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# THE IMPACT OF EXCHANGE RATE VOLATILITY ON FIRM VALUE OF SOUTH AFRICAN MINING FIRMS LISTED ON THE JSE

**by**

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**A research report submitted to the Faculty of Commerce, Law and Management, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Business Administration**

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# ABSTRACT

Real and nominal exchange rates have been very volatile after the collapse of the Bretton Woods system of fixed exchange rates. The advocates of managed or fixed exchange rates have referred to this type of volatility as unfavourable due to the contagion effect on the valuation of multinational firms. While the relationship between exchange rates volatility and its impact on firm's value has been significantly researched, it is noticeable that this relationship has not been subject to much empirical research in the mining industry. This study empirically investigates the impact of exchange rate volatility on the valuation of South African mining firms listed on the Johannesburg Stock Exchange.

The study focused on top 10 (by value) South African mining firms listed only on the Johannesburg Stock Exchange. Secondary data was used for the study, and it was collected from the Johannesburg Stock Exchange, South African Reserve Bank, South Africa's Department of Trade and Industry and Bloomberg Terminal for the period between January 2000 and December 2016.

The generalised autoregressive conditional heteroskedasticity, $GARCH\,(1,1)$ conditional standard deviation was used to estimate exchange rate volatility from the trade-weighted exchange rate constructed from South Africa's top nine trading partners. The two-factor model of the Capital Asset Pricing Model was used to estimate the relationships between the mining firm's share returns (firm value) and exchange rates volatility.

The study's results revealed that there was an insignificant relationship between the mining firms share returns (firm value) and exchange rates volatility for eight out of ten selected firms. The two firms, Kumba Iron Ore Ltd (KIO) and Exxaro Resources Ltd (EXX) share returns were significantly and positively correlated to exchange rate volatility. All mining firms' share returns were significantly and positively correlated with the market returns (i.e. positive betas). Also, the results showed that there was no causal relationship that existed between the exchange rate volatility and mining firms share returns for most of the mining firms. However, a unidirectional causal relationship was noted between exchange rate volatility and Kumba Iron Ore Ltd share returns, and between Northam Platinum Ltd share returns and exchange rates volatility.

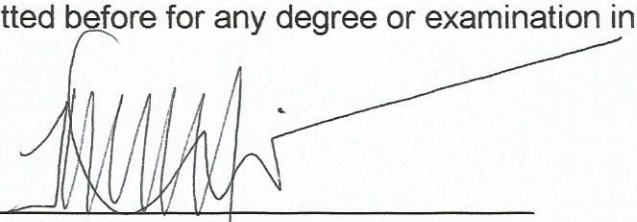
The regression results from determinants of the exchange rate exposure showed that the significant relationships between KIO and EXX share returns and exchange rates exposure cannot be explained by potential explanatory variables used for regression (i.e. the foreign sales to total sales ratio, firm value and age of the firm).

The results suggest that the study needs to be extended to include more mining companies and other parameters like foreign debts to total debt ratio, as well as mining firms which are listed on other stock markets outside South Africa and hold foreign assets.

Keywords: $GARCH$, exchange rate volatility, exchange rate exposure and trade-weighted exchange rates

# DECLARATION

I declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.



Avhashoni Edward Mavhungu, Student Number: 763122

Signed at Wits Business School, Park Town

On the 19th day of June 2017

# DEDICATION

I would like to dedicate this research to my late brother, Dzulani, who left us tragically, I would have loved to be singing the songs of joy with you, you will forever be missed, may you soul rest in peace. To all my friends, family and relatives, without you all, this would not have been possible.

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I would also like to thank my family for their support throughout my studies, to my wife Livhuwani, son Mulalo and daughter Orifha Mavhungu, I really appreciate your understanding and support. To my mother, Shumani and mother-in-law Aifheli, you have encouraged me to not settle for less in life, your words of encouragement helped me grow and allowed me to stay focused even when there seems to be no hope. To my brother, Michael, thank you for your support.

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# LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| 2000M1 | January 2000 |
| 2016M12 | December 2016 |
| ADF | Augmented Dickey-Fuller |
| AFRO Index | Trade-Weighted Real Exchange Rate Index for Africa |
| ALSI | Johannesburg Stock Exchange All Share Index |
| ANG | AngloGold Ashanti Limited |
| AMS | Anglo American Platinum Limited |
| ARCH | Autoregressive Conditional Heteroskedasticity |
| ARI | African Rainbow Minerals Limited |
| ASR | Assore Limited |
| CAPM | Capital Asset Pricing Model |
| CNY | Chinese Yuan Renminbi |
| DF | Dickey and Fuller |
| DTi | Department of Trade and Industry |
| EViews | Statistical Enterprise Edition Software |
| ExRVol | Exchange Rate Volatility |
| EXX | Exxaro Resources Limited |
| FDI | Foreign Direct Investment |
| GARCH | Generalized Autoregressive Conditional Heteroskedasticity |
| GBP | Great Britain Pounds |

| | |
|---|---|
| GDP | Gross Domestic Product |
| IMP | Impala Platinum Holdings Limited |
| INR | Indian Rupee |
| JSE | Johannesburg Stock Exchange |
| KIO | Kumba Iron Ore Limited |
| KRW | South Korean Won |
| NHM | Northam Platinum Limited |
| OLS | Ordinary Least Squares |
| RBP | Bafokeng Rasimone Platinum Limited |
| SARB | South African Reserve Bank |
| SIC | Schwartz Bayesian Information Criterion |
| TwExR | Trade-Weighted Exchange Rate |
| US | United States of America |
| USD | United States Dollars |
| WEZ | Wesizwe Platinum Limited |
| YEN | Japanese Yen |
| ZAR | South African Rand |

# CHAPTER 1. INTRODUCTION

Since the collapse of the Bretton Woods system of fixed exchange rates, the real and nominal exchange rates have been very volatile (Volz, 2010). This type of exchange rate volatility has been referred by the advocates of managed or fixed exchange rates as detrimental because of its impact on the valuation of multinational firms (Barumwete & Rao, 2008). Shapiro (1975) and Dumas (1978) published their seminal work on the developed models which predicted that exchange rate volatility has a negative impact on multinational firms cash flows, profitability and the firm's market value.

Exchange rate volatility has been known to affect a firm's profitability due to increasing costs of covering exchange rate risk under flexible rate regimes (Sekmen, 2011). Further, it has also been asserted that the profitability of mining firms is especially sensitive to exchange rate movements (Khoo, 1994). These movements in the foreign exchange market have the ability to change the home currency incomes and the operating costs of companies with external sales and operations, thereby affecting the value of a firm for various economic reasons (Gao, 2000).

Studies on the impact and effects of exchange rates have been done in the banking sector (Chamberlain, Howe, & Popper, 1997; Wong, Wong, & Leung, 2009) on the motor industry (Barumwete & Rao, 2008; Requena-Silvente & Walker, 2007); on multinational and fast moving consumer goods (Fung & Liu, 2009; Gao, 2000; Liang & Yu, 2014) and on non-financial firms at industry level analysis (El-Masry, 2006). Very few such studies have been done in the mining sector, especially South African firms listed on the Johannesburg Stock Exchange. Sekmen (2011) examined the impact of exchange rate volatility on stock returns for US firms involved in international trade. Chamberlain et al. (1997) in their study on the impact of exchange rate regimes on banks noted that exchange rates would affect mostly those banks that deal directly with foreign exchange transactions and foreign operations. The authors were able to demonstrate that foreign exchange volatility will affect the banking industry indirectly through the influence on the extent of foreign competition, demand for loans and other aspects of the banking conditions. Barumwete and Rao (2008) on the other hand, examined the exchange rate risk in the automobile industry in Sweden, France and Germany. They found out that volatility of exchange rates did exert additional risk to motor

manufacturing firms. In addition, Barumwete and Rao (2008) showed that macroeconomic variables like GDP and oil price did not display any significant relationship with the profits of automotive manufacturing firms. The market index, however, exhibited a significant impact on the profits of these firms.

This leaves the question of the impact of exchange rate volatility on the value of the firm largely unanswered. The aim of this study was to investigate the impact of exchange rates on the value of mining firms listed on the Johannesburg Stock Exchange (JSE). Exchange rates fluctuations can directly or indirectly affect the firms' cash flows and market value. It is for this reason that this subject will remain important to both investors and firms' managers.

## 1.1 Purpose of the study

The purpose of the study was to determine the impact of exchange rate volatility on South African mining firms' value as exhibited by the Johannesburg Stock Exchange's (JSE) records. The importance of exchange rate volatility is explained by Kyereboah-Coleman and Agyire-Tettey (2008) who state that exchange rate volatility is crucial because it could make the difference between naturally competitive firms being prosperous or closing down. Jorion (1990) and Flota (2014) also state that it is a widely held notion that exchange rates affect the value of a firm, and it is the main source of uncertainty for most multinational corporations. Conventional wisdom would dictate that currency volatility has a direct impact on the value of firms with international operations (Flota, 2014).

There have been significant movements in the rates of exchange of the South African rand (ZAR) versus the major trading currencies over the last few years. This has affected the profitability and value of some of these firms that are listed on the JSE. This study will add to the current literature that seeks to provide an understanding of the relationships that exists between the currency fluctuations and a firm's share returns (value) in the financial markets. Flota (2014) posits that the need to understand may be for management or academic reasons. The corporate managers of the mining firms or any other industry are always quoted setting the expectations that changes in the exchange rate will have direct impact on the performance of their international operations, while the standard economic thinking by academics suggests that fluctuations in currency exchange rates may influence the profitability and share returns (value) of firms with international operations (Flota, 2014).

## 1.2 Rationale of the study

South Africa is known worldwide for having huge reserves of unexploited ore resources (Deaton, 1999), hence mining as a sector will continue to play a significant role in the country's economy through employment, foreign exchange earnings and its contribution to Gross Domestic Product (GDP). Demand for minerals continues to depend on the performance of the global economy, which in turn is influenced by sector performance in the economies (Igbinoba, 2016). There is thus a need to understand the dynamics that are at play behind the linkages of foreign exchange earnings and firm performance, especially for those firms that are involved in the mining sector.

Most of the mining firms listed on the South African Johannesburg Stock Exchange (JSE) trade their commodities outside South Africa, typically in China, Europe, United Kingdom and the United States. Commodities sold by these firms are mainly contracts that are denominated in the Chinese Yuan, Indian Rupee, United States (US) dollars or European Euros. Therefore, these mining firms are also exposed to the volatility of the exchange rates because of their foreign activities. The choice of the mining firms is informed by two reasons; first, mining is still important for the South African economy and contributes significantly to the country's exports and earning Foreign Direct Investment (FDI). In 2015 mining contributed 7,7% to South Africa's Gross Domestic Product (GDP), 15% in FDI and 25% of exports (Baxter, 2016). Secondly, the use of mining firms ensures that there are no changes to the foreign exchange rate exposure experience by other sectors of the economy.

Most studies on firm performance and exchange rate volatility have been on banking (Chamberlain et al., 1997), car manufacturing (Barumwete & Rao, 2008), consumer goods (Fung & Liu, 2009; Gao, 2000; Liang & Yu, 2014) multi-nationals and other stock exchanges (Dominguez & Tesar, 2006; Flota, 2014; Jorion, 1990). Few studies have dealt with the mining sector in general, and even fewer linking foreign exchange volatility to firm profitability and share returns (value) for firms listed on the JSE. Shapiro (1975) states that the issue of different rates of inflation and fluctuations in the exchange rate regime and their effects on firm profitability and value is important in the proper management of these firms and plays an important role in forecasting their long-term profitability, as such this study becomes relevant.

## 1.3 Research Objectives and Questions

The main aim of this research was to investigate the direction empirically, and the strength of the impact of the exchange rates volatility on a firm's value (share returns) of South African JSE listed mining firms.

This research study will attempt to answer the following questions pertaining to the mining firms in South Africa;

- What is the direction and the strength of the response of mining firms' value to the volatility of the exchange rates?
- Is there a causal relationship that can be deduced from the mining firms' value and the volatility in exchange rates?
- Does the mining firm's exchange rate exposure get influenced by the foreign sales to total sales ratio, firm size (market capitalization) and age of the firm?

## 1.4 Delimitations and Limitations

### 1.4.1 *Delimitations*

The scope of this research was limited to top 10 (by value) South African mining firms listed on the JSE security exchange as depicted in Table 1-1 below.

**Table 1-1: The list of the mining firms used for the research**

| | |
|---|---|
| Kumba Iron Ore Ltd (JSE:KIO) | AngloGold Ashanti Limited (JSE:ANG) |
| Impala Platinum Holdings Limited (JSE:IMP) | African Rainbow Minerals Ltd (JSE:ARI) |
| Royal Bafokeng Platinum (JSE:RBP) | Northam Platinum Limited (JSE: NHM) |
| Anglo American Platinum Ltd (JSE: AMS) | Assore Limited (JSE: ASR) |
| Exxaro Resources Limited (JSE: EXX) | Wesizwe Platinum Ltd. (JSE: WEZ) |

There was no attempt made to investigate the firms listed on security exchanges outside South Africa.

The trade-weighted exchange rate was used for the analysis. The trade-weighted exchange rate was based on the nine top South Africa's trading partners. Secondary data was collected monthly for the analysis. Other intervals were not considered in this study.

This study limits itself to the period between January 2000 to December 2016. This is because the South African government adopted the floating exchange regime with inflation targeting framework of monetary policy in February 2000 (Mtonga, 2011). Exchange rate volatility has been a source of concern for many countries because of its effects on the economy. Mlambo, Maredza, and Sibanda (2013) contend that the South African Rand (ZAR) has been the most volatile among emerging currencies during this period.

### 1.4.2 *Limitations*

Although some of the firms are listed on more than one stock exchange, only the data of those firms only listed on the JSE was used for analysis.

It is acknowledged that the profitability, and performance of the mining sector is affected by macroeconomic factors such as openness of the economy, political stability and speculation, these factors are however difficult to measure and as such were not considered in this study.

Because of the uniqueness of the mining industry generalisation of the findings that will emanate from the study might not be applicable to other sectors such as banking, manufacturing, industrials, etc.

## 1.5 Definitions

*Exchange rate risk* – in this thesis the term refers to "the unexpected changes in a currency's purchasing power relative to its initially expected value at some specific future date" (Flota, 2014).

*Exchange rate exposure* – the term refers to the sensitivity of the firm's value to fluctuations in the exchange rate.

*Firm value* – it is defined as the value of the firm equals to the present value of all its expected future cash flows.

## 1.6 Structure of the Research Report

The remainder of the document is constructed as follows; the study comprises of five chapters. Chapter one sets the scene including background, rationale and purpose of the study; chapter two presents a literature review, chapter three the research methodology, chapter four presents analysis and interpretation of results, chapter five conclusions and recommendation emanating from the study.

# CHAPTER 2. LITERATURE REVIEW

This chapter presents the review of the literature relevant to the impact of exchange rate volatility on the value of South African mining firms listed on the Johannesburg Stock Exchange (JSE). It commences with the presentation of the key issues pertaining to the exchange rates, it then proceeds to discuss the empirical review from previous studies to help identify the area of focus. The research questions that will guide the study are then formulated from the discussed constructs on firm value and exchange rate movements over the study time span. Throughout the discussion, the focus is on exchange rates and its volatility, firm value, profitability, firm exposure to exchange rates and lastly, the mining firms in South Africa listed on the JSE.

## 2.1 Exchange Rates

The exchange rate also referred to as currency exchange rate or foreign exchange rate refers to the unit amount paid in local currency to purchase one unit in foreign currency. (Janse van Rensburg, McConnell, & Brue, 2011; Ross, Westerfield, & Jordan, 2008). Khoo (1994) states that exchange rate movement can be measured in nominal or real terms. Real exchange rates are nominal fluctuations that are calibrated for price level changes across countries.

Various factors are considered to cause the currency to either appreciate or depreciate. In general, the change in demand or supply of the local currency will either have a positive or negative impact on the exchange rate. Further, the change in another nation's currency also has an impact on the local currency which will also cause it to either appreciate or depreciate (Janse van Rensburg et al., 2011). The determinants of the exchange rate fluctuations include but are not limited to a country's inflation, interest rates, political stability, speculation and changes in preferences.

Devaluation and revaluations are mechanisms which are employed by governments in their monetary policies (Cohen, 2005). Shapiro (1975) observes that devaluations are most often preceded by inflation. It then becomes paramount that the entire inflation-devaluation cycle and its impact on firm profitability and firm value be understood.

### 2.1.1 *Exchange Rate Regimes*

The exchange rate regime is closely related to the country's monetary policy, and it is mainly used to manage the local currency relative to other foreign currency and the foreign exchange market (Jalan, 2016). The main types of the foreign exchange rates regime adopted by different countries include the floating/flexible exchange rates, pegged floating exchange rates, fixed exchange rates, currency boards and dollarization. Barumwete and Rao (2008) stated that the type of the exchange rate adopted by different countries is influenced by different factors, such as the objectives that the policy makers want to address and the structural characteristics of the economy.

*Floating/flexible exchange rates* – the floating or flexible exchange rate is the type of exchange rate where the market supply and demand forces determine the exchange rate, and there is no government intervention to correct the exchange rate (Mzyece, 2012). Although there is no intervention from government, the central bank steps in when there is excessive appreciation and depreciation of the local currency, hence it is also referred to as managed floating exchange rate or a dirty float. The floating exchange rate is the most adopted type of foreign exchange regime by many emerging and developed countries (Janse van Rensburg et al., 2011). The disadvantages associated with this type of exchange rate regime includes the uncertainty and diminished trade brought about by the risk and uncertainties that could impact on the flow of trade into the country, terms of trade changes. This is because the decline in local currency can at times worsen the terms of trade, and instability from the higher exchange rate fluctuations can also either stimulate or depress the profits of those firms exporting products to foreign markets (Janse van Rensburg et al., 2011).

*Fixed exchange rate* – which is also referred to as pegged exchange rate is a regime in which the currency value is fixed relative to the other currencies, grouped currencies or another measure of value. The central bank will always try to stabilise the currency by intervention using countries reserves, change in trade policies to control the flow of trade and finance directly, and by use of domestic macroeconomic adjustment though the monetary policy and fiscal policy reforms to eliminate the shortage of foreign currency. The floating exchange rate is predictable and reduces risk between the trading countries (Shambaugh, 2004).

Mtonga (2011) provides empirical evidence of how exchange rate dynamics may be successfully related to monetary policies. Using a systems approach, Mtonga (2011) discusses the South African Rand's pricing, in particular, whether it matters to note the monetary policy regime being utilised at a specific time. Highlighting the importance of knowledge and awareness of the regimes that monetary decisions should be informed of, Mtonga (2011) demonstrated that "policy regime change matters a lot for currency pricing", hence the necessity of consciousness to the exchange rate patterns.

