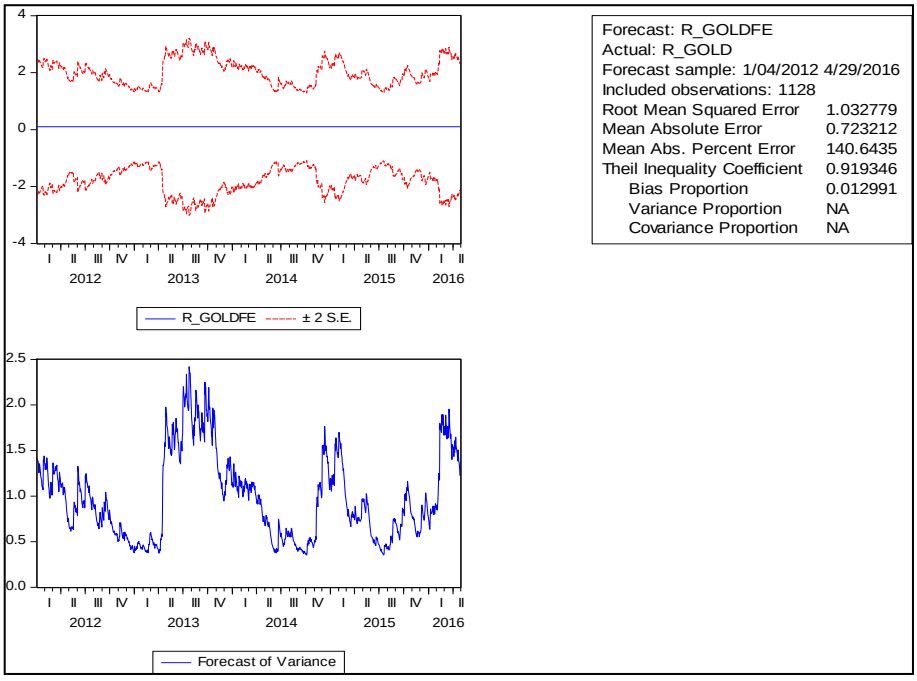
b) Copper



Forecast: R_COPPERFE
Actual: R_COPPER
Forecast sample: 1/04/2012 4/29/2016
Included observations: 1128

Root Mean Squared Error	1.194741
Mean Absolute Error	0.869889
Mean Abs. Percent Error	94.89415
Theil Inequality Coefficient	0.994623
Bias Proportion	0.001437
Variance Proportion	NA
Covariance Proportion	NA

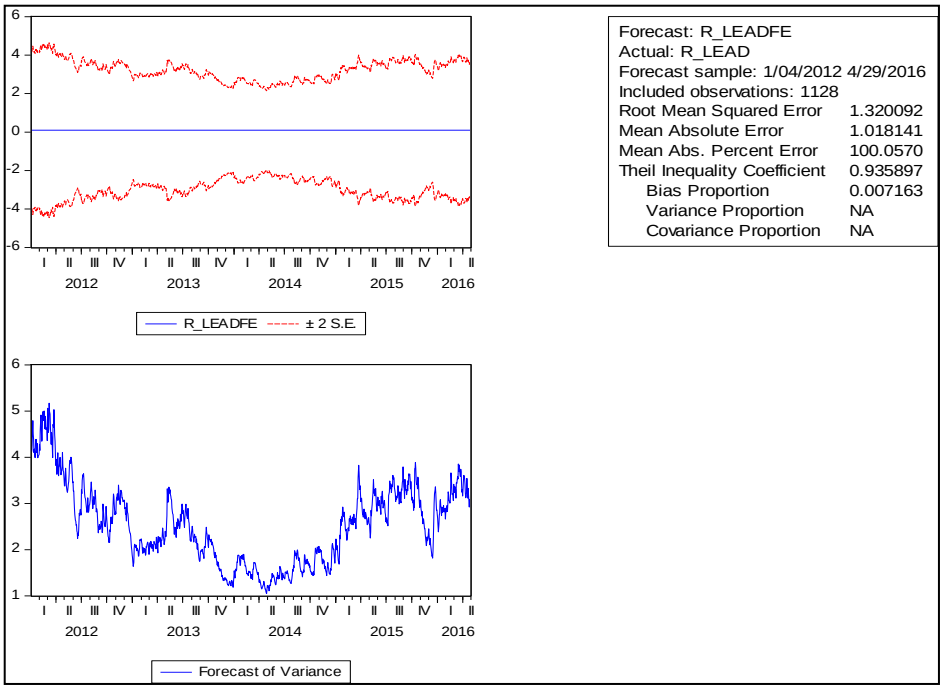
c) Gold



Forecast: R_GOLDFE
Actual: R_GOLD
Forecast sample: 1/04/2012 4/29/2016
Included observations: 1128