### 2.1.2 *Exchange rates in South Africa*

In trying to stabilise the currency foreign exchange market and as a strategy to adapt with the economic and political turmoil that the country faced, South Africa focused its attention on the measures that will stabilise the economy. It was in February 2000 when South Africa changed its monetary policy regime to that of inflation targeting. This was a lengthy process and involved testing different exchange regimes from fixed exchange rates in the 1960s and 1970s, different forms of floating exchange rates in the 1980s and 1990s (Mtonga, 2011; Van der Merwe, 1996). After this change, the South African Reserve Bank (SARB) was tasked to put stringent exchange rate control regulations and to intervene in the control of the exchange rates.

The exchange rate management in South Africa is better understood by the timeline of how the exchange rate changed over the years provided by Mtonga (2011) and presented in Table 2-1. The adoption of different exchange rates regime in South Africa was mainly influenced by the apartheid, political instabilities and the international sanctions imposed on the country during the old regime.

The year 2000 saw a monetary policy shift where inflation targeting was introduced in place of the previous stringent foreign exchange controls that were in operation. After 2000, market forces were left to influence the domestic, foreign exchange regime. Under this approach, there were no fixed exchange rate targets, benchmarks had to be set regularly, and interest rates were used as a policy instrument (Van der Merwe, 1996). The SARB does not intervene to stabilise the value of South African rand unless it is solely for foreign currency reserve accumulation. Mtonga (2011) states that this approach has been implemented successfully and seems to be working. The country's mode of using inflation targeting to manage

exchange rates has become consistent with what is expected of a free float. There have been concerns however on whether there is need to completely remove foreign exchange controls. This is because the use of interest rates by SARB means that the foreign exchange rate market is not completely operating on the basis of demand and supply forces alone, which is considered to be a major tenet of liberalisation. Mtonga (2011) argues that given the macroeconomic volatility that has been experienced globally, a complete liberalisation of the foreign exchange regime for an emergent market like South Africa may not be ideal.

**Table 2-1: Exchange Rate Changes in South Africa Since the 1960s**

| Episode | Period | Exchange Rate Regime |
|---|---|---|
| I | February 1961 - July 1971 | Fixed exchange rate regime: rand pegged to the British pound |
| II | August 1971 - Novemeber 1971 | Fixed exchange rate regime: rand pegged to the US dollar |
| III | December 1971 - September 1972 | Fixed exchange rate regime: rand pegged to the British pound |
| IV | October 1972 - May 1974 | Fixed exchange rate regime: rand pegged to the US dollar |
| V | June 1974 - May 1975 | Crawling peg rand: rand pegged to a basket of currencies |
| VI | June 1975 - May 1979 | Fixed exchange rate regime: rand pegged to the US dollar |
| VII | June 1979 - January 1983 | Dual exchange rate regime: crawling peg commercial rand and free floating financial rand |
| VIII | February 1983 - August 1985 | Unitary exchange rate: Managed float rand |
| IX | September 1985 - February 1995 | Dual exchange rate regime: crawling peg commercial rand and free floating financial rand |
| X | March 1995 - January 2000 | Unitary exchange rate: Managed float rand |
| XI | February 2000 - Present | Unitary exchange rate: free floating rand, with inflation targeting frmawork of monetary policy |

Source: Mtonga (2011)

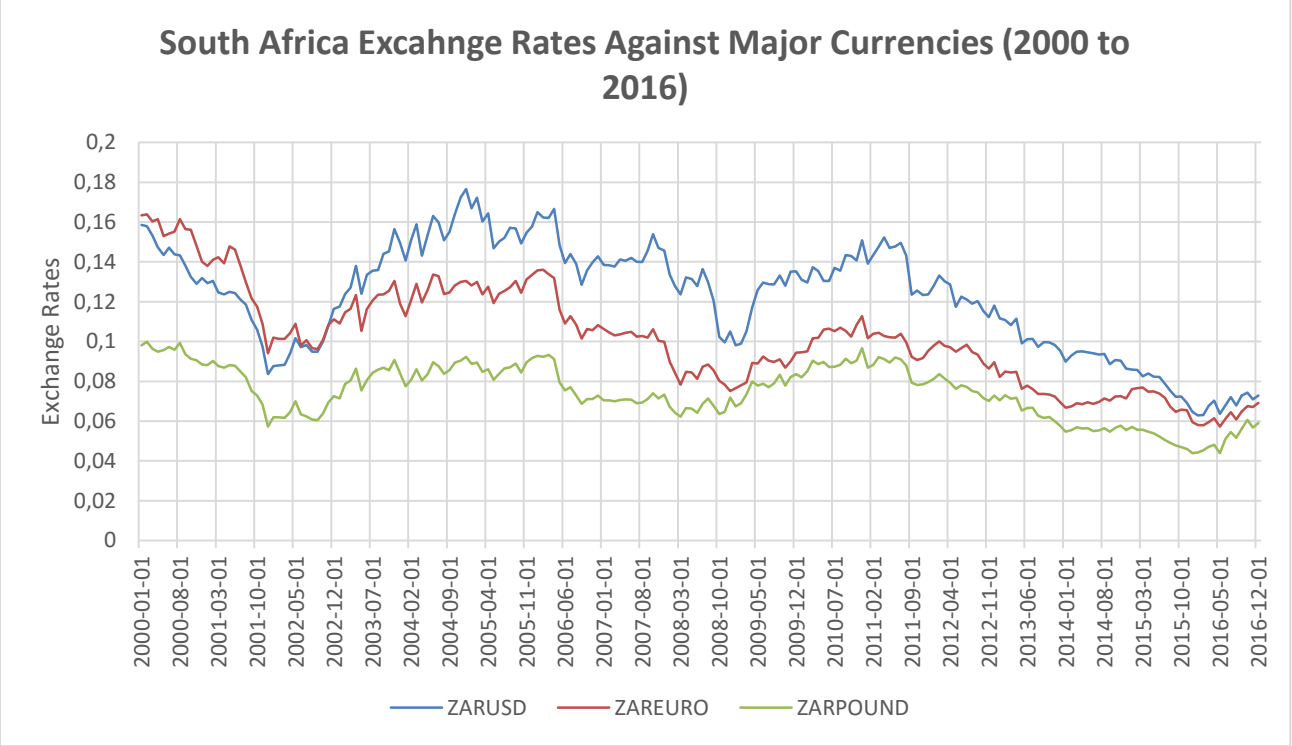
### 2.1.3 *Exchange Rates Volatility*

According to Ozturk (2006), exchange rate volatility can be defined as the risk brought about by the unexpected ups and down movements in the exchange rate. Some of the factors that influence these fluctuations include the inflation rate, interest rate and balance of payment which has been very volatile during the 1980s and early 1990s. Further, Ozturk (2006) posited that in recent times, the increase in cross-border flows had been mainly due to the drift towards liberalisation of the capital account, technology advancement and currency speculation.

Exchange rate volatility has been the subject of discussion in many economies, South Africa included. In the past few years, the South African rand has been very volatile compared to other emerging market currencies (Figure 2-1 ZAR/USD, ZAR/Euro and ZAR/GBP volatility between 2000M1 and 2016M12). The measures put in place by South Africa to minimise the rand's fluctuation have not yielded positive outcome thus far. The rand has been more volatile

as a result of global economic instability and capital inflows from developed countries (Mlambo et al., 2013). The South African rand experienced significant volatility in the past decade, and it was because of this worrying trend that the Myburg commission of inquiry was appointed in 2002 to look into the rapid collapse of the rand (Mlambo et al., 2013).

As part of managing risk associated with the currency fluctuations, firms often protect themselves through the application of hedging strategies. This ensures that the impact of exchange rates are minimised, however, in other instances, it also increases the risk since hedging is not an exact science (Arize, Osang, & Slottje, 2000; Firer, Ross, Westerfield, & Jordan, 2012).




Source: (SARB, 2016)

**Figure 2-1: The volatility of the South African Rand (ZAR) against the three major currencies, USD, EURO and British Pound for period 2001M1 to 2016M12**

### 2.1.4 *Measures of exchange rate volatility*

It is widely accepted that the definition of a financial variable volatility is the standard deviation of the returns (Ng'ambi, 2015). Engle and Patton (2001) posits that the model to capture

financial variable volatility must be able to superiorly forecast volatility. The authors used two classes to describe the volatility models, the conditional variance found in autoregressive conditionally heteroscedastic $(ARCH)$ and the generalized autoregressive conditionally heteroscedastic $(GARCH)$ models, and the stochastic volatility that was described as not functionally observable. Further, Engle and Patton (2001) state that the best model is one that is able to capture the stylized financial asset price facts, volatility clustering and mean reversion. Using the assets price characteristics of the Dow Jones Index the author found the $GARCH$ model was superior, however it had some disadvantages in that frequency of sampling determined the empirical specification of the model.

McKenzie and Brooks (1997) conducted research into the impact of exchange rate volatility on German-US trade flows and found that the $ARCH$ and $GARCH$ model offered the best results compared to all the models used. They postulated that the potential problem with the other models was that they ignored the stochastic process in which exchange rates are generated.

Using the standard deviation of the real exchange rate from the log-linear trend, the standard deviation of the percentage change in the real exchange rate and standard deviation or the error of the real exchange rate from a first order autoregressive equation. Kenen and Rodrik (1986) based their modelling approach on differing views with regards to the formation of expectations.

Ng'ambi (2015) conducted the research using the $GARCH\ (1,1)$ to estimate the volatility of the exchange rates. In this work, weighted trade exchange rate was developed from which the $GARCH\ (1,1)$ could be applied. The choice of the model was based on the feel of the investigator and the notion that he believed it was the best to represent the research objectives.

In his research into central bank intervention and exchange rate volatility, Dominguez (1998) used the double measures of exchange rates volatility. The $GARCH$ model was used since in the authors views it represented well the leptokurtosis and volatility clustering of daily exchange rates fluctuations. Other authors supported this notion with Black and McMillan (2004) asserting that the $GARCH$ model is better than the other models because it offers the best representation of the volatility in exchange rates.

The majority of research work conducted dealing with exchange rates volatility made use of either the $ARCH$ and $GARCH$ models or other types of standard deviation models (Black & McMillan, 2004; Dominguez, 1998; Kenen & Rodrik, 1986; Ng'ambi, 2015). Literature suggests that the choice of the type of the model to use is basically dependent on the objectives that the author wants to achieve.

### 2.1.5 *Real vs. Nominal Exchange Rates*

Kenen and Rodrik (1986) in (Ng'ambi, 2015) defines "the real exchange rates as nominal exchange rates deflated by the consumer price index". The question of whether to use the real or nominal exchange rates feature prominently whenever a study deals with exchange rates. In a study conducted by Thursby and Thursby (1987) using the behavioural model into bilateral trade flows the study showed that the results obtained when using the real and nominal exchange rates were indistinguishable. Further, this agrees with the work conducted by McKenzie and Brooks (1997), who used the $ARCH$ model to determine the real and nominal exchange rates. They concluded that there was an immaterial difference whether real or nominal exchange rates were used. Additional studies were conducted by Demir (2010), revealing that real and nominal exchange rates were highly correlated, i.e. with a coefficient of determination of 92%.

Ng'ambi (2015) further posits that the major drawback of using nominal exchange rates is that it only provides a measure of the value of the country's currency when compared with one of the other countries, thus not fully reflecting the major trading partner country's overall value of their currency. Thus the real exchange rate is used as it represents the currency of the local country in relation to the major trading country's currency index.

### 2.1.6 *Exchange Rates and Firm Value*

Flota (2014) defines firm value as "*the value of the firm equals the present value of all expected future cash flows".* Two approaches are normally used to determine the firm value, the cash flow method and the market capitalization or share return method. The cash flow method is the least preferred by most researchers since the internal firm data is not frequently available, i.e. the data is available only semi-annually during interim and final firm performance results and they are lagged variables, while the share prices or returns are reported more frequently and allows one to be as granular as possible.

In the likelihood that fluctuations in exchange rates affect the present and future cash flows of the firm, then the exchange rates have an impact on the value of the firm. The firm exposure or the sensitivity of its value can be affected by whether it has overseas debt and or assets (Flota, 2014).

## 2.2 Exchange Rate Risk and Firms Economics

Prasad and Rajan (1995) posit that since the introduction of the flexible exchange rates systems, the unexpected exchange rates fluctuations have created uncertainty and risk for firms operating in the international markets. Jorion (1990) asserts that executives, management and investors have always considered exchange rate risk posed by the exchange rates volatility since it has the ability to affect firm's performance and its value. Further, exchange rates contribute significantly to uncertainty as they are normally four times as volatile as interest and ten times as volatile as inflation rates (Jorion, 1990). The impact on the profitability and value of the firms caused by the exchange rates can be substantial, more so for those firms involved in international trade (Flota, 2014).

Exchange rate movements may have an impact on the firm's future cash flows by changing the firm's economic and competitive conditions in the product and factor markets (Prasad & Rajan, 1995). The fluctuations may also change the value of the local currency of cash flows from foreign operations, and this may lead to translational gains or losses when converting the foreign subsidiaries assets and liabilities (Prasad & Rajan, 1995).

Flota (2014) conducted research into the impact of exchange rate movements on the equity value of individual firms using the sample of Mexican publicly traded non-financial firms. Firms within the industrial sector were exposed to the fluctuations in exchange rates. Mid-size firms were less exposed compared to the small or large sized firms. There was a significant negative relationship between currency exposure and the level of international trade. There is a negative relationship between currency exposure and foreign currency denominated liabilities. Flota (2014) posits that firms that trade in international markets and hold foreign currency denominated debt are considerably less sensitive to exchange rate volatility than those that primarily deals in local markets.

The study conducted by Heckerman (1972) investigating the exchange risks of foreign operations using the present discounted value valuation techniques of foreign income stream showed that firms that own foreign operations have assets, incur operating costs and receive their revenues denominated in foreign currencies. Significant differences were noted in potential capital gains or losses of those firms than those where the conventional accounting techniques were used because it ignored changes in the trade terms (Heckerman, 1972). US-based firms that sold their produce to foreign countries were more significantly exposed than those that supplied their product from foreign operations. Adler and Dumas (1984) also assert that the currency exposure is a function of what you have at risk. Firms that do not own operations in foreign countries, assets in foreign currency, liabilities or transactions can still be exposed to foreign currency risk.

Firm's value is in many ways affected by the volatility in the exchange rate, however, how can this be related to the performance of the firm share price? Fama (1991) posits that as per the efficient market hypothesis, a firm's share price reflects all information at our disposal and this also includes the information of currency exchange rates effects. The research conducted by Fama and French (1989) into business conditions and expected returns on stocks and bonds, firm's share prices were found to adjust efficiently based on the firm's specific information.

## 2.3 Firms Exposure to Exchange Rates

In general firm exposure to foreign exchange is the impact of exchange rate fluctuations on its market value, net cash flow and profitability (Shapiro, 2008). It is important for management of the firm to know how the firm value is affected by a given fluctuations in exchange rates and the significance of the volatility caused by exchange rates. This will help to devise the hedging strategies that will protect the firm against future fluctuations (Khoo, 1994). Additionally, Jorion (1990) posits that firm exposure to foreign exchange fluctuations epitomises the sensitivity of the firm value to exchange rate volatility.

It is common that exchange rate fluctuations will affect the value of those firms with foreign interests (Jorion, 1990). The firm profitability and value should fluctuate with the depreciation or appreciation of the trading currency (Bartov & Bodnar, 1994). According to David, Arthur, and Michael (2001) and Martin and Mauer (2003) firms are exposed to exchange rates in

three ways, namely translation exposure, transaction exposure and operating exposure. Theoretically, it is believed that fluctuations in exchange rates will have an impact on firm profits, value, growth and performance. Further, Dumas (1978) asserts that the exposure also includes the operational element which represents the ability of the firm to respond to exchange rates randomness and hedging strategy which can be used to manage the exposure through the balance sheet and transactions adjustments.

*Transaction exposure* – this type of firm exposure relates to the exposure that is brought about by the business transaction that involves the use of foreign currency (Loudon, 1993). When businesses purchase equipment in foreign currency, and it is not settled immediately, the payment will be subjected to the fluctuation of the exchange rates. For example, mining firms source most of their equipment abroad, and this is also exposed to foreign currency exchange. Transactional exposure may result in gain or losses for the firms which may, in turn, affect the cash flow (David et al., 2001).

*Translational exposure* – also known as accounting exposure because the firm accounting books are translated from the foreign to local currencies. This is normally conducted for legal compliance and to inform the shareholders (Martin & Mauer, 2003). Jorion (1990) notes that foreign exchange exposure can be decomposed into the effect of exchange rate randomness on the value of net monetary assets with fixed nominal payoffs, and on the value of real assets held by the firm. When this is abstracted from inflation uncertainty, short-term monetary assets will generally be exposed to exchange risk whereas domestic monetary assets will not. Jorion (1990) refers to this as 'translational exposure'. A typical example of this would be a firm that is listed on different stock markets. Gains or losses may arise as a result of the translation of books, however since these losses are not realised they do not have implication for the business (David et al., 2001).

*Economic exposure* – this type of exposure has a direct impact on the firms' value due to likelihood to have an impact on the firms' assets and cash flows. So far there is no easy way to measure the impact of this type of exposure, which implies that the firms' value will be impacted by the fluctuations posed by the exchange rates. Even though the firms' asset exposure is measurable and can be accounted for in the books, operating exposure has links to other factors like competitiveness, barriers of entry, etc. which cannot be fully accounted for and are subjective (Martin & Mauer, 2003).

Choi and Prasad (1995) posit that the volatility in exchange rates affect the firm's operating cash flows and value of the firm through the translation, transaction and operating exposure. The risks posed by exchange rate fluctuation will not have the same impact in all firms since it depends on the firm's operating profile, financial strategies and other firm-specific variables. Loudon (1993) also asserts that firm's translational and transactional arises as a result of overseas currency denominated trade.

This section of the literature review revealed that South African mining firms are not immune to exchange rate risk and exposure since they are also involved in foreign trades and have significant exports that are traded in foreign currencies. The mining firms' major source of exposure will be leaning more towards the transactional exposure arising from the exports trade with foreign countries like China, Europe, United States, etc. In some instances, these firms may have long term service level agreements, future contracts with the buyers in foreign markets.

## 2.4 Exchange Rates Effects on Firm Performance

Rodrik (2008) observes that "economists have long known that poorly managed exchange rates can be disastrous for economic growth". This observation echoes the same sentiment as many other authors, concurring that there is a relationship between an economy's exchange rate and, by inference, profitability, and ultimately, economic growth. Requena-Silvente and Walker (2007) studying the same phenomena, and relating them in a similar manner, are of the view that profit margins tend to adjust following changes in the exchange rate. Studying the car market in the United Kingdom, the authors' work reveals firms achieved profit gains in foreign markets when the currency of their foreign market depreciated. This suggests that the converse is true; firms' profit margins decrease when the currency of their economic market appreciates. Thus one may safely assume that there is a direct relationship between the exchange rate, its fluctuations and profitability for firms.

To ensure and protect profitability, some firms devise coping methods to deal with the exchange rate changes. Berman, Martin, and Mayer (2009) in Kelilume (2016) note that high and low productivity firms react differently to exchange rate movements. The authors argue that high performance or productivity firms increase their export prices in reaction to exchange rate depreciation, while low productivity firms increase their export volumes. "More

firms enter the export market following depreciation, these firms are small, and their productivity is low, and their extensive margin response to exchange rate movement is small when compared to other firms at the aggregate level" (Berman et al., 2009). All these efforts are undertaken upon noticing that there is a significant relationship between the exchange rate and a firm's profitability. It is thus important for firms to take note of this relationship as it directly affects their main reason for being in the market; making a profit.

Kwasi et al. (2012), in reference to the International Finance Corporation's Sub-Saharan Africa Regional Report of 2003, assert that small and medium enterprises are the lifeblood of growing economies. Several mining firms in Africa, South Africa included, fall within this description. They isolate those that are perceived to attract little direct investment and employ between 10 and 300 employees. The same authors proceed to assert that these growing firms face challenges in the presence of global markets, which expose them to greater risks presented by these global factors, for example, competition. Kwasi et al. (2012) also contend that exchange rate volatility does not only affect profitability but transcends even competitiveness to affect the product's perception in the minds of the consumers.

## 2.5 Research in South Africa

Using regression analysis Jordaan (1986) conducted research into the relationship between share returns and the Rand/USD exchange rates in South Africa over a period 1983 to 1986. The sample included a random selection of thirty mining, financial and industrial shares. The study found that only seventeen of the ninety selected shares in mining, financial and industrial shares were significantly correlated as determined by the size of the regression coefficients. However, the further interpretation could not be made because the direction of the significant regression coefficients was unsteady. The study concluded that there was no significant relationship between firm's share returns and exchange rates.

Mutwanamba (2014) investigated the impact of exchange rates on the chemical industry in South Africa using descriptive and analytical techniques. The study showed that there is no relationship between the exchange rates volatility and prices of chemical products. Further, the results also showed a significant amount of sensitivity to a different definition of the variable used.

van Druten (2005) studied the relationship between the exchange rates (Rand/USD and Rand/Euro) and the value of construction firms listed on the Johannesburg Stock Exchange, using correlation analysis. Looking at weekly and monthly data, the study demonstrated that the Murray and Roberts share price was significantly positively correlated with the Rand/Euro exchange rate. In addition, increase in the share price corresponded with the weakening of the exchange rate.

Lumley (2002) studied the relationship between the Rand/USD exchange rate and the value of resource firms listed on the JSE. The method used was to calculate the direction and significance of the operating exposure regression coefficient of the resource firms on the JSE. The regression of share prices and exchange rates was used to determine the operating firm beta. The results showed that there was no significant positive operational beta over the periods analysed. Lumley (2002) asserts that other factors such as fluctuations in commodity prices may have masked the impact of exchange rates.

## 2.6 Empirical Review

Mining firms have been a significant contributor to foreign exchange earnings in the country (Jones, 2002). The foreign exchange regime, however, has been volatile. Few studies have been done on the impact of large exchange rate movements on firm productivity especially at the industry level. Fung and Liu (2009) state that due to the experience of many countries on large currency depreciation or devaluation in the 1990s, understanding the direction and magnitude of exchange rates on firm performance are of great importance to both policy makers and the firms themselves.

Gao (2000) states that there has been a failure to recognise the significant relationship between exchange rate volatility and contemporaneous changes in the firms' value. Gao (2000) further adds that "theory predicts that an unexpected depreciation of domestic currency will cause a positive abnormal return proportional to a firm's share of foreign sales in its total sales, and a negative return proportional to a firm's share of production located in foreign countries".

Liang and Yu (2014) have stated that floating exchange rates have become a popular exchange regime for many countries. This is because the floating exchange regime is based

on market supply and demand and is normally referenced to a basket of currencies. The referencing of the local currency to others coupled with demand and supply mechanics is then capable of resulting in volatility in the market. Barumwete and Rao (2008) & Baum, Caglayan, and Barkoulas (2001) posit that breakup of the Bretton Woods Gold standard regime in the early seventies, floating exchange rates have proved to be extremely volatile with fluctuations compounded to aggressive short-term fluctuations and also long over – and undervaluation of major currencies such as the dollar and sterling pound. Giving a historical context to this, Mzyece (2012) states that the collapse of the fixed exchange system as propagated by the Bretton woods system in the early seventies led to a broad consensus that on the need to allow for greater flexibility in the international monetary system. The prevailing fixed exchange rate then had to be replaced by the floating exchange rate which has been subject to high market volatility.

Baggs, Beaulieu, and Fung (2008) argue that exchange rate volatility movements can be compared to effects of prolonged episodes of tariff changes because they act in a similar way by changing the competitive position of local firms in the global setting. Exchange rate volatility can result in either appreciation or devaluation of currencies. El-Masry (2006) asserts that a change in the exchange rates, particularly the 'real' exchange rate is likely to affect a firm's future value and expected cash flows. This can result both in the short and long run in a firm losing or gaining a competitive advantage. Mzyece (2012) contends that exchange rate arrangements are part of a bundle of policy options that are available to governments for them to try and ensure stability in their currency markets. It has been noted that real depreciation of the home currency will have a positive effect on a firm's performance, in terms of exports and output. This is in context with what Baggs et al. (2008) assert that exchange rate volatility might lead to either reduction or increases in trade volumes. Such increases in output scales as induced by depreciation will result in higher productivity. Given the large magnitude of currency depreciation, the exchange rate effects on a firm's exports, output and productivity may then be of economic importance.

The deflation policy as will be indicated by a currency appreciation, on the other hand, has been explained by Liang and Yu (2014) as being capable of having an impact on a firm's performance in two ways. It may be positive or negative. Giving an example of the Chinese context, Liang and Yu (2014) observe that there have been consequences in the country as

a result of this policy where firms have begun to go bankrupt in succession. While government officials in the country have tried to counter this trend by insisting that devaluation leads to cheaper imports, the reality is that in the case whether there is inefficiency in the operations of a firm this devaluation is not going to encourage local sales at all and the overall effect may then be closure of the firm. Devaluation, as expected by many government officials, is expected to assist a country to achieve its goal of boosting domestic consumption as imported consumer items become more affordable. Appreciation, on the other hand, should reduce import costs and provide access to capital goods (Liang & Yu, 2014). However, this appreciation is capable of reducing the competitiveness of local products, hence affecting the profitability of local firms. El-Masry (2006) has a similar argument on exchange rates and states that a change in the exchange rate is likely to affect future expected returns and cash flows. The impact of the change in the exchange rates on an industries stock may most likely continue for a considerable period. It is suggested then that due to this lagging, several lags of the exchange rate variables should be included in the projections to cater for any price adjustments that might occur due to these exchange rate fluctuations.

Fung and Liu (2009) demonstrated two opposing effects of an exchange rate appreciation on the sales of local firms (to both international and local markets). The argument advanced by these authors is that the cost advantage faced by domestic firm's forces them to sell less, resulting in inefficient firms exiting the field and in the process leaving existing efficient firms with a larger share of the market. The negative side to this is that higher levels of appreciation will lead to a reduction in the profitability of firms which have a large local market but depends on imports as inputs in their operations.

Di Mauro, Rüffer, and Bunda (2008) are of the opinion that traditionally, the most important way in which exchange rates affect that market is through their impact on trade performance. Liang and Yu (2014) opine that there will be significant negative effects on the appreciation of exporter's profitability. This is because in most cases the profit margins fall due to the decreased capacities of exporters to generate revenue and the declining sales margins.

To further explain this, Bodnar and Marston (2002) developed a simple model to measure the effects of an individual firm's exposure to exchange rate volatility. The model demonstrated that measured exposure elasticities are a function of net foreign currency revenue, and hence will affect profit margins. Large exposure elasticities will normally arise

in firms with large imbalances of foreign currency revenues and costs coupled with low-profit margins. In contrast, Bodnar and Marston (2002) point out that firms with adequate operational hedges in which they offset currency revenue costs can protect themselves from large-scale fluctuations in foreign exchange regimes. Barumwete and Rao (2008) observe that at present many firms attempt to measure, monitor and manage the exchange rate exposure through hedging. Hedging in this context is understood to be taking a contract that will rise (or fall) in value to offset a drop (or rise) in the value of an existing operation (Barumwete & Rao, 2008).

In an attempt to understand the impact of exchange rates on a firm's performance, Arbeláez, Steiner, and Salamanca (2010) state that certain conditions have to be met. One of these conditions is that the firms should be operating in a reasonably flexible exchange rate regime. In addition, the economy in which the firm is operating must equally be both reasonably open financially and communication wise. Agyei-Ampomah, Mazouz, and Yin (2013) studied the sensitivity of 269 UK non-financial firms using the standard Jorion (1990) method and found significant exposure to exchange rate risk. They also assert that the determinants of exchange rates exposure were model dependent.

El-Masry (2006) has pointed out that any exposure to fluctuations in an exchange rate will normally affect the value of a firm or industry. Exchange rate exposure in this regard should be considered as being the extent to which the value of a firm is affected by prevailing exchange rates. This is in agreement with Mzyece (2012) who states that floating exchange rates are determined by supply and demand forces. In this regard, floating exchange rates will adjust to receipts and payments involved in international transactions. This will be related to the demand and supply of goods and services that are needed or are exported by a country. Individual firms will then be affected depending on the type and volume of goods or services that they supply at the international level.

Using a sample of 3788 firms for a period between 1984 and 2013 from developed countries, Hutson and Stevenson (2010) posited that the firms were significantly affected by the randomness of the exchange rates when operating in countries with more open economies, this observation was made even when the firm size, industry and several variables were controlled. The study further suggests that there was a strong inverse relationship that existed

between the firms' exchange rate exposure and the extent of creditor protection in the country in which they operate.

## 2.7 Summary of literature review

The literature review presented existing theoretical views regarding what experts in the field have argued about the phenomena under study. The intention has been to review the arguments that have been put forward on the relationship between exchange rates and firm profitability and share returns (firm value). It was noted that a paucity of information exists in the context of firms within the South Africa, particularly those in the mining sector.

The literature review also showed that it is difficult to make a conclusion based on the past research since it showed conflicting views, this can be noted from the findings made by, Bartov and Bodnar (1994) and Jorion (1990) which showed that the firm's values are not affected by the exchange fluctuations, however, recent studies by Agyei-Ampomah et al. (2013), Choi and Prasad (1995), Dominguez and Tesar (2006), El-Masry (2006), and Hutson and Stevenson (2010) found that firms were very sensitive to exchange rates volatility.

It is apparent from the review that majority of the studies conducted did not focus on the mining firms particularly those listed on the JSE. Additionally, most studies focused on developed countries and looking mainly on the multinationals and financial institutions. Thus there is a lack of focus on the mining firms particularly those listed on the JSE. This study will contribute to the current body of knowledge and help mining firms' manager in decision making amid foreign exchange exposure and risk.

# CHAPTER 3. METHODOLOGY

This chapter presents the methodology used in carrying out the study. This is then followed by a description of the research method. In this section, the approach used in carrying out the study is identified. The population of the study is then postulated. The research design and data collection methods are identified. Validity and reliability of the study are then discussed before conclusions of the chapter are made.

## 3.1 Research approach

The scientific method has always been adopted in any academic research. Barumwete and Rao (2008) posit that there are two methods of reasoning in a scientific approach. These are the inductive and deductive approaches. While a deductive approach is aimed at testing theory, the inductive approach, on the other hand, will attempt to generate new theories from the data that will have been collected during the course of the research. Trochim, Donnelly, and Arora (2015) state that deductive reasoning works from the more general to the more specific and is sometimes referred to as the 'top down' approach. It begins with a theory and narrows down to the specific testable hypothesis. Observations can be made from the data collected to address the hypothesis. This will lead to the testing of the hypothesis by analysing the data to confirm or reject the original theory.

Inductive reasoning, on the other hand, works the opposite way. It begins with specific observations and then moves to broader generalisations and theories, and has often been referred to as a 'bottom up' approach. Its mode of operation is that it begins with specific observations and measures, tries to recognise emergent patterns and regularities in the data, formulates some tentative hypothesis that can be explained, and ends by developing some conclusion that can lead to theories. Trochim et al. (2015) further add that while inductive reasoning is more open-minded and exploratory, deductive reasoning, on the other hand, is narrower in nature and will be concerned with testing or confirming hypotheses.  state that the inductive approach will very often be associated with the qualitative method, while the deductive approach which is a hypothesis testing method, is more often associated with the quantitative approach. This research adopts a deductive reasoning approach to examine the impact of foreign exchange volatility on firm performance.

## 3.2 Research method

Several research methods have been suggested for use in business research. These are the quantitative, qualitative and mixed methods approaches. The qualitative method uses non-numeric values and is more interested in richness, quality or 'feeling' of raw data (Barumwete & Rao, 2008). The quantitative method on the other hand normally comprises a measurement and will be interested in the analysis of causal and effect relationships between the variables under study. Bryman and Bell (2007) assert that this approach places core emphasis on issues of design, measuring and sampling.

This study, as stated earlier, adopts a quantitative approach. This is because it is interested in the impact of causal and effect relationships between exchange rate volatility and firm value, which is best measured by numerical data. The study intends to identify the variables that are important in determining firm performance and linking them to foreign exchange volatility. Data will hence be collected on these variables. The variables will then be divided into independent and dependent variables. The E-views 9.5 enterprise statistical software package was used to analyse the data. After the variables have been identified, they will undergo regression and correlation analyses to determine the relationships that exist between these variables. Specifically, regression and correlation analysis will be able to determine the impact of foreign exchange volatility on firm value as the collected data will be on movements in share prices, exchange rates and profits of mining firms that are listed on the JSE over a period of sixteen years, i.e. from January 2000 to December 2016.

## 3.3 Research design

This study is aimed at examining the impact of exchange rate volatility on firm value. As such it requires that data be collected on share prices, exchange rates and other macroeconomic factors for the period between January 2000 and December 2016. A suitable research design hence has to be selected to facilitate this. Barumwete and Rao (2008) describe a research design as being a framework for conducting a research and analysing collected data. A research design will outline the processes needed to obtain relevant information to approve or disapprove the formulated hypothesis in a quantitative study or answer the research question in a qualitative study. A longitudinal study was considered to be ideal in researching this topic. Rajulton (2001) states that longitudinal studies are concerned with progress and

change in status over time. Longitudinal studies derive repeated measurements of the same concept over a time span long enough to encompass a detectable change in their developmental status. Rajulton (2001) further adds that the span of observation in such a study will depend mainly on the issues of investigation and its rate of change. In this study, the time span selected was sixteen years. During the selected time period, there has been marked fluctuations in the foreign exchange regime in the country, which was worsened by the 2008/9 financial crisis that affected global trade. This study considers the longitudinal design to be ideal as it will be able to show the impact (if any) of volatility in the foreign exchange market and how it has impacted on individual firm value.

## 3.4 Population

The population of a study refers to the entire group of individuals or objects for which the study attempts to generalise its findings of (Schindler & Cooper, 2005). The target population for this study was the top 10 mining firms (by value) based in South Africa and only listed on the JSE. There is a total of 39 active mining firms in the basic resources sector of the bourse. All these firms are export oriented and as such are exposed to the volatilities associated with the foreign exchange regime.

## 3.5 Data collection

Secondary data was used in this study. The data was obtained from the Johannesburg Stock Exchange, South Africa's department of Trade and Industry, Bloomberg Terminal and South African Reserve Bank (SARB). The time line of the data has been indicated earlier as from January 2000 to December 2016. This timeline is sufficient as it will enable the portrayal of the volatilities that have been experienced in the foreign exchange market.

## 3.6 Data analysis

Frost (2015) posits that although it is difficult to develop a model that is a complete representation of the problem, a good regression model will include variables that are being tested and additional variables that will affect the outcome of the model to avoid spurious results. This section presents the framework in which the empirical work will be conducted.

The variable to be used in the regression equation are informed by two areas that encapsulate the firm value. Further, the variables are divided into two groups, the macroeconomic variables, those that the firm has no control of and the firm-specific variables, those that the firm can control. The macroeconomic variables are borrowed from the determinants of exchange rates exposure and those include inflation, interest rates, gross domestic products. The exchange rates were modelled using the $GARCH\ (1.1)$; a constructed trade weighted real exchange rates was used to measure exchange rate volatilities and it is explained in the subsequent sections. The firm specific variables includes the share price, market capitalization (size of the firm), market index (Fama & French, 1993). The data used for the study was collected monthly and it spans from January 2000 to December 2016.

Following Adjasi and Biekpe (2005), Brooks (2002) and Jorion (1990), all the time series data were converted to logarithmic returns using the formula presented by equation (1),

$$r = \left(\frac{sp_t - sp_{t-1}}{sp_{t-1}}\right) \quad \text{or} \quad r = (lnsp_t - lnsp_{t-1}) \tag{1}$$

In logarithmic form, $r$ the returns, $sp_t$ is the share price at time $t$, $sp_{t-1}$ is the share price for previous period $t-1$. Thus, the stock market return $s$ and the exchange rate movement or changes $e$ is computed as depicted in equation (2) and (3),

$$s = (lnP_t - lnP_{t-1}) \tag{2}$$

$$e = (lnE_t - lnE_{t-1}) \tag{3}$$

where $P$ and $E$ are the stock market index and exchange rate respectively.

### 3.6.1 *Trade-Weighted Real Exchange Rate*

Due to the reasons mentioned in the literature review, the real exchange rate was used for this study as it enables the representation of the country's currency in relation to the other major trading partners' index. In order to develop the trade-weighted exchange rates, the study adopts the model "Afro currency index" developed by Kodongo and Ojah (2011) which in their earlier studies referred to it as the AFRO index (Kodongo & Ojah, 2014). The AFRO index equation is presented in equation (4) below

$$I_t = I_{t-1} \prod_{i=1}^{n} \left( \frac{RER_{j,t}}{RER_{j,t-1}} \right)^{W_{j,t}} \quad (4)$$

where $I_t$ is the real exchange index at time $t$, $I_{t-1}$ is the real exchange index at previous time $t-1$, $RER_{j,t}$ and $W_{j,t}$ are the local currency to foreign real exchange rate and the weight of country $j$ at time $t$ respectively. The formula to compute the weight of country $j$ at time $t$ is given by equation (5) below,

$$W_{jt} = \frac{X_{jt}}{\sum X_{jt}} \quad \text{where } X_{jt} = \varphi_{jt} + \emptyset_{jt} \text{ and } \sum_{j=1}^{n} W_{jt} = 1 \quad (5)$$

Such that,

$$\varphi_{jt} = \frac{country\ j's imports\ from\ foreign\ country\ in\ month\ t}{country\ j's total\ imports\ in\ month\ t} \quad (6)$$

$$\phi_{jt} = \frac{country\ j's\ exports\ to\ foreign\ country\ in\ month\ t}{country\ j's total\ exports\ in\ month\ t} \quad (7)$$

substituting (6) and (7) into (5) will result in equation (8) presented below

$$W_{jt} = \frac{X_{jt}}{\sum X_{jt}} = \frac{\varphi_{jt} + \emptyset_{jt}}{\sum(\varphi_{jt} + \phi_{jt})} \quad (8)$$

The variables, $j$ is the foreign country in this case the South Africa's top trading partners, $\chi_j$ represents the total value of trade exports of local country to foreign country $j$, $\varphi_j$ is the total value of trade imports from foreign county $j$ to local country, $\varphi_j$ and $\phi_j$ refers to the exports and imports of foreign country $j$ respectively.