Root Mean Squared Error	1.032779
Mean Absolute Error	0.723212
Mean Abs. Percent Error	140.6435
Theil Inequality Coefficient	0.919346
Bias Proportion	0.012991
Variance Proportion	NA
Covariance Proportion	NA

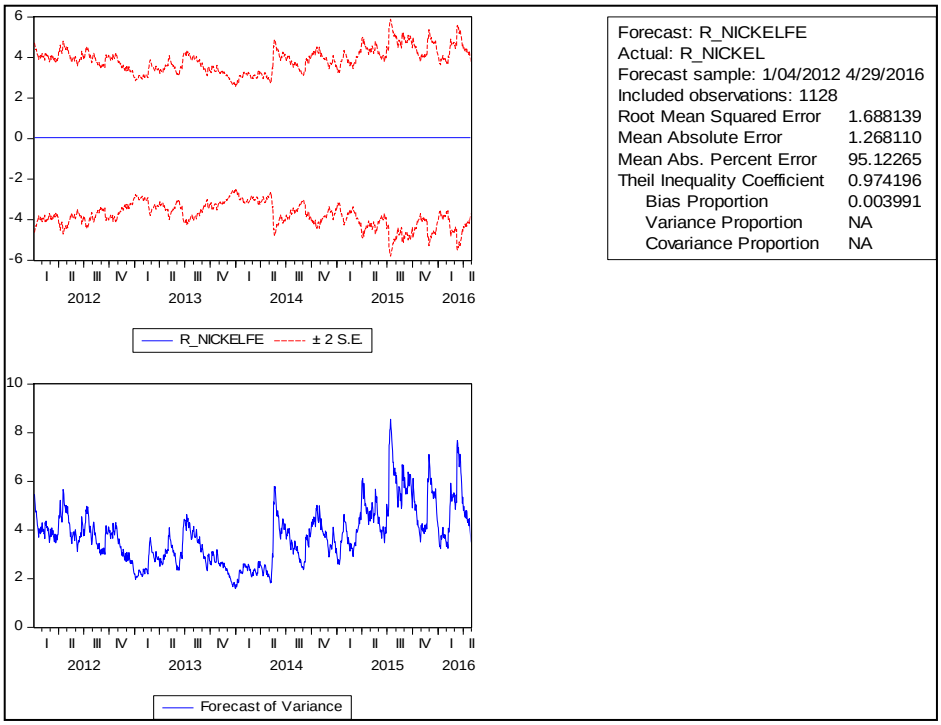
d) Lead



Forecast: R_LEADFE
Actual: R_LEAD
Forecast sample: 1/04/2012 4/29/2016
Included observations: 1128

Root Mean Squared Error	1.320092
Mean Absolute Error	1.018141
Mean Abs. Percent Error	100.0570
Theil Inequality Coefficient	0.935897
Bias Proportion	0.007163
Variance Proportion	NA
Covariance Proportion	NA