Kodongo and Ojah (2014) and Fung and Liu (2009) asserts that because of its ability to capture the exchange rates movements across South Africa major trading countries this model is robust and can be used for the representation of the South African rand exchange rates. The trade-weighted exchange index was referred to as $TwExR$ in this study.

### 3.6.2 *Calculating the Exchange Rate Volatility*

The exchange rate volatility was called the degree of the exchange rates fluctuations. Various literature (Black & McMillan, 2004; Dominguez, 1998; Engle & Patton, 2001; Kenen & Rodrik, 1986; McKenzie & Brooks, 1997; Ng'ambi, 2015) suggests that there is numerous method

that can be adopted for the computation of the degree of exchange rate volatility. In this study the generalised autoregressive conditional heteroscedasticity, $GARCH\ (1,1)$ progressed by Bollerslev (1986) was used to model volatility in the exchange rates.

The logarithmic difference return of the South Africa's major trading partners trade-weighted exchange index was used when modelling the exchange rate volatility as depicted in equation (9) similar to Bodnar and Marston (2002). The modified return of trade-weighted equation is depicted in equation (9).

$$R_r = ln\left(\frac{I_t}{I_{t-1}}\right) \times 100 \tag{9}$$

in this equation, $R_t$ represents the daily return on trade weighted exchange rate, $I_t$ trade weighted exchange index at time $t$ and $I_{t-1}$ is the trade weighted exchange index at previous time $t-1$.

**The $GARCH\ (1,1)$ Model**

Hansen and Lunde (2005) posits that due to its simplicity and intuitive appeal $GARCH\ (1,1)$ by Bollerslev (1986) is a good starting point for modelling risk and uncertainty usually associated with financial returns. The $GARCH\ (1,1)$ is and extension by (Bollerslev, 1986) of the $ARCH$ model progressed by (Engle, 1982). Similarly, any other $ARCH$ models, the $GARCH$ also incorporate the descriptive variable the lags of the squared error terms, however it also extends to, incorporate the lags variance term as a descriptive variable.

The $GARCH\ (1,1)$ incorporate the mean equation and the variance equation as depicted by equations (10) and (11) respectively.

$$Y_t = X_t'\theta + \epsilon_t \tag{10}$$

Equation 10 is represented as an exogenous variable of $X$ and the $\epsilon$ error term.

$$\sigma_t^2 = \alpha_0 + \alpha\epsilon_{t-1}^2 + \beta\sigma_{t-1}^2 \tag{11}$$

Where (11) is the conditional variance equation as an element of three parameters, namely, $\alpha_0$ the mean term, $\alpha\epsilon_{t-1}^2$ the squared error term of the $ARCH$ model, $\beta\sigma_{t-1}^2$ the squared variance term of the $GARCH$ model. Brooks and Rew (2002) asserts that the $ARCH$ existence

should be tested for residuals before the estimation by $GARCH$ model is applied. The testing procedure to be followed is outlined below.

Initially, the regression on autoregressive model depicted by equation (1) for the trade-weighted exchange rate is conducted. The ordinary least square (OLS) is used to obtain the residuals. The proposed autoregressive equation (12) for the trade-weighted exchange rate (1) see Engle (1982) for details.

$$TwExR = \alpha_0 + \sum_{i=1}^{k} \gamma TwExR_{t-1} + \epsilon t \quad (12)$$

The $TwExR$ represents the trade weighted exchange rate, $TwExR_{t-1}$ depicts the lagged term, $\alpha_0$ is a constant, $\epsilon_t$ is the error term, $k$ is the number of lags. By dropping the insignificant lags until the last lag is significant, it enables us to determine the dependent variable lag length selection, $k$.

The second step after determining the residuals is to conduct a regression on the squared residuals on own $q$ lags, as represented by equation (13) below

$$\epsilon_t = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \alpha_2 \epsilon_{t-2}^2 + \cdots + \alpha_q \epsilon_{t-q}^2 + v_t \quad (13)$$

the terms $\alpha_0$ represents a regression constant, $\epsilon^2$ is the squared residual term, $v_t$ is the error while $q$ is the lag length. Equation (14) is used to test the Null hypothesis, $H_0$, there is no $ARCH$ effects in the residual series against the alternative hypothesis (15), $H_1$ there is an $ARCH$ effects in the residual series.

$$H_0 = \alpha_1 = \alpha_2 = \cdots = \alpha_q = 0 \quad (14)$$

$$H_1 = \alpha_1 = \alpha_2 = \cdots = \alpha_q > 0 \quad (15)$$

To test the Null or the alternative hypothesis, the critical value of the test statistics $(TR^2)$ was determined by multiplying the number of observations by $R$-squared and assessed against the Chi-squared of the lag length $q$, $\chi^2(q)$. In a case where the $TR^2 > \chi^2(q)$ the Null $(H_o)$ will be rejected the it will be concluded that there $ARCH$ effects are present in the series, whereas if the $TR^2 < \chi^2(q)$ the null hypothesis will be accepted, and the conclusion will be there are no ARCH effects in the residual series (Ng'ambi, 2015).

In cases where there is a presence of $ARCH$ in the time series, the (Bollerslev, 1986) $GARCH\ (1,1)$ model will be used to as depicted in equation (16) bellow.

$$\sigma_t^2 = \omega + \sum_{i=1}^{p} \alpha_1\, \epsilon_{t-1}^2 + \sum_{i=1}^{q} \beta_1 \sigma_{t-1}^2 \quad (16)$$

Where $\epsilon_{t-1}^2$ squared error term, $p$ is the $ARCH$ term, and squared variance term, is the $GARCH\ (q)$ term. The $GARCH\ (1,1)$ model represents the modeled exchange rate volatility, henceforth referred the term as $ExRVol$ is kept in the research to evaluate the effect of exchange rate volatility on the firm's value of the South African mining firms listed on the JSE.

## 3.7 Stationarity Tests

Kelilume (2016) asserts that to prevent false results the unit root test is conducted to ensure that the data is stationary because a non-stationary data will tend to show a trend. Using the ordinary least square (OLS) regression procedure on non-stationary data can lead to spurious results and wrong conclusions being made. It is recommended therefore that, the trending nature of the data (i.e. non-stationery) must be eliminated before the regression can be conducted using the data. In addition, Brooks (2002) added that it is inherent for macroeconomic data to be non-stationary, which often create a problem in research since they exhibit a trend.

The Augment Dickey-Fuller (ADF) which is an extension of Dickey and Fuller (DF) was used in this work. The ADF includes additional lagged terms of the dependent variables to get rid of the autocorrelation (Adjasi & Biekpe, 2005). Brooks (2002) discredited the DF method and liked the ADF, the former has greater critical values and may reject some of the hypothesis even though they are correct.

The methods test for the following hypothesis, whether there is a non-stationary data or not? i.e. whether the hypothesis contains the unit root test. The Null ($H_o$) hypothesis of the unit root test will state that there is unit root;

$$H_0: \alpha_i = 0 \quad (17)$$

While the alternative hypothesis will state that there is no unit root;

$$H_1: \alpha_i < 0 \quad (18)$$

The results from the hypothesis testing suggest that the rejection of the null hypothesis will imply that the data is stationary while the converse is true (i.e. the acceptance of the $H_o$ imply that the data is non-stationary). The process of generating the hypothesis testing is described below in equation (19).

$$\Delta Y_t = \emptyset Y_{t-1} + \sum_{i=1}^{k} \alpha_i \Delta Y_{t-1} + \epsilon_t \quad (19)$$

The terms $\Delta Y_t$ refers to the lag of the dependent variable, $\epsilon_t$ the error term while $k$ is the dependent variable's augmented lag length. The lag length will be dropped until the last lag is significant. The EViews 9.5 enterprise statistical software was used to conduct the unit root tests. For the stationery and non-stationary series, the variable $Y_t$ was integrated to the order $d$ (Kelilume, 2016).

This procedure was followed to avoid arriving at wrong results and making the wrong conclusion in this work. Once the variables were tested for stationarity, the tests for causality and regression was then conducted to evaluated the relationship that existed between the dependent and independent variables. Their significance and the nature of impact was also determined by regressions.

## 3.8 Causality Analysis

The main aim of this work is to study the impact rendered by exchange rate volatility on the firm value of South African mining firms listed on the JSE. Granger, Huangb, and Yang (2000) assert that it is important to investigate causality between the stock returns and exchange rates movement to improve the current understanding. To test for the causality and the direction of causality, the Granger causality test was used to test for causality between the regression variables (Granger, 1969). The bivariate vector autoregression (VAR) model was used to compute the Granger causality between the exchange rate volatility and the share returns and market capitalization since the VAR deems all variables in the system as endogenous.

Brooks (2002) posits that if one variable causes the other "Granger cause the other", there should be significant lags of that variable in the equation. The Schwartz Bayesian Information Criteria (SIC) was used in this study to specify the lag length. The rationale behind the selection is to choose the number of parameters that can minimise the value the of the

information criteria. The SIC was selected in this case because it offers the correct order model without becoming too large (Brooks, 2002). The SIC is specified as follows (20):

$$SIC = log\left[\check{\Sigma}\right] + \frac{k'}{T} + \log(T) \quad (20)$$

where $\check{\Sigma}$ represents the covariance matrix, T number of observations, $k'$ the sum of all regressors in the equation. The lower the value of the SIC the better the model fit.

The VAR model is depicted by equation (21) below

$$ExRVol_t = \alpha_0 + \sum_k \beta_{11k}\, ExRVol_{t-k} + \sum_k \beta_{12k}\, SR_{t-k} + \epsilon_t \quad (21)$$

$$SR_t = \alpha_0 + \sum_k \beta_{21k}\, SR_{t-k} + \sum_k \beta_{22k}\, ExRVol_{t-k} + \epsilon_t \quad (22)$$

the symbol $SR_t$ represent the share return while the $ExRVol_t$ represent the exchange rate volatility at time period $t$, $\epsilon_t$ is the error term and $k$ Schwartz Bayesian information criterion optimal lag length computed in equation (22).

The null hypothesis for causality determined by equation (23) and (24) states that the exchange rate volatility does not cause share return (i.e. value) of the mining firms in South Africa listed on the JSE.

Therefore, $ExRVol$ to $SR$ equation (23)

If $H_o = \beta_{12k}$=0 (23)

If the Null hypothesis cannot be rejected it means that the exchange rates volatility does not Granger cause share returns.

From the $SR$ to $ExRVol$ in equation (24)

If $H_o = \beta_{22k} = 0$ (24)

If the null hypothesis (24) cannot be rejected it means that the share returns do not Granger cause the exchange rate volatility.

The same can also be repeated for the other variables to check for causality between the regression variables, both dependent and independent variables. The other alternative test

that can be used to check for the causality in the variable is the ordinary least square (OLS) technique (Stock & Watson, 2001).

## 3.9 Estimation Model

El-Masry, Bartram, and Bodnar (2007) posit that the most common method employed by the academics to measure the firm exposure to exchange rate volatility is a simple linear regression of stock returns on the exchange rate variable. Additionally, Jorion (1990) asserts that exposure of firms to foreign exchange volatility represents the sensitivity of the value of the firm to exchange rate randomness and can be measured by the regression coefficient of the change in the value of the firm on the change in the exchange rate.

In recent studies, Flota (2014) and El-Masry et al. (2007) put forward that a dual-stage regression model which is based on the Capital Asset Pricing Model (CAPM) is most commonly applied to literature on exchange rate exposure. In the first stage of the model, the exchange rate exposure of the firm is measured while the second stage deals with the estimation of the determinants of the exposure (Dominguez & Tesar, 2006).

### 3.9.1 *Measuring Exchange Rate Exposure*

In this two-factor model, for a firm to be considered exposed to exchange rate risk, the firm stock returns must be correlated with the changes in the exchange rates randomness (Dominguez & Tesar, 2006; El-Masry et al., 2007; Flota, 2014). The model is also similar to the time series regression with multilateral exchange rate index as suggested by Adler and Dumas (1984) and , and the equation presented in (25).

$$R_{it} = \alpha_i + \beta_i R_{Mkt,t} + \delta_i R_{FXt} + \epsilon_{it} \quad (25)$$

Where $R_{it}$ is the rate of returns on the $i^{th}$ firm's ordinary stock at time $t$, $R_{Mkt,t}$ is the is the return on the market portfolio (index), $R_{FTt}$ is the rate of change of the trade weighted exchange rate $(ExRVol)$, computed as described in section 3.6.1, $\beta_i$ is the firms market beta, $\delta_i$ represents all the changes in the returns that can be explained by the exchange rate movements after adjusting for the market return. In this model the exchange rate exposure of the firm to is defined by the coefficient $\delta_i$ (Dominguez & Tesar, 2006; Flota, 2014; Jorion, 1990).

Dominguez and Tesar (2006) asserts that the CAPM model interpretation indicates the firms' asset price should only be explained by market risk and therefore it is only the changes from market risk that should affect the firms share returns ($R_{i,t}$). The further argued that if this model was a good representation of the asset price, the coefficient of firm exposure to exchange rates ($\delta_i$) would be zero indicating that exchange rates are not important for share returns and that the market would efficiently prices the systematic risk.

It must be noted that in this work equation (25) is used as a framework in a cross-section of mining firms for separating the association between excess returns and exchange rates. No attempt will be made to approve or disapprove any of the CAPM theories or to test whether the exchange rates risk is better priced (Dominguez & Tesar, 2006).

### 3.9.2 *Estimating the Determinant of Firms' Exposure*

The second part of the model's objective is to determine whether currency exposure is correlated with significant differences in stock returns. The firm level exchange rate exposure coefficient $\delta_i$ obtained in the prior regression step is regressed on a series of likely firm level explanatory variables that have potential to explain the causes of firm exposure (Dominguez & Tesar, 2006; Flota, 2014). The regression equation is given by (26)

$$\delta_i = \lambda + \gamma_i X_i + \omega_i \tag{26}$$

Where $\delta_i$ coefficient represents firm $i^{th}$ exchange rate exposure i.e. the change in returns that can be explained by the fluctuation in the exchange rates after conditioning for the market return, $X_i$ represents the firm size, age variables and ratio of foreign sales, where firm size in this case is computed as market value or market capitalization of the firm and as the logarithm of the firm's market value of equity, the age computed as the date on which the firm was first listed on the JSE and the foreign sales was computed as the firm's ratio of the sales outside South Africa to total sales. Additional parameter not included in this work include the liabilities denominated in foreign currencies (Dominguez & Tesar, 2006; Flota, 2014).

## 3.10 Reliability and Validity

To ensure the quality of the study is up to the required standard, validity and reliability will have to be considered, in order to reduce the possibility of incorrect findings emerging from

the study, which may lead to flawed interpretation. Field (2009) states that reliability deals with the accuracy and precision of a measurement procedure while validity is the extent to which test measures what it is intended to measure.

This leads to the concept of internal and external validity. To achieve external validity, the data obtained should be able to be generalizable across the whole population. Schindler and Cooper (2005) indicate that “external denotes generalisation, which is deemed to be a result of an inductive process of extrapolating beyond the data collected”. Since the data being collected comprises of informal records by both the firms, South Africa department of Trade and Industry (DTi), the JSE, Reserve Bank of South Africa and Statistics South Africa, it is deemed to be reliable and as such meets the criteria of validity. The data collected also meets the requirements of internal validity, which has been defined by Mouton and Marais (1988) as being able to generate valid findings of the specific phenomena under study. This means that the data collected must be accurate or reliable and that the methods employed for analysing the data are relevant to the type of data collected. Regression and correlation analysis will enable this criterion to be met. The measurement used will then be proven to be valid and conclusions made will be able to be supported by the data.

## 3.11 Summary

The methodology chapter detailed the approach that will be followed to achieve the objectives of this research. It outlined how the exchange trade-weighted exchange rate will be calculated, how the $GARCH\ (1,1)$ was used to determine the rate of exchange rate volatility. The Augmented Dicky Fuller (ADF) tests for unit roots (test for stationary) on the economic variables time series and the regression equation based on the two-factor CAPM model. The regression model was used to determine the relationships that exist between the dependent and independent variable. The E-views 9.5 enterprise statistical software was utilised to conduct all the necessary calculations. The model can now be used to conduct the tests required and the results of these test will be presented in Chapter 4.

# CHAPTER 4. RESULTS AND ANALYSIS

The chapter presents the results obtained with the econometric analysis as outlined in chapter 3 with regards to the impact rendered by the exchange rate volatility on the firms' value of the South African mining firms listed on the JSE. The study includes monthly data for a period from January 2000 to December 2016 (i.e. sixteen years). This data was collected from the JSE, South Africa's department of Trade and Industry (DTi), South African Reserve Bank, and Bloomberg Terminal database. To carry out the computations, all the time series data were transformed into returns.

The remainder of this chapter is structured as follows; the chapter starts by outlining the construction of the trade-weighted exchange rate in section 4.1, description of variables to be used in this study i.e. descriptive statistics of the data in section 4.2,the use of $GARCH\ (1,1)$ for modelling of exchange rate volatility in section 4.3, testing for stationarity of the data, unit root testing in section 4.4, the regression results are presented in section 4.5, the causality tests in section 4.6, and lastly section 4.7 covers the summary of the results section.

## 4.1 Trade-Weighted Exchange Rate

The construction of the trade-weighted exchange rate was conducted following the procedure described in chapter 3 section 3.6.1. The countries used for calculation were chosen based on the bilateral trade agreements between them and South Africa. The import and export data gathered from the DTi was used for the calculation of the index. These countries ranked amongst the top nine trading partners for South Africa (Department of Trade and Industry, 2017). The weightings assigned to each one of them based on the DTi ranking and authors' own computations is presented in Table 4-1 below.

It is important to note that some of the African countries that feature prominently on the list of South Africa's top trading partners include Botswana, Namibia, Mozambique and Angola, the first three feature on the top 10 in terms of South Africa exports to the world and do not feature on the top 20 of South Africa's import from the world. Angola, on the other hand, features on the top 10 import partners and does not feature on the top 20 exports to the world by South Africa. Thus, these countries data did not feature on the calculations of the trade-weighted exchange rate.

**Table 4-1: The weights assigned to South Africa's top trading partners**

| South Africa Trading Partner | | Weight of Trade (Percentage of Total) | Currency |
|---|---|---|---|
| i. | China | 28.4% | Renminbi (CNY) |
| ii. | Germany | 28.3% | Euro (€) |
| iii. | United States | 14.5% | US Dollar (USD,US$) |
| iv. | India | 8.88% | Rupee (INR) |
| v. | Japan | 8.32% | Yen (JPY) |
| vi. | United Kingdom | 7.44% | British Pound (GBP, £) |
| vii. | Netherlands | 4.55% | Euro (€) |
| viii. | Belgium | 4.33% | Euro (€) |
| ix. | The Republic of Korea | 3.26% | Won (KRW) |
| **Total** | | **100%** | |

Source: (Department of Trade and Industry, 2017) and author's own calculations

The trade-weighted exchange rate ($TwExR$) series was used to measure the volatility rendered by the exchange rates in this investigation, i.e. individual country exchange rates was not used.

## 4.2 Data Description

All the data used for the study of the impact of exchange rate volatility on the firm value of South African mining firms listed on the JSE was summarised by the descriptive statistics of the samples used. The statistical description of the data provides a glimpse of the data used for the study. The descriptive statistics summary is presented in Table 4-2 below.

The descriptive statistics showed that a total of 204 data points was used for each variable, except for EXX, KIO, RBP and WEZ were 182, 122, 74 and 133 data points were used respectively. The fewer data points were because of the date of the listing for these firms, i.e. EXX, KIO, RBP and WEZ were first listed on the JSE in 2001, 2006, 2010 and 2005 respectively.

The kurtosis of the data exceeds three in all variables which indicate that the data is leptokurtic, the data has more outliers when compared to a normal distribution. It is also noticeable that TWER, ASR, EXX, KIO and WEZ were positively skewed while all the other variables were negatively skewed. The Jarque-Bera was used to tests if the variables used have the skewness and kurtosis that matches the normal distribution. The test rejects the null

hypothesis of normality for most of the variables, except the ALSI and ANG variables confirming that all the financial variables are non-normal distributed. The trade-weighted exchange rate ($TwExR$) had the lowest volatility with a standard deviation of 0.019 compared to all the other variables, while WEZ had the highest volatility with a standard deviation of 0.178. The results can be seen as a sign that the standard deviation obtained with the trade weighted exchange rate showed some sort of variability (volatility).

**Table 4-2: The descriptive statistics summary of the data**

| | ALSI | TWEXR | AMS | ANG | ARI | ASR | EXX | IMP | KIO | NHM | RBP | WEZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.01 | -0.001 | 0.002 | 0.000 | 0.003 | 0.018 | 0.014 | 0.002 | 0.003 | 0.008 | -0.008 | -0.009 |
| Median | 0.01 | -0.001 | 0.014 | 0.000 | 0.0062 | 0.019 | 0.011 | -0.002 | 0.008 | 0.010 | 0.000 | -0.017 |
| Maximum | 0.130 | 0.135 | 0.350 | 0.412 | 0.424 | 0.441 | 0.430 | 0.340 | 0.733 | 0.520 | 0.283 | 0.695 |
| Minimum | -0.150 | -0.058 | -0.621 | -0.393 | -0.753 | -0.381 | -0.361 | -0.498 | -0.390 | -0.389 | -0.319 | -0.679 |
| Std. Dev. | 0.050 | 0.019 | 0.124 | 0.123 | 0.1265 | 0.114 | 0.118 | 0.125 | 0.145 | 0.129 | 0.096 | 0.178 |
| Skewness | -0.272 | 1.518 | -0.620 | -0.009 | -1.387 | 0.099 | 0.034 | -0.221 | 0.618 | -0.030 | -0.420 | 0.368 |
| Kurtosis | 3.596 | 15.85 | 5.863 | 3.766 | 10.53 | 4.488 | 4.028 | 4.344 | 8.225 | 4.074 | 4.571 | 6.664 |
| Jarque-Bera | 5.527* | 1482** | 82.78** | 4.986* | 547.9** | 19.15* | 8.054* | 17.02** | 146.5** | 9.840* | 9.792* | 77.40** |
| Probability | 0.063 | 0.000 | 0.000 | 0.083 | 0.000 | 0.001 | 0.018 | 0.000 | 0.000 | 0.007 | 0.007 | 0.000 |
| Sum | 1.800 | -0.210 | 0.370 | 0.030 | 0.610 | 3.650 | 2.530 | 0.320 | 0.330 | 1.660 | -0.590 | -1.260 |
| Sum Sq. Dev. | 0.470 | 0.070 | 3.130 | 3.080 | 3.250 | 2.630 | 2.500 | 3.150 | 2.530 | 3.370 | 0.680 | 4.170 |
| Observations | 204 | 204 | 204 | 204 | 204 | 204 | 182 | 204 | 122 | 204 | 74 | 133 |

The ALSI – JSE All Share Index, TWEXR – Trade-Weighted Exchange Rate, AMS – Anglo American Platinum Ltd, ANG – AngloGold Ashanti Limited, ARI – African Rainbow Minerals Ltd, ASR – Assore Limited, EXX – Exxaro Resources Limited, IMP – Impala Platinum Holdings Limited, KIO – Kumba Iron Ore Ltd., NHM – Northam Platinum Limited, WEZ – Wesizwe Platinum Ltd., Std. Dev – Standard Deviation. The * and ** denote the 5% and 1% level of significance to reject the null hypothesis of Jarque-Bera tests.

## 4.3 Exchange Rate Volatility

The plot of the trade-weighted exchange rate ($TwExR$) for the period between 2000M1 and 2016M12 is presented in Figure 4.1 below.

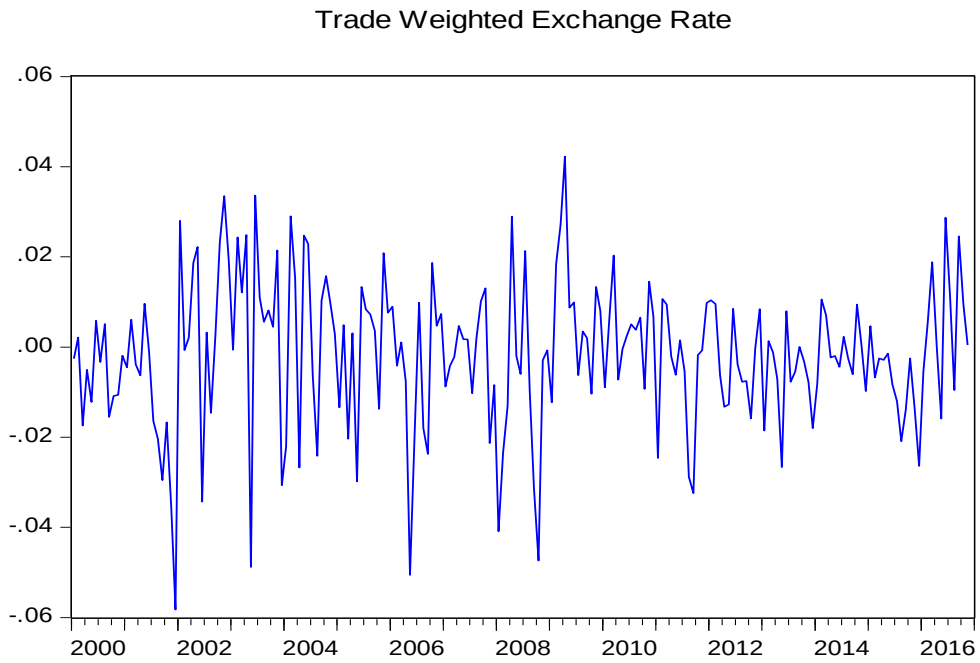



**Figure 4-1: The Trade-Weighted Exchange Rate plot for period 2000M1 to 2016M12**

The line graph of $TwExR$ return series clearly exhibits the volatility clustering which is one of the inherent features of the financial time series data. Brooks (2002) posits that when a return series exhibit the clustering, the small and large movement of the time series track each other. After plotting the time series, the $TwExR$ data was tested for the presence of the $ARCH$ in the return series. The results of the tests are presented Table in 4-3 below.

**Table 4-3: The test for presence of $ARCH$ in the $TwExR$ return series**

| **Heteroskedasticity Test: $TwExR$** | | | |
|---|---|---|---|
| F-statistic | 1796.23 | Prob. F (1,201) | 0.00 |
| Obs*R-squared | 182.57 | Prob. Chi-Square (1) | 0.00 |

Note: The null hypothesis is that there is no $ARCH$ and the alternative is that there is a presence of $ARCH$. Obs*R-Squared is the number of observations times the R-Square. Prob.F is the p-value of the F-statistics and Prob. Chi-Square is the probability of Chi-Square.

The results of the test showed that the p-value of the F-statistics was below the critical value, i.e. 5% level of significance, therefore the null hypothesis can be significantly rejected with a p-value of zero. The results showed that there is a presence of an $ARCH$ in the $TwExR$ return series. The test implies that the $GARCH(1,1)$ model can be applied to the $TwExR$ data. The results of the $GARCH\ (1,1)$ are presented in Table 4-4 below.

**Table 4-4: The results of the estimated $\boldsymbol{GARCH\ (1,1)}$ model**

| | Coefficient | Std. Error | z-Statistic | Prob. |
|---|---|---|---|---|
| **Mean Equation** | | | | |
| c | -0.0068 | 0.0025 | -2.6993 | 0.0069 |
| **Variance Equation** | | | | |
| c | 0.0001 | 0.0001 | 1.3326 | 0.1826 |
| ARCH (p) | 0.1814 | 0.0569 | 3.1876 | 0.0014 |
| GARCH (q) | 0.7706 | 0.0749 | 10.2898 | 0.0000 |

Note: The mean and variance equations of the Dlog($TwExR$) c is given $R_t = c + \epsilon_t$ and $\sigma_t^2 = \omega + \alpha\epsilon_{t-1}^2 + \beta\sigma_{t-1}^2$ respectively.

The sum of the coefficients of the $ARCH(p)$ and $GARCH(q)$ is close to one, i.e. 0.9519 which indicates that there are persistent volatility shocks in the series. The results satisfy the rule that total sum of the $ARCH$ and $GARCH$ term in this test must not exceed one. This is the further testament that the $GARCH(1,1)$ is appropriate for modelling the financial series data.

The $GARCH\ (1,1)$ was used to estimate the exchange rate volatility using trade weighted exchange rate *($TwExR$)*. The $GARCH$ conditional standard deviation was used to represent the volatility of the trade weighted exchange rate, and this volatility was named $ExRVol$. Figure 4-2 below presents the volatility of the trade weighted exchange rate as exhibited by the modelled $GARCH$ conditional standard deviation.

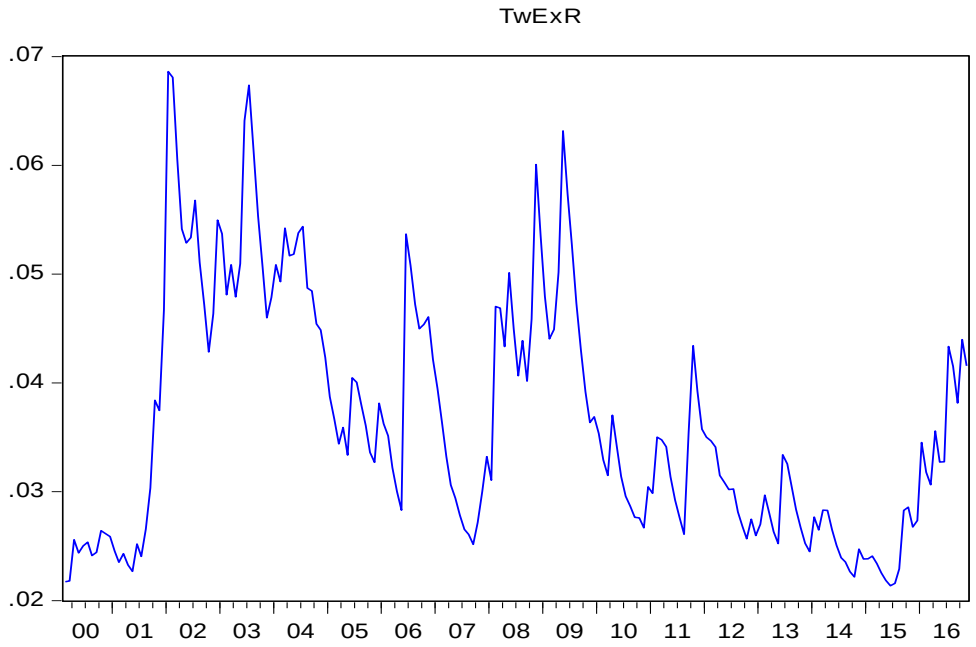



**Figure 4-2: The trade-weighted exchange rate volatility for period 2000M1 to 2016M12**

The $ExRVol$ was used for all the econometric analysis to determine the impact rendered by exchange rate volatility on the firm's value of the South African mining firms listed on the JSE. Further to the determination of the $ExRVol$ the test for the presence of $ARCH$ in the $ExRVol$ return series was also conducted and the results of this test are presented in Table 4-5 below.

**Table 4-5: The results of the $ARCH$ test applied to the $ExRVol$ of the $GARCH(1,1)$ Model**

| Heteroskedasticity Test: $ExRVol$ | | | |
|---|---|---|---|
| F-statistic | 0.2880 | Prob. F (1,199) | 0.5921 |
| Obs*R-squared | 0.2905 | Prob. Chi-Square (1) | 0.5899 |

Note: The null hypothesis is that there is no $ARCH$ and the alternative is that there is a presence of $ARCH$. Obs*R-Squared is the number of observations times the R-Square. Prob.F is the p-value of the F-statistics and Prob. Chi-Square is the probability of Chi-Square.

The heteroscedastic tests were conducted to the $ExRVol$ obtained from the $GARCH\ (1,1)$ model to test for the presence of the $ARCH$ in the volatility series. The results of the test showed that there was no $ARCH$ present at 5% significance level, i.e. The p-value of the F-statistic was significantly greater than 5% critical point, therefore cannot reject the null hypothesis. The detailed results of the $GARCH\ (1,1)$ modelling tests are presented in Annexure 1.

## 4.4 Stationarity Tests

The stationarity unit root tests were conducted for all variables (i.e. both the dependent and independent variables) using the Augmented Dickey-Fuller tests as described in section 3.7. The procedure is followed when one wants to test if the time series data is non-stationary and has a unit root. The null hypothesis for the test is often defined as there is a unit root and the alternative there is no unit root. The t-statistics and the probability are used to determine the significance of the unit root in the time series. The stationarity tests results are presented in Table 4-6 below.

**Table 4-6: The results of the stationary tests of dependent and independent variables**

| Variable | Augmented Dickey-Fuller (ADF) with a constant | | | Order of Integration |
|---|---|---|---|---|
| | Test for Unit Root | t-statistics | Prob.* | |
| TWEXR | Level | -1.982 | 0.295 | I(1) |
| | 1st Difference | -11.49 | 0.000 | |
| ALSI | Level | -0.036 | 0.953 | I(1) |
| | 1st Difference | -15.57 | 0.000 | |
| AMS | Level | -1.824 | 0.368 | I(1) |
| | 1st Difference | -6.360 | 0.000 | |
| ANG | Level | -2.576 | 0.0997 | **I(0)** |
| | 1st Difference | -16.23 | 0.000 | |
| ARI | Level | -1.909 | 0.328 | I(1) |
| | 1st Difference | -11.98 | 0.000 | |
| ASR | Level | -1.158 | 0.692 | I(1) |
| | 1st Difference | -12.55 | 0.000 | |
| EXX | Level | -1.494 | 0.535 | I(1) |
| | 1st Difference | -14.13 | 0.000 | |
| IMP | Level | -1.503 | 0.530 | I(1) |
| | 1st Difference | -12.61 | 0.000 | |
| KIO | Level | -1.217 | 0.666 | I(1) |
| | 1st Difference | -10.40 | 0.000 | |
| | | | | |

| Variable | Augmented Dickey-Fuller (ADF) with a constant | | | Order of Integration |
|---|---|---|---|---|
| | Test for Unit Root | t-statistics | Prob.* | |
| NHM | Level | -2.168 | 0.219 | I(1) |
| | 1st Difference | -13.51 | 0 | |
| RBP | Level | -1.408 | 0.574 | I(1) |
| | 1st Difference | -7.488 | 0.000 | |
| WEZ | Level | -1.788 | 0.385 | I(1) |
| | 1st Difference | -8.292 | 0.000 | |

Notes: AMS – Anglo American Platinum Ltd, ANG – AngloGold Ashanti Limited, ARI – African Rainbow Minerals Ltd, ASR – Assore Limited, EXX – Exxaro Resources Limited, IMP – Impala Platinum Holdings Limited, KIO – Kumba Iron Ore Ltd., NHM – Northam Platinum Limited, WEZ – Wesizwe Platinum Ltd.

*MacKinnon (1996) one-sided p-values. The critical values at 1% = -3.463; 5% = -2.876 and 10% = -2,574 indicates the level of significance. The Augmented Dickey-Fuller are tested based on the Null ($H_0$) hypothesis that there is a unit root.

The unit root test results revealed that all the variables are stationary in 1st difference except ANG which is stationary at the level, i.e. ANG was integrated at order zero. The null hypothesis was rejected at 1st difference since all the t-statistic values for all the variables were significantly negative compared to the critical values at 1% level of significance. This can be because all variables were not transformed into logarithmic returns when tested for a unit root. The results agree well with what was described in section 3.7 and now can be used for the regression analysis. The detailed unit root tests results are presented in Annexure 2.

## 4.5 Econometric Regressions

The multiple regressions based on the ordinary least square (OLS) were conducted with the variables as per equation (25) – measure of exchange rate exposure and (26) – estimation of determinants of firms' exposure, as detailed in section 3.10 of the methodology. The regression was used to measure the association between the exchange rate volatility ($ExRVol$) and the firms' share returns.

### 4.5.1 *Measure of Exchange Rate Exposure*

The measure of exchange rate exposure regression for all the South African mining firms was conducted using equation (25). The equation's variables are defined as per Table 4-3 below.

**Table 4-7: The multiple regression variables specifications**

| Equation | Dependent Variables | Independent Variables |
|---|---|---|
| (25) | $R_{it}$ | $R_{mkt,t}$ – Market Index (All Share Index) |
| | $i$ = AMS, ANG, ARI, ASR, EXX, IMP, KIO, NHM, RBP, and WEZ | $R_{ExRVol,t}$ – Exchange Rate Volatility, $ExRVol$ |
| (26) | $\delta_i$ = Exposure of firm $i$ | $X_i$- determinants of firm exposure |
| | | $i$ = Size, and Age |

Note: (25) refers to the first stage determination of firms' exposure equation while (26) is the second stage equation used to estimate the determinants of firms exposure.

The regression results of the estimation of the association between the dependent and independent variables in equation (25) – $R_{it} = \alpha_i + \beta_i R_{mkt,t} + \delta_i R_{ExRVol,t} + \epsilon_t$ are presented in Table 4-7 below. Detailed regression results are presented in Annexure 3.