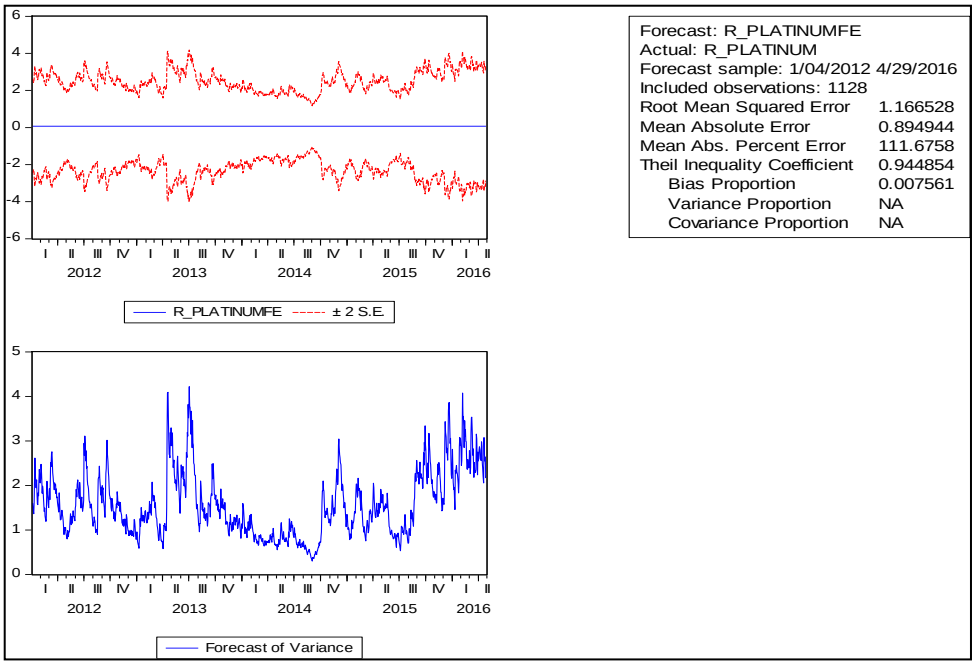
e) Nickel



Forecast: R_NICKELFE
Actual: R_NICKEL
Forecast sample: 1/04/2012 4/29/2016
Included observations: 1128

Root Mean Squared Error	1.688139
Mean Absolute Error	1.268110
Mean Abs. Percent Error	95.12265
Theil Inequality Coefficient	0.974196
Bias Proportion	0.003991
Variance Proportion	NA
Covariance Proportion	NA

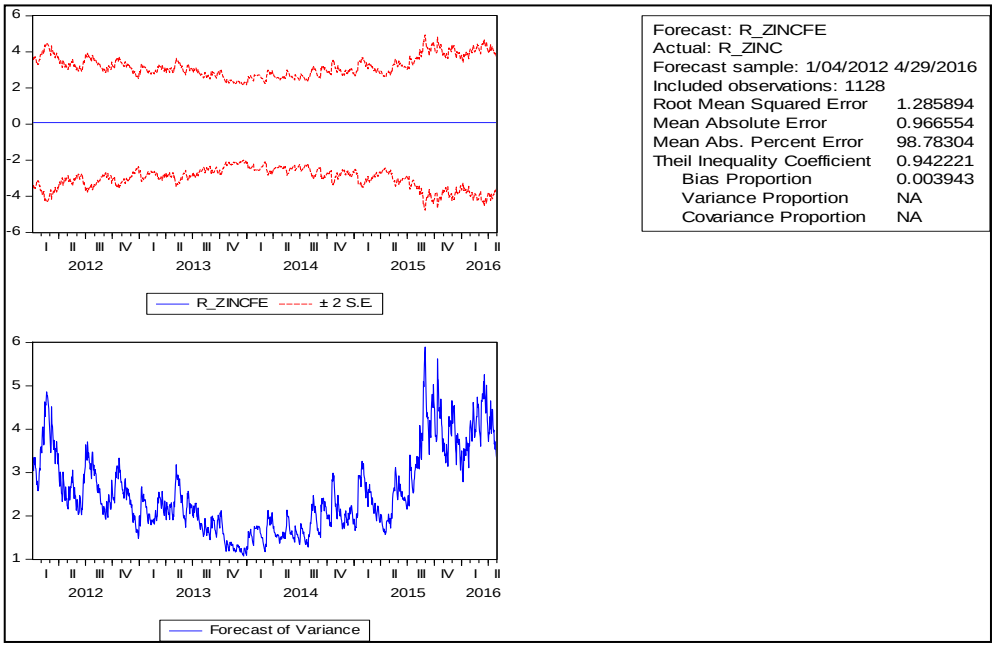
f) Platinum



Forecast: R_PLATINUMFE
Actual: R_PLATINUM
Forecast sample: 1/04/2012 4/29/2016
Included observations: 1128

Root Mean Squared Error	1.166528
Mean Absolute Error	0.894944
Mean Abs. Percent Error	111.6758
Theil Inequality Coefficient	0.944854
Bias Proportion	0.007561
Variance Proportion	NA
Covariance Proportion	NA

g) Zinc



Forecast: R_ZINCFE
Actual: R_ZINC
Forecast sample: 1/04/2012 4/29/2016
Included observations: 1128

Root Mean Squared Error	1.285894
Mean Absolute Error	0.966554
Mean Abs. Percent Error	98.78304
Theil Inequality Coefficient	0.942221
Bias Proportion	0.003943
Variance Proportion	NA
Covariance Proportion	NA