The regression results showed that all the dependent variables (mining firms share returns) were positively correlated with the market returns beta. The results showed that the beta coefficient of the market returns (ALSI) t-statistic is mostly greater than one with a p-value of less than 5% significance level, contrary to the study conducted by Lumley (2002) investigating the relationship between the ZAR/USD exchange rate and the value of resource firms, where an insignificant positive relationship was found between the firms operational beta and the share returns of the firm.

The delta coefficient of the exchange rate volatility exposure of the mining firms was insignificantly correlated to the share returns of these firms except for Kumba Iron Ore Ltd. (KIO) and Exxarro Resources (EXX) where the t-statistics greater than two and the p-values less than 0.05 were obtained, i.e. significantly exposed to exchange rate volatility. The results agree well with the findings by Jordaan (1986) who found no significant relationship between exchange rates and share returns of selected mining, financial and industrial firms. Similarly, (Mlambo et al., 2013) using the $GARCH\ (1,1)$ approach also found an insignificant relationship between the exchange rates volatility and South Africa's stock market returns. In addition, Khoo (1994) in his study on the estimation of foreign exchange exposure of Australian mining firms found that there was a small sensitivity of firm's stock returns to exchange rate fluctuations and the proportions of share returns that can be explained by the exchange rates

volatility. The significant relationship that exists between EXX and KIO share returns will be further explored in stage two where the potential determinants of exposure are examined.

NHM was the only mining firm where the coefficient of exchange rate volatility was negative, which implied that exchange rate volatility exerts a negative effect on NHM by approximately -0.4934. The cause of potential causes of the exchange rate volatility impact on NHM share returns will be further reviewed in step two of the regression analysis.

**Table 4-8: The Summary of the regression results for equation (25)**

| | Alpha ($\alpha_i$)** | | | | Beta ($\beta_i$)*** | | | | Delta ($\delta_i$)**** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coeff. | Std. Error | t-Stats | Prob. | Coeff. | Std. Error | t-Stats | Prob. | Coeff. | Std. Error | t-Stats | Prob. |
| AMS* | -0.0137 | 0.0232 | -0.5895 | 0.5562 | 1.6491 | 0.1407 | 11.7217 | 0.0000 | 0.0320 | 0.6056 | 0.0528 | 0.9580 |
| ANG* | -0.0365 | 0.0283 | -1.2894 | 0.1987 | 0.8000 | 0.1719 | 4.6536 | 0.0000 | 0.8143 | 0.7400 | 1.1004 | 0.2725 |
| ARI* | -0.0406 | 0.0271 | -1.5001 | 0.1352 | 1.2178 | 0.1642 | 7.4177 | 0.0000 | 0.9063 | 0.7067 | 1.2824 | 0.2012 |
| ASR* | -0.0267 | 0.0260 | -1.0289 | 0.3048 | 0.7668 | 0.1575 | 4.8676 | 0.0000 | 1.0198 | 0.6781 | 1.5038 | 0.1342 |
| EXX* | -0.0530 | 0.0269 | -1.9704 | 0.0503 | 1.2600 | 0.1620 | 7.7780 | 0.0000 | 1.4515 | 0.6804 | 2.1334 | 0.0343 |
| IMP* | -0.0400 | 0.0233 | -1.7188 | 0.0872 | 1.6366 | 0.1412 | 11.5897 | 0.0000 | 0.7272 | 0.6079 | 1.1963 | 0.2330 |
| KIO* | -0.1022 | 0.0476 | -2.1460 | 0.0339 | 1.2699 | 0.2788 | 4.5542 | 0.0000 | 2.9124 | 1.3798 | 2.1108 | 0.0369 |
| NHM* | 0.0125 | 0.0260 | 0.4810 | 0.6310 | 1.4729 | 0.1580 | 9.3214 | 0.0000 | -0.4934 | 0.6802 | -0.7254 | 0.4691 |
| RBP* | -0.0693 | 0.0583 | -1.1886 | 0.2386 | 1.1126 | 0.3465 | 3.2113 | 0.0020 | 1.8106 | 1.9362 | 0.9352 | 0.3529 |
| WEZ* | -0.0626 | 0.0585 | -1.0706 | 0.2863 | 1.2709 | 0.3418 | 3.7184 | 0.0003 | 1.2453 | 1.6671 | 0.7470 | 0.4564 |

Note: AMS – Anglo American Platinum Ltd, ANG – AngloGold Ashanti Limited, ARI – African Rainbow Minerals Ltd, ASR – Assore Limited, EXX – Exxaro Resources Limited, IMP – Impala Platinum Holdings Limited, KIO – Kumba Iron Ore Ltd., NHM – Northam Platinum Limited, WEZ – Wesizwe Platinum Ltd. * represents the dependent variables, **α the exposure equation constant, ***β the coefficient of market returns, **** δ the coefficient of exchange rate volatility , t-stats – t-statistics and Prob. Is the p-value at 5% significance level.

An additional measure of the quality of the ordinary least squares (OLS) multiple regression results is presented in Table 4-9 below. The results include the Durbin-Watson statistics, Adjusted R-squared, S.E. of regression, etc.

**Table 4-9: Additional measures of the quality of the OLS regression**

| Statistical Measure/Variables | AMS | ANG | ARI | ASR | EXX | IMP | KIO | NHM | RBP | WEZ |
|---|---|---|---|---|---|---|---|---|---|---|
| Durbin-Watson statistics | 2.0377 | 2.0777 | 1.7086 | 1.6653 | 2.1415 | 2.0896 | 1.9917 | 1.8596 | 1.9432 | 1.9685 |
| Adjusted R-squared | 0.4027 | 0.0953 | 0.2156 | 0.1082 | 0.2602 | 0.4011 | 0.1637 | 0.2975 | 0.1133 | 0.0882 |
| S.E. of regression | 0.0964 | 0.1177 | 0.1124 | 0.1079 | 0.1013 | 0.0967 | 0.1327 | 0.1082 | 0.0913 | 0.1704 |
| F-statistic | 68.769 | 11.583 | 28.616 | 13.189 | 32.660 | 68.308 | 12.743 | 43.555 | 5.6016 | 7.3338 |
| Prob (F-statistic) | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0055 | 0.0010 |

Note: AMS – Anglo American Platinum Ltd, ANG – AngloGold Ashanti Limited, ARI – African Rainbow Minerals Ltd, ASR – Assore Limited, EXX – Exxaro Resources Limited, IMP – Impala Platinum Holdings Limited, KIO – Kumba Iron Ore Ltd., NHM – Northam Platinum Limited, WEZ – Wesizwe Platinum Ltd.

The Durban-Watson is used to measure the spot the presence of autocorrelation in the regression results; the results suggest that all the variables have a value greater than 1,69 except ASR where it is marginally lower. This suggests that there is no autocorrelation detected in all variables using the 1% Durban-Watson critical values. The F-statistic and its p-values showed that both the independent variables are significant for this regression with a p-value of lower than 0.01 in all cases. This is a good sign for this type of the regression. It was also noted that the R-squared and adjusted R-squared were lower. However, the p-values were significant, this indicated that although the fit may not have been well fitted, the independent variables are still significant.

### 4.5.2 *Determinants of Exchange Rate Exposure*

The second part of the regression involved taking the results from the first stage regression tests and regress them with potential explanatory variables that might help explain the South African mining firms exposure in equation (25). In this case the $\delta_i$ values obtained in equation

(25) were used for the regression. The $X_i$ indicates the possible explanatory independent variables, i.e. $i$ represents the foreign sales to total sales ratio, size or age of the firm. Table 4-10 below presents the summary of the regression results.

**Table 4-10: The summary of the exchange rate exposure determinants regression results**

| | $X_i$, $i$ = foreign sales | | | | $X_i$, $i$ = size | | | | $X_i$, $i$ = age | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mining Firms | Coeff. | Std. Error | t-Stats | Prob. | Coeff. | Std. Error | t-Stats | Prob. | Coeff. | Std. Error | t-Stats | Prob. |
| AMS | 8.3973 | 16.949 | 0.4954 | 0.6310 | 11.451 | 8.4862 | 1.3493 | 0.2070 | 0.4624 | 1.1437 | 0.4043 | 0.6945 |
| ANG* | 5.0052 | 40.275 | 0.1243 | 0.9036 | -22.373 | 9.9041 | -2.2590 | 0.0475 | 1.6376 | 1.2502 | 1.3099 | 0.2195 |
| ARI** | -33.964 | 18.074 | -1.8791 | 0.0970 | 7.7875 | 4.0463 | 1.9246 | 0.0832 | 0.9668 | 0.6532 | 1.4801 | 0.1697 |
| ASR | -6.2191 | 5.2341 | -1.1882 | 0.2652 | -3.2550 | 3.9841 | -0.8170 | 0.4330 | 0.0206 | 0.9535 | 0.0216 | 0.9832 |
| EXX | 3.4061 | 19.813 | 0.1719 | 0.8673 | 5.1610 | 4.7357 | 1.0898 | 0.3014 | 0.2038 | 0.5815 | 0.3504 | 0.7333 |
| IMP | 6.3476 | 14.254 | 0.4453 | 0.6656 | 5.3662 | 3.8125 | 1.4075 | 0.1896 | -0.1838 | 0.7408 | -0.2481 | 0.8091 |
| KIO | 42.668 | 115.273 | 0.3702 | 0.7198 | 3.2841 | 2.1789 | 1.5073 | 0.1660 | -0.8649 | 0.4982 | -1.7362 | 0.1165 |
| NHM** | -24.820 | 27.515 | -0.9020 | 0.3883 | 12.482 | 5.6344 | 2.2153 | 0.0511 | 0.8497 | 0.7618 | 1.1154 | 0.2908 |
| RBP | *** | *** | *** | *** | 9.8532 | 12.497 | 0.7885 | 0.4661 | 0.6539 | 1.5949 | 0.4100 | 0.6988 |
| WEZ | *** | *** | *** | *** | 7.9477 | 6.6721 | 1.1912 | 0.2640 | -0.3797 | 1.1445 | -0.3318 | 0.7477 |

Note: AMS – Anglo American Platinum Ltd, ANG – AngloGold Ashanti Limited, ARI – African Rainbow Minerals Ltd, ASR – Assore Limited, EXX – Exxaro Resources Limited, IMP – Impala Platinum Holdings Limited, KIO – Kumba Iron Ore Ltd., NHM – Northam Platinum Limited, WEZ – Wesizwe Platinum Ltd.

* Measured at 5% significant level, **10% level of significance and *** RBP and WEZ sales data was not segmented by geography and as such it was not possible to report the foreign to total sales ratio.

The results showed an insignificant relationship between the foreign to total sales and the exposure for nine out of ten mining firms analysed in this work. Only ARI foreign to total sales was significantly and negatively related to the exposure at 10% level of significance. The ARI results showed that the foreign sales to total sales ratio exert significant negative effect on the exposure, reducing it by -33.964. Most of the firms' foreign to total sales were positively and insignificantly related to the exposure. The results are somewhat contrary to what was observed by Flota (2014) where a significant negative relationship between exposure and foreign sales to total sales ratio was found. Although, the ARI's relationship between the foreign to total sales and exposure is in line with the observation made by Flota (2014). Jorion (1990) on the other hand, found a positive and reliable correlation that exists between firms involved in foreign activities. This observation is also different to the findings from the South African mining firms.

Seven out of ten mining firms' size were insignificantly related to the exposure of the mining firm. Only three firms' results showed that size mattered as a determinant for their exposure to foreign exchange volatility, i.e. ANG and NHM size was significantly related to the exposure at 5% level of significance while ARI was significantly exposed at 10% level of significance. The study conducted by Jorion (1990) showed significant cross-sectional differences between the size and the exchange rate exposure of the firms. The results showed that the firm size did not matter to most of the firms. Flota (2014) also found that the mid-sized firms were less sensitive to the exposure to exchange rates compared to the small or large sized firms. On the other hand, Dominguez and Tesar (2006) showed that the exchange rate sensitivity was more prevalent for small sized firms that medium to large sized firms, a finding that is different to findings by Flota (2014).

The age of the firm was insignificantly correlated to the firms' exposure, with most of the firms being positively correlated. Only three mining firms' age, i.e. IMP, KIO and WEZ was negatively correlated with the exposure. It is evident from the results that the age of the firm does not have a major or significant impact on the exposure of firms. The results suggest that even though some of the firms are much older, the exchange rate risk remains important and doesn't matter how long the firm has been in existence.

## 4.6 VAR Granger Causality Tests

The variables under investigation were further interrogated to evaluate the causal relationships that may exist amongst them. The VAR Granger causality tests were conducted on EViews enterprise statistical software. The tests will be used as supplements to the regression analysis results. The Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC) were used to select the lag order for the tests. The Granger Causality tests results are presented in Table 4.12, and the detailed results are presented in Annexure 4.

**Table 4-11: VAR Granger Causality Tests results**

| Null Hypothesis | $X^2$ | p-Value | α = 0.05 | α = 0.10 |
|---|---|---|---|---|
| Real Exchange Rate Volatility does not Granger cause AMS Share Returns | 0.048 | 0.827 | Accept | Accept |
| AMS Share Returns does not Granger cause Real Exchange Rate Volatility | 0.193 | 0.660 | Accept | Accept |
| Real Exchange Rate Volatility does not Granger cause ANG Share Returns | 0.034 | 0.853 | Accept | Accept |
| ANG Share Returns does not Granger cause Real Exchange Rate Volatility | 0.552 | 0.458 | Accept | Accept |
| Real Exchange Rate Volatility does not Granger cause ARI Share Returns | 1.491 | 0.222 | Accept | Accept |
| ARI Share Returns does not Granger cause Real Exchange Rate Volatility | 1.336 | 0.248 | Accept | Accept |
| Real Exchange Rate Volatility does not Granger cause ASR Share Returns | 1.004 | 0.316 | Accept | Accept |
| ASR Share Returns does not Granger cause Real Exchange Rate Volatility | 0.007 | 0.933 | Accept | Accept |
| Real Exchange Rate Volatility does not Granger cause EXX Share Returns | 1.434 | 0.231 | Accept | Accept |
| EXX Share Returns does not Granger cause Real Exchange Rate Volatility | 0.467 | 0.494 | Accept | Accept |
| Real Exchange Rate Volatility does not Granger cause IMP Share Returns | 0.676 | 0.411 | Accept | Accept |
| IMP Share Returns does not Granger cause Real Exchange Rate Volatility | 0.865 | 0.352 | Accept | Accept |
| Real Exchange Rate Volatility does not Granger cause KIO Share Returns | 2.716 | 0.099 | Accept | **Reject** |
| KIO Share Returns does not Granger cause Real Exchange Rate Volatility | 0.943 | 0.331 | Accept | Accept |
| Real Exchange Rate Volatility does not Granger cause NHM Share Returns | 0.276 | 0.600 | Accept | Accept |
| NHM Share Returns does not Granger cause Real Exchange Rate Volatility | 2.772 | 0.096 | Accept | **Reject** |

| Null Hypothesis | $X^2$ | p-Value | α = 0.05 | α = 0.10 |
|---|---|---|---|---|
| Real Exchange Rate Volatility does not Granger cause RBP Share Returns | 1.229 | 0.268 | Accept | Accept |
| RBP Share Returns does not Granger cause Real Exchange Rate Volatility | 0.185 | 0.667 | Accept | Accept |
| Real Exchange Rate Volatility does not Granger cause WEZ Share Returns | 0.120 | 0.729 | Accept | Accept |
| WEZ Share Returns does not Granger cause Real Exchange Rate Volatility | 0.930 | 0.335 | Accept | Accept |

Note: α represents the level of statistical significance, at 5% and 10%

The causality tests results showed that the null hypothesis that there is a causal relationship between the exchange rate volatility and mining firms' share returns (value) could be rejected at both 5% and 10% level of significance. A unidirectional causal relationship between real exchange rate volatility and KIO share returns was noted, and the null hypothesis cannot be rejected at 10% level of significance; the results showed no causal relationship from KIO share returns to the exchange rate volatility. Further, there was also a unidirectional causal relationship noted for NHM; the results showed that NHM share returns granger cause exchange rate volatility; there was no evidence of the causal relationship that runs from exchange rate volatility to NHM share returns.

Step one regression results also showed that KIO was significantly and positively correlated to the exchange rate volatility. The coefficient of the exchange rates volatility was found to be at 2.91, implying that a unit change in exchange rates volatility will result in an average increase of 2,9124 in KIO share returns.

KIO was formed as part of the split from Kumba Resources coal and heavy minerals to form Kumba Iron Ore Ltd (heavy minerals) and Exxaro Resources Ltd (coal). EXX and KIO were listed on the JSE in 2001 and 2006 respectively. For years KIO signed a long-term agreement to supply iron ore to Arcelor Mittal[1] (due to its shareholding in Sishen mine) at cost plus 3% (Anglo American, 2010) . The contract meant that although the iron ore prices in the global market and exchange rates were fluctuating, KIO could not change the prices of this contract.

[1] ArcelorMittal South Africa is the largest steel producer on the African continent and it is headquartered in Vanderbijlpark. The company supplies over 61% of the steel used in South Africa and exports the rest to sub-Saharan Africa

This could help explain some factors on why KIO is significantly correlated to the exchange rate exposure since substantial sales of their products were sold locally on this contract. EXX would also be significantly affected since it holds significant stake (approximately 20%) in KIO (Exxaro, 2017). Additionally, EXX sells over 70% of the coal products locally most of it on a contract with Eskom[2].

The results showed that the share returns of NHM might help explain some of the exchange rate volatility. This relationship was unidirectional. This could be attributed to the market capitalization of NHM; it is one of the smaller platinum producers compared to AMS and IMP. In a separate regression (presented in Annexure 5), a simple OLS regression results showed the significant positive relationship between commodity price index and NHM share returns. The observation agrees with what was observed by Dominguez and Tesar (2006) that firm exposure is associated with firm size, international status, foreign sales, and competitiveness and trade at the industry level.

## 4.7 Summary of the Results and Analysis

The chapter presented the results from the empirical analysis conducted based on the methodology described in chapter three. The econometric analysis was used, applying various ways of analysis including the $GARCH(1,1)$, unit root tests, two factor CAPM model and causality to answer the research questions raised in chapter one. The focus being to understand the impact rendered by the exchange rates volatility on the firm value of the mining firms listed on the JSE.

The statistical description of the variables allowed an examination of the variables used. The $GARCH$ conditional standard deviation was used to model the exchange rates volatility, this analysis allowed us to conduct regression and causality between the dependent and independent variables. The study showed that there was significant relationship between the firms' beta and the share returns of the firm while the exchange rate exposure was found to be insignificantly correlated to most of the mining firms' share returns.

[2] "Eskom is a South African State Owned Enterprise that generates approximately 95% of the electricity used in South Africa and approximately 45% of the electricity used in Africa. The company is headquartered in Woodmead, Johanneburg".

The results from the second stage regression described in section 3.9.2 of the methodology section allowed for the examination of the determinants of exchange rates exposure. An insignificant and differing relationship between the exchange rate exposure and the foreign to total sales was noted for nine out of ten firms selected for the study. The results obtained differ from those obtained in previous studies looking at US multinational firms and firms listed on the Mexico stock exchange by Jorion (1990) and Flota (2014) respectively. Only the ARI results were similar to the observation made by (Flota, 2014) where he found a significant negative relationship between exchange rate exposure and foreign sales to total sales ratio at the firm level.

Seven out of ten mining firms' size were insignificantly related to the exposure of the firm. Only three firms' results showed that size mattered as a determinant for their exposure to foreign exchange volatility, i.e. ANG and NHM size was significantly related to the exposure at 5% level of significance while ARI was significantly exposed at 10% level of significance.

The results obtained in this chapter will be used in to draw conclusions and recommendation of this study.

# CHAPTER 5. CONCLUSIONS

The study's purpose was to empirically attempt to evaluate the impact rendered on South African mining firms' value by the volatility in the exchange rates. Monthly firm-level data for the period between January 2000 and December 2016 was collected from the JSE, Department of Trade and Industry, South African Reserve Bank, and Bloomberg Terminal.

The main key research questions that the study aimed to answer included; (1) the direction and the strength of the response of mining firms' value to the volatility of the exchange rates, (2) the causal relationship that can be deduced from the mining firms' value and the volatility in exchange rates, and (3) if the mining firm's exchange rate exposure get influenced by the foreign to total sales ratio, firm size (market capitalization) and age of the firm.

The study made use of the constructed trade-weighted exchange rate ($TwExR$) of the South African Rand (ZAR) against its major trading partners. The generalized autoregressive conditional heteroskedasticity, $GARCH\ (1,1)$ developed by (Engle, 1982) and advanced by (Bollerslev, 1986) was utilised in this study to capture the exchange rate volatility of the ZAR against its trading partners, herein represented by the trade weighted exchange rate. The $GARCH$ conditional standard deviation (volatility) was used for the regressions.

Following the test for volatility clustering, an inherent characteristic of financial time series data with the $GARCH$ model, the data was evaluated for stationarity using the Augmented Dickey-Fuller (ADF) tests for stationarity. The ADF analysis showed that all variables were stationary at first difference, i.e. integrated at order one I(1) while only one variable, ANG was stationary at level, i.e. integrated at order zero I(0). The results are consistent with the data used since it was not differences or no logarithmic test were applied to data.

The two-factor regression model was used to establish the relationship that existed between the dependent variables (i.e. firm's share returns – value) and the independent variables (i.e. market returns and exchange rate volatility). In addition, the determinants of the exchange rates exposure were also tested; the dependent variable (i.e. exchange rates exposure) and the independent variables (i.e. foreign sales to total sales ratio, firm size and age of the firm) were used. The results of the study when measuring the exchange rate exposure of the mining firms showed that there was a significant relationship between the mining firms' share

returns and the firms' beta (market returns). The exchange rate volatility was found to be insignificantly correlated to most of the mining firms' share returns. KIO and EXX share returns were found to be significantly and positively correlated to exchange rate volatility with the coefficient of exchange rate volatility ( a measure of exposure) at 2.9124 and 1,4515 respectively. In addition, the results showed that there were no causal relationships that existed between the exchange rate volatility and South African mining firms' share returns except for KIO and NHM.

Using the second stage regression to determine the factors that contribute to mining firms' exposure to exchange rates (i.e. potential explanatory variables), the results revealed an insignificant relationship between the foreign sales to total sales ratio and the exposure for nine out of ten mining firms analysed in this work. Only ARI foreign to total sales was significantly and negatively related to the exposure at 10% level of significance. Most of the firms' foreign sales to total sales ratios were positively and insignificantly related to the exposure. In addition, seven out of ten mining firms' size was insignificantly related to the exposure of the firm. Only three firms' results showed that size mattered as a determinant for their exposure to foreign exchange volatility, i.e. ANG and NHM size was significantly related to the exposure at 5% level of significance while ARI was significantly exposed at 10% level of significance. Finally, all the firms' age was insignificantly correlated to the exchange rates exposure. The results suggest that majority of the firms' exposure is not influenced by the level of international sales, firm size (market capitalization) and age of the firm.

In addition, using the Granger causality tests, unidirectional causal relationships were noted between the exchange rates volatility and share returns of Kumba Iron Ore Ltd, and the Northam Platinum Ltd share returns and the exchange rate volatility, both at 10% level of significance. KIO could have been affected by the contracts that it had with Arcelor Mittal which limited the extent of the company's exposure to exchange rates volatility, while NHM could be because of its market position and size in the market.

The review of the literature showed conflicting and inconclusive results when the studies looked at the impact rendered by the exchange rates volatility on the value of the firm. Although this study's findings answer all the research questions, it does present another set of conflicting results. The most important element of the study is that it shows some important and reliable relationships that exist between the South African mining firms' share returns

and exchange rate volatility. In addition, the determinants of exposure also showed significant relationships with potential explanatory variables (i.e. foreign sales to total sales ratio, firm size and age of the firm).

In conclusion, the study allows us to conclude that market returns are significantly correlated to South African mining firms' share returns, i.e. mining firms' value. Further, the exchange rate volatility (exposure) of the mining firms was not significantly correlated to the firms' share returns of seven out of ten considered in this study. However, three firms' share returns remained significantly correlated exchange rate exposure. The determinants of these firms' exposure were not ascertained in this study since the three potential determinants tested were mostly not significantly correlated to the exchange rate exposure of these firms.

# CHAPTER 6. RECOMMENDATIONS

The findings from the study provided an insight into the impact of exchange rates volatility on the value of South African mining firms particularly those listed on the Johannesburg Stock Exchange. One of the most important factors with regards to managing exchange rate risk was the use of hedging and contracts to protects the firm returns. The following is recommended can be made from this study;

- The results revealed that exchange rate volatility was insignificantly and differently correlated to mining firms share returns (firm value). It was only significant for two of the ten firms considered for the study. The results suggest that it cannot be ruled out completely that exchange rate volatility does not have an impact on the firm value of the South African mining firms.
- Additionally, there was no significant relationship found when the determinants of exposure (potential explanatory variables) were investigated that could be linked to those firms that are significantly affected by the exchange rate volatility. It is therefore recommended that further studies be conducted to ascertain the findings.
- The mining firms used for this study were those that are only listed on the Johannesburg Stock Exchange and have most of their operations in South Africa. It will also be interesting to see if the same results will be obtained if this study was to be extended to those that are listed on other stock markets, i.e. multinational mining firms and have foreign operations.

Overall, the study provided additional insight to the existing literature on the impact of exchange rates volatility on the firms' value, particularly those listed on the Johannesburg Stock Exchange. In addition, it is the duty of the managers to ensure that the mining firms investigated in this study remain profitable, the study provided guidance on how the managers can respond to the exchange rate and market risk posed by the fluctuations in the exchange rates.

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# CHAPTER 8. APPENDICES

## 8.1 Appendix 1 – $GARCH\ (1,1)$ MODEL

Dependent Variable: DLOG(TWEXR)
Method: ML - ARCH (Marquardt) - Normal distribution
Date: 03/07/17 Time: 18:58
Sample (adjusted): 2000M02 2016M11
Included observations: 202 after adjustments
Convergence achieved after 25 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1)

| Variable | Coefficient | Std. Error | z-Statistic | Prob. |
|---|---|---|---|---|
| C | -0.007 | 0.003 | -2.699 | 0.007 |
| | Variance Equation | | | |
| C | 0.000 | 0.000 | 1.333 | 0.183 |
| RESID(-1)^2 | 0.181 | 0.057 | 3.188 | 0.001 |
| GARCH(-1) | 0.771 | 0.075 | 10.290 | 0.000 |

| | | | |
|---|---|---|---|
| R-squared | -0.006 | Mean dependent var | -0.004 |
| Adjusted R-squared | -0.006 | S.D. dependent var | 0.037 |
| S.E. of regression | 0.038 | Akaike info criterion | -3.828 |
| Sum squared resid | 0.284 | Schwarz criterion | -3.762 |
| Log likelihood | 390.625 | Hannan-Quinn criter. | -3.801 |
| Durbin-Watson stat | 1.697 | | |

| | | | |
|---|---|---|---|
| Heteroskedasticity Test: ARCH | | | |
| | | Prob. F(1,201) | |
| F-statistic | 1796.2289 | | 0.00 |
| | 182.570193 | Prob. Chi-Square(1) | |
| Obs*R-squared | 5 | | 0.00 |

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 03/07/17 Time: 22:20
Sample (adjusted): 2000M02 2016M12
Included observations: 203 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 11.738 | 7.685634 | 1.527288207 | 1.28E-01 |
| RESID^2(-1) | 9.35E-01 | 2.21E-02 | 42.38194073 | 3.55E-102 |
| R-squared | 0.8993 | Mean dependent var | | 236.822 |
| Adjusted R-squared | 0.8989 | S.D. dependent var | | 248.892 |
| S.E. of regression | 79.154 | Akaike info criterion | | 11.5904 |
| Sum squared resid | 1259337 | Schwarz criterion | | 11.6231 |
| Log likelihood | -1.17E+03 | Hannan-Quinn criteria. | | 11.6037 |
| F-statistic | 1796.2289 | Durbin-Watson stat | | 1.6890 |
| Prob(F-statistic) | 3.55E-102 | | | |

## 8.2 Appendix 2 – Stationarity Tests

### 8.2.1 *Level*

Null Hypothesis: TWEXRR has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=14)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -12.20685356 | 1.20E-20 |
| Test critical values: | 1% level | -3.462736563 | |
| | 5% level | -2.875679647 | |
| | 10% level | -2.574384502 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(TWEXRR)
Method: Least Squares
Date: 03/19/17 Time: 08:04
Sample (adjusted): 2000M02 2016M11
Included observations: 202 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| TWEXRR(-1) | -0.85392 | 0.069954714 | -12.206 | 5.65E-26 |
| C | -0.0014 | 0.001141663 | -1.2559 | 0.21058 |

| | | | |
|---|---|---|---|
| R-squared | 0.42694 | Mean dependent var | 1.50E-05 |
| Adjusted R-squared | 0.42408 | S.D. dependent var | 0.02126 |
| S.E. of regression | 0.01613 | Akaike info criterion | -5.40541 |
| Sum squared resid | 0.05208 | Schwarz criterion | -5.37265 |
| Log likelihood | 547.946 | Hannan-Quinn criteria. | -5.39215 |
| F-statistic | 149.007 | Durbin-Watson stat | 1.991864 |
| Prob(F-statistic) | 5.65E-26 | | |

### 8.2.2 *1st Difference*

Null Hypothesis: D(TWEXR) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=14)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -11.494 | 0.000 |
| Test critical values: | 1% level | -3.463 | |
| | 5% level | -2.876 | |
| | 10% level | -2.574 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(TWEXR,2)
Method: Least Squares
Date: 03/05/17 Time: 12:59
Sample (adjusted): 2000M03 2016M12
Included observations: 202 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(TWEXR(-1)) | -0.884 | 0.077 | -11.494 | 0.000 |
| C | -0.156 | 0.207 | -0.754 | 0.452 |

| | | | |
|---|---|---|---|
| R-squared | 0.398 | Mean dependent var | 0.080 |
| Adjusted R-squared | 0.395 | S.D. dependent var | 3.763 |
| S.E. of regression | 2.928 | Akaike info criterion | 4.996 |
| Sum squared resid | 1714.355 | Schwarz criterion | 5.029 |
| Log likelihood | -502.617 | Hannan-Quinn criteria. | 5.09 |
| F-statistic | 132.107 | Durbin-Watson stat | 1.820 |
| Prob(F-statistic) | 0.000 | | |

## 8.3 Appendix 3 – Regression Results

### 8.3.1 *Stage One Regressions – Measuring Exchange Rate Exposure*

Dependent Variable: AMSR
Method: Least Squares
Date: 03/07/17 Time: 22:35
Sample (adjusted): 2000M02 2016M11
Included observations: 202 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -0.014 | 0.023 | -0.589 | 0.556 |
| ALSIR | 1.649 | 0.141 | 11.722 | 0.000 |
| EXRVOL | 0.032 | 0.606 | 0.053 | 0.958 |

| | | | |
|---|---|---|---|
| R-squared | 0.409 | Mean dependent var | 0.002 |
| Adjusted R-squared | 0.403 | S.D. dependent var | 0.125 |
| S.E. of regression | 0.096 | Akaike info criterion | -1.827 |
| Sum squared resid | 1.848 | Schwarz criterion | -1.778 |
| Log likelihood | 187.501 | Hannan-Quinn criter. | -1.807 |
| F-statistic | 68.769 | Durbin-Watson stat | 2.038 |
| Prob(F-statistic) | 0.000 | | |

Dependent Variable: ANGR
Method: Least Squares
Date: 03/07/17 Time: 22:37
Sample (adjusted): 2000M02 2016M11
Included observations: 202 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -0.037 | 0.028 | -1.289 | 0.199 |
| ALSIR | 0.800 | 0.172 | 4.654 | 0.000 |
| EXRVOL | 0.814 | 0.740 | 1.100 | 0.273 |

| | | | |
|---|---|---|---|
| R-squared | 0.104 | Mean dependent var | 0.000 |
| Adjusted R-squared | 0.095 | S.D. dependent var | 0.124 |
| S.E. of regression | 0.118 | Akaike info criterion | -1.426 |
| Sum squared resid | 2.759 | Schwarz criterion | -1.377 |
| Log likelihood | 147.017 | Hannan-Quinn criter. | -1.406 |
| F-statistic | 11.583 | Durbin-Watson stat | 2.078 |

| | |
|---|---|
| Prob(F-statistic) | 0.000 |

Dependent Variable: ARIR
Method: Least Squares
Date: 03/07/17 Time: 22:38
Sample (adjusted): 2000M02 2016M11
Included observations: 202 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -0.041 | 0.027 | -1.500 | 0.135 |
| ALSIR | 1.218 | 0.164 | 7.418 | 0.000 |
| EXRVOL | 0.906 | 0.707 | 1.282 | 0.201 |

| | | | |
|---|---|---|---|
| R-squared | 0.223 | Mean dependent var | 0.003 |
| Adjusted R-squared | 0.216 | S.D. dependent var | 0.127 |
| S.E. of regression | 0.112 | Akaike info criterion | -1.518 |
| Sum squared resid | 2.516 | Schwarz criterion | -1.469 |
| Log likelihood | 156.317 | Hannan-Quinn criter. | -1.498 |
| F-statistic | 28.616 | Durbin-Watson stat | 1.709 |
| Prob(F-statistic) | 0.000 | | |

Dependent Variable: ASRR
Method: Least Squares
Date: 03/07/17 Time: 22:39
Sample (adjusted): 2000M02 2016M11
Included observations: 202 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -0.027 | 0.026 | -1.029 | 0.305 |
| ALSIR | 0.767 | 0.158 | 4.868 | 0.000 |
| EXRVOL | 1.020 | 0.678 | 1.504 | 0.134 |

| | | | |
|---|---|---|---|
| R-squared | 0.117 | Mean dependent var | 0.017 |
| Adjusted R-squared | 0.108 | S.D. dependent var | 0.114 |
| S.E. of regression | 0.108 | Akaike info criterion | -1.601 |
| Sum squared resid | 2.317 | Schwarz criterion | -1.551 |
| Log likelihood | 164.663 | Hannan-Quinn criter. | -1.581 |
| F-statistic | 13.189 | Durbin-Watson stat | 1.665 |

| | |
|---|---|
| Prob(F-statistic) | 0.000 |

Dependent Variable: EXXR
Method: Least Squares
Date: 03/07/17 Time: 22:40
Sample (adjusted): 2001M11 2016M11
Included observations: 181 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -0.053 | 0.027 | -1.970 | 0.050 |
| ALSIR | 1.260 | 0.162 | 7.778 | 0.000 |
| EXRVOL | 1.451 | 0.680 | 2.133 | 0.034 |

| | | | |
|---|---|---|---|
| R-squared | 0.268 | Mean dependent var | 0.014 |
| Adjusted R-squared | 0.260 | S.D. dependent var | 0.118 |
| S.E. of regression | 0.101 | Akaike info criterion | -1.726 |
| Sum squared resid | 1.825 | Schwarz criterion | -1.673 |
| Log likelihood | 159.197 | Hannan-Quinn criter. | -1.704 |
| F-statistic | 32.660 | Durbin-Watson stat | 2.141 |
| Prob(F-statistic) | 0.000 | | |

Dependent Variable: IMPR
Method: Least Squares
Date: 03/07/17 Time: 22:41
Sample (adjusted): 2000M02 2016M11
Included observations: 202 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -0.040 | 0.023 | -1.719 | 0.087 |
| ALSIR | 1.637 | 0.141 | 11.590 | 0.000 |
| EXRVOL | 0.727 | 0.608 | 1.196 | 0.233 |

| | | | |
|---|---|---|---|
| R-squared | 0.407 | Mean dependent var | 0.001 |
| Adjusted R-squared | 0.401 | S.D. dependent var | 0.125 |
| S.E. of regression | 0.097 | Akaike info criterion | -1.819 |
| Sum squared resid | 1.861 | Schwarz criterion | -1.770 |
| Log likelihood | 186.752 | Hannan-Quinn criter. | -1.799 |
| F-statistic | 68.308 | Durbin-Watson stat | 2.090 |

| | |
|---|---|
| Prob(F-statistic) | 0.000 |

Dependent Variable: KIOR
Method: Least Squares
Date: 03/07/17 Time: 22:41
Sample (adjusted): 2006M11 2016M11
Included observations: 121 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -0.102 | 0.048 | -2.146 | 0.034 |
| ALSIR | 1.270 | 0.279 | 4.554 | 0.000 |
| EXRVOL | 2.912 | 1.380 | 2.111 | 0.037 |

| | | | |
|---|---|---|---|
| R-squared | 0.178 | Mean dependent var | 0.003 |
| Adjusted R-squared | 0.164 | S.D. dependent var | 0.145 |
| S.E. of regression | 0.133 | Akaike info criterion | -1.177 |
| Sum squared resid | 2.078 | Schwarz criterion | -1.108 |
| Log likelihood | 74.217 | Hannan-Quinn criter. | -1.149 |
| F-statistic | 12.743 | Durbin-Watson stat | 1.992 |
| Prob(F-statistic) | 0.000 | | |

Dependent Variable: NHMR
Method: Least Squares
Date: 03/07/17 Time: 22:42
Sample (adjusted): 2000M02 2016M11
Included observations: 202 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.013 | 0.026 | 0.481 | 0.631 |
| ALSIR | 1.473 | 0.158 | 9.321 | 0.000 |
| EXRVOL | -0.493 | 0.680 | -0.725 | 0.469 |

| | | | |
|---|---|---|---|
| R-squared | 0.304 | Mean dependent var | 0.008 |
| Adjusted R-squared | 0.297 | S.D. dependent var | 0.129 |
| S.E. of regression | 0.108 | Akaike info criterion | -1.594 |
| Sum squared resid | 2.331 | Schwarz criterion | -1.545 |
| Log likelihood | 164.044 | Hannan-Quinn criter. | -1.575 |
| F-statistic | 43.555 | Durbin-Watson stat | 1.860 |

| | |
|---|---|
| Prob(F-statistic) | 0.000 |

Dependent Variable: RBPR
Method: Least Squares
Date: 03/07/17 Time: 22:43
Sample (adjusted): 2010M11 2016M11
Included observations: 73 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -0.069 | 0.058 | -1.189 | 0.239 |
| ALSIR | 1.113 | 0.346 | 3.211 | 0.002 |
| EXRVOL | 1.811 | 1.936 | 0.935 | 0.353 |

| | | | |
|---|---|---|---|
| R-squared | 0.138 | Mean dependent var | -0.008 |
| Adjusted R-squared | 0.113 | S.D. dependent var | 0.097 |
| S.E. of regression | 0.091 | Akaike info criterion | -1.909 |
| Sum squared resid | 0.583 | Schwarz criterion | -1.815 |
| Log likelihood | 72.692 | Hannan-Quinn criter. | -1.872 |
| F-statistic | 5.602 | Durbin-Watson stat | 1.943 |
| Prob(F-statistic) | 0.006 | | |

Dependent Variable: WEZR
Method: Least Squares
Date: 03/07/17 Time: 22:44
Sample (adjusted): 2005M12 2016M11
Included observations: 132 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -0.063 | 0.058 | -1.071 | 0.286 |
| ALSIR | 1.271 | 0.342 | 3.718 | 0.000 |
| EXRVOL | 1.245 | 1.667 | 0.747 | 0.456 |

| | | | |
|---|---|---|---|
| R-squared | 0.102 | Mean dependent var | -0.010 |
| Adjusted R-squared | 0.088 | S.D. dependent var | 0.178 |
| S.E. of regression | 0.170 | Akaike info criterion | -0.679 |
| Sum squared resid | 3.744 | Schwarz criterion | -0.614 |
| Log likelihood | 47.830 | Hannan-Quinn criter. | -0.653 |
| F-statistic | 7.334 | Durbin-Watson stat | 1.968 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Prob(F-statistic) | | | | | 0.001 | | | | | | |

### 8.3.2 *Step Two Regressions – Determinants of Exchange Rates Exposure*

| | | AMS | ANG | ARI | ASR | EXX | IMP | KIO | NHM | RBP | WEZ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $X_{foreignsales}$ | Durbin-Watson stat | 2.182 | 1.764 | 1.784 | 1.691 | 2.121 | 2.634 | 1.532 | 2.210 | | |
| | R-squared | 0.024 | 0.002 | 0.306 | 0.136 | 0.003 | 0.019 | 0.015 | 0.075 | | |
| | Adjusted R-squared | -0.074 | -0.098 | 0.219 | 0.040 | -0.107 | -0.079 | -0.094 | -0.017 | | |
| | S.E. of regression | 13.622 | 16.169 | 7.466 | 11.095 | 7.343 | 8.799 | 5.991 | 9.289 | | |
| | Sum squared resid | 1855.682 | 2614.488 | 445.965 | 1107.809 | 485.313 | 774.224 | 323.077 | 862.913 | | |
| | Log likelihood | -47.274 | -49.331 | -33.178 | -40.976 | -36.436 | -42.029 | -34.198 | -42.680 | | |
| | F-statistic | 0.245 | 0.015 | 3.531 | 1.412 | 0.030 | 0.198 | 0.137 | 0.814 | | |
| | Prob(F-statistic) | 0.631 | 0.904 | 0.097 | 0.265 | 0.867 | 0.666 | 0.720 | 0.388 | | |
| $X_{size}$ | Durbin-Watson stat | 1.815 | 2.393 | 1.869 | 1.503 | 2.435 | 2.434 | 1.235 | 2.233 | 1.164 | 1.481 |
| | R-squared | 0.154 | 0.338 | 0.270 | 0.063 | 0.106 | 0.165 | 0.202 | 0.329 | 0.111 | 0.136 |
| | Adjusted R-squared | 0.069 | 0.272 | 0.197 | -0.031 | 0.017 | 0.082 | 0.113 | 0.262 | -0.067 | 0.040 |
| | S.E. of regression | 12.682 | 13.167 | 7.367 | 11.040 | 6.615 | 8.118 | 5.394 | 7.912 | 8.092 | 11.224 |
| | Sum squared resid | 1608.388 | 1733.776 | 542.779 | 1218.922 | 437.546 | 659.015 | 261.889 | 625.948 | 327.396 | 1133.850 |
| | Log likelihood | -46.416 | -46.866 | -39.898 | -44.752 | -38.605 | -41.062 | -33.043 | -40.753 | -23.391 | -41.103 |
| | F-statistic | 1.821 | 5.103 | 3.704 | 0.668 | 1.188 | 1.981 | 2.272 | 4.907 | 0.622 | 1.419 |
| | Prob(F-statistic) | 0.207 | 0.047 | 0.083 | 0.433 | 0.301 | 0.190 | 0.166 | 0.051 | 0.466 | 0.264 |
| $X_{age}$ | Durbin-Watson stat | | | | | | | | | | |
| | R-squared | 0.016 | 0.146 | 0.180 | 0.000 | 0.012 | 0.006 | 0.251 | 0.111 | 0.033 | 0.012 |
| | Adjusted R-squared | -0.082 | 0.061 | 0.098 | -0.100 | -0.087 | -0.093 | 0.168 | 0.022 | -0.161 | -0.098 |
| | S.E. of regression | 13.677 | 14.950 | 7.811 | 11.403 | 6.954 | 8.859 | 5.225 | 9.110 | 8.440 | 12.003 |
| | Sum squared resid | 1870.653 | 2235.055 | 610.171 | 1300.226 | 483.575 | 784.748 | 245.702 | 829.882 | 356.132 | 1296.751 |
| | Log likelihood | -47.322 | -48.390 | -40.600 | -45.140 | -39.205 | -42.110 | -32.693 | -42.446 | -23.685 | -41.842 |
| | F-statistic | 0.163 | 1.716 | 2.191 | 0.000 | 0.123 | 0.062 | 3.014 | 1.244 | 0.168 | 0.110 |
| | Prob(F-statistic) | 0.695 | 0.220 | 0.170 | 0.983 | 0.733 | 0.809 | 0.117 | 0.291 | 0.699 | 0.748 |

## 8.4 Appendix 4 – Granger Causality

VAR Lag Order Selection Criteria
Endogenous variables: AMSR EXRVOL
Exogenous variables: C
Date: 03/05/17 Time: 17:56
Sample: 2000M01 2016M12
Included observations: 192

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 638.4072 | NA | 4.53E-06 | -6.629242 | -6.59531 | -6.615499 |
| 1 | 832.9518 | 383.0096 | 6.22e-07* | -8.614081* | -8.512284* | -8.572853* |
| 2 | 835.0039 | 3.99732 | 6.35E-07 | -8.593791 | -8.424129 | -8.525076 |
| 3 | 839.4407 | 8.550043 | 6.32E-07 | -8.59834 | -8.360815 | -8.502141 |
| 4 | 841.3335 | 3.608234 | 6.46E-07 | -8.576391 | -8.271001 | -8.452705 |
| 5 | 844.2918 | 5.577682 | 6.53E-07 | -8.56554 | -8.192285 | -8.414369 |
| 6 | 846.4123 | 3.953766 | 6.66E-07 | -8.545961 | -8.104842 | -8.367305 |
| 7 | 854.6129 | 15.11995* | 6.38E-07 | -8.589718 | -8.080735 | -8.383576 |
| 8 | 854.7677 | 0.282029 | 6.64E-07 | -8.549663 | -7.972815 | -8.316035 |
| 9 | 858.7548 | 7.185119 | 6.65E-07 | -8.549529 | -7.904816 | -8.288416 |
| 10 | 860.8429 | 3.71943 | 6.78E-07 | -8.529613 | -7.817036 | -8.241014 |
| 11 | 861.4878 | 1.135281 | 7.03E-07 | -8.494664 | -7.714223 | -8.17858 |
| 12 | 862.2115 | 1.258901 | 7.28E-07 | -8.460536 | -7.61223 | -8.116966 |

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

VAR Lag Order Selection Criteria
Endogenous variables: ANGR EXRVOL
Exogenous variables: C
Date: 03/05/17 Time: 17:59
Sample: 2000M01 2016M12
Included observations: 192

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 640.3091 | NA | 4.44E-06 | -6.649053 | -6.615121 | -6.635311 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 836.7181 | 386.6801 | 5.98e-07* | -8.653314* | -8.551517* | -8.612085* |
| 2 | 838.8684 | 4.188657 | 6.10E-07 | -8.634046 | -8.464385 | -8.565332 |
| 3 | 844.4197 | 10.6977 | 6.00E-07 | -8.650205 | -8.412679 | -8.554005 |
| 4 | 845.5357 | 2.127423 | 6.19E-07 | -8.620163 | -8.314773 | -8.496478 |
| 5 | 849.1031 | 6.726098 | 6.21E-07 | -8.615657 | -8.242403 | -8.464487 |
| 6 | 849.7556 | 1.216602 | 6.44E-07 | -8.580787 | -8.139668 | -8.402131 |
| 7 | 859.1688 | 17.35551* | 6.08E-07 | -8.637175 | -8.128191 | -8.431032 |
| 8 | 861.0351 | 3.402196 | 6.22E-07 | -8.614949 | -8.038101 | -8.381321 |
| 9 | 861.6292 | 1.070577 | 6.45E-07 | -8.579471 | -7.934758 | -8.318357 |
| 10 | 862.5026 | 1.555713 | 6.67E-07 | -8.546902 | -7.834325 | -8.258303 |
| 11 | 863.5475 | 1.839572 | 6.88E-07 | -8.51612 | -7.735678 | -8.200036 |
| 12 | 864.5085 | 1.671759 | 7.11E-07 | -8.484464 | -7.636158 | -8.140894 |

VAR Lag Order Selection Criteria
Endogenous variables: ARIR EXRVOL
Exogenous variables: C
Date: 03/05/17 Time: 18:01
Sample: 2000M01 2016M12
Included observations: 192

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 650.9702 | NA | 3.97E-06 | -6.760106 | -6.726174 | -6.746364 |
| 1 | 846.8114 | 385.5623 | 5.39e-07* | -8.758452* | -8.656655* | -8.717223* |
| 2 | 848.6737 | 3.627587 | 5.51E-07 | -8.736184 | -8.566523 | -8.66747 |
| 3 | 851.9272 | 6.269853 | 5.55E-07 | -8.728408 | -8.490883 | -8.632209 |
| 4 | 854.0192 | 3.987928 | 5.66E-07 | -8.708534 | -8.403143 | -8.584848 |
| 5 | 857.9385 | 7.389459 | 5.67E-07 | -8.707693 | -8.334438 | -8.556522 |
| 6 | 858.197 | 0.48195 | 5.89E-07 | -8.668719 | -8.227599 | -8.490062 |
| 7 | 865.5961 | 13.64216* | 5.69E-07 | -8.704126 | -8.195143 | -8.497984 |
| 8 | 866.7842 | 2.165793 | 5.86E-07 | -8.674836 | -8.097987 | -8.441208 |
| 9 | 870.0404 | 5.867859 | 5.91E-07 | -8.667087 | -8.022374 | -8.405974 |
| 10 | 870.6012 | 0.999056 | 6.13E-07 | -8.631263 | -7.918686 | -8.342664 |
| 11 | 871.6786 | 1.896592 | 6.32E-07 | -8.600819 | -7.820377 | -8.284734 |
| 12 | 873.1384 | 2.53946 | 6.49E-07 | -8.574358 | -7.726052 | -8.230788 |

VAR Lag Order Selection Criteria
Endogenous variables: ASRR EXRVOL
Exogenous variables: C
Date: 03/05/17 Time: 18:04
Sample: 2000M01 2016M12
Included observations: 192

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 654.6969 | NA | 3.82E-06 | -6.798926 | -6.764994 | -6.785184 |
| 1 | 850.806 | 386.0896 | 5.17e-07* | -8.800062* | -8.698265* | -8.758834* |
| 2 | 853.4231 | 5.098029 | 5.24E-07 | -8.785658 | -8.615996 | -8.716944 |
| 3 | 855.6496 | 4.290534 | 5.34E-07 | -8.767183 | -8.529657 | -8.670983 |
| 4 | 858.819 | 6.041775 | 5.39E-07 | -8.758532 | -8.453141 | -8.634846 |
| 5 | 860.3708 | 2.925669 | 5.53E-07 | -8.733029 | -8.359774 | -8.581858 |
| 6 | 861.1248 | 1.405887 | 5.72E-07 | -8.699216 | -8.258097 | -8.52056 |
| 7 | 867.5448 | 11.83695* | 5.58E-07 | -8.724425 | -8.215441 | -8.518283 |
| 8 | 868.4548 | 1.658859 | 5.76E-07 | -8.692237 | -8.115389 | -8.45861 |
| 9 | 870.5749 | 3.820688 | 5.88E-07 | -8.672656 | -8.027943 | -8.411542 |
| 10 | 871.0571 | 0.85884 | 6.10E-07 | -8.636012 | -7.923434 | -8.347413 |
| 11 | 871.6703 | 1.079542 | 6.32E-07 | -8.600733 | -7.820291 | -8.284648 |
| 12 | 874.7524 | 5.361583 | 6.39E-07 | -8.591171 | -7.742865 | -8.247601 |

VAR Lag Order Selection Criteria
Endogenous variables: EXXR EXRVOL
Exogenous variables: C
Date: 03/06/17 Time: 00:35
Sample: 2000M01 2016M12
Included observations: 170

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 589.0122386 | NA | 3.43E-06 | -6.906026 | -6.869135 | -6.891056 |
| 1 | 760.8764547 | 337.6626 | 4.77e-07* | -8.880899* | -8.770224* | -8.835989* |
| 2 | 763.6229403 | 5.331413 | 4.84E-07 | -8.866152 | -8.681694 | -8.791301 |
| 3 | 766.9486824 | 6.3776 | 4.88E-07 | -8.85822 | -8.599978 | -8.753428 |
| 4 | 769.0191698 | 3.921747 | 4.99E-07 | -8.83552 | -8.503494 | -8.700787 |
| 5 | 772.9750814 | 7.399882 | 4.99E-07 | -8.835001 | -8.429192 | -8.670328 |
| 6 | 775.1220148 | 3.965512 | 5.10E-07 | -8.8132 | -8.333607 | -8.618587 |
| 7 | 781.0018273 | 10.72201* | 4.99E-07 | -8.835316 | -8.281939 | -8.610762 |
| 8 | 784.622765 | 6.517688 | 5.02E-07 | -8.830856 | -8.203696 | -8.576362 |
| 9 | 789.8923539 | 9.36127 | 4.95E-07 | -8.845792 | -8.144849 | -8.561358 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 10 | 790.7205515 | 1.451782 | 5.14E-07 | -8.808477 | -8.03375 | -8.494102 |
| 11 | 791.2589533 | 0.931118 | 5.35E-07 | -8.767752 | -7.919242 | -8.423437 |
| 12 | 792.4068297 | 1.958142 | 5.54E-07 | -8.734198 | -7.811904 | -8.359942 |

VAR Lag Order Selection Criteria
Endogenous variables: IMPR EXRVOL
Exogenous variables: C
Date: 03/05/17 Time: 18:40
Sample: 2000M01 2016M12
Included observations: 192

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 638.5668 | NA | 4.52E-06 | -6.630904 | -6.596972 | -6.617161 |
| 1 | 833.0704 | 382.929 | 6.22e-07* | -8.615317* | -8.513520* | -8.574088* |
| 2 | 834.4227 | 2.634116 | 6.39E-07 | -8.587736 | -8.418075 | -8.519022 |
| 3 | 838.5717 | 7.995481 | 6.38E-07 | -8.589288 | -8.351762 | -8.493089 |
| 4 | 839.6048 | 1.969343 | 6.58E-07 | -8.558383 | -8.252993 | -8.434698 |
| 5 | 841.2536 | 3.108677 | 6.74E-07 | -8.533891 | -8.160637 | -8.38272 |
| 6 | 841.9635 | 1.323799 | 6.98E-07 | -8.49962 | -8.058501 | -8.320964 |
| 7 | 851.805 | 18.14523* | 6.57E-07 | -8.560469 | -8.051485 | -8.354327 |
| 8 | 852.3085 | 0.917856 | 6.82E-07 | -8.524047 | -7.947199 | -8.290419 |
| 9 | 854.2302 | 3.46305 | 6.97E-07 | -8.502398 | -7.857685 | -8.241285 |
| 10 | 854.9958 | 1.363651 | 7.21E-07 | -8.468706 | -7.756129 | -8.180107 |
| 11 | 855.6861 | 1.215239 | 7.47E-07 | -8.43423 | -7.653789 | -8.118146 |
| 12 | 856.6037 | 1.596237 | 7.72E-07 | -8.402122 | -7.553816 | -8.058552 |

VAR Lag Order Selection Criteria
Endogenous variables: KIOR EXRVOL
Exogenous variables: C
Date: 03/06/17 Time: 00:39
Sample: 2000M01 2016M12
Included observations: 114

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 387.5002522 | NA | 3.96E-06 | -6.763162 | -6.715159 | -6.74368 |
| 1 | 492.3445941 | 204.1706 | 6.75e-07* | -8.532361* | -8.388351* | -8.473916* |
| 2 | 494.3590962 | 3.852293 | 6.99E-07 | -8.497528 | -8.257511 | -8.400118 |
| 3 | 497.1810827 | 5.297413 | 7.14E-07 | -8.476861 | -8.140837 | -8.340488 |
| 4 | 502.9745315 | 10.67214* | 6.92E-07 | -8.508325 | -8.076294 | -8.332988 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | 507.2987196 | 7.813884 | 6.89E-07 | -8.514013 | -7.985974 | -8.299711 |
| 6 | 509.0784744 | 3.153601 | 7.17E-07 | -8.475061 | -7.851016 | -8.221796 |
| 7 | 514.0466378 | 8.628915 | 7.05E-07 | -8.492046 | -7.771994 | -8.199817 |
| 8 | 515.988504 | 3.304579 | 7.32E-07 | -8.455939 | -7.639879 | -8.124746 |

VAR Lag Order Selection Criteria
Endogenous variables: NHMR EXRVOL
Exogenous variables: C
Date: 03/05/17 Time: 18:17
Sample: 2000M01 2016M12
Included observations: 192

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 634.7337 | NA | 4.71E-06 | -6.590976 | -6.557043 | -6.577233 |
| 1 | 830.754 | 385.915 | 6.37e-07* | -8.591187* | -8.489390* | -8.549959* |
| 2 | 833.4241 | 5.201269 | 6.46E-07 | -8.577335 | -8.407674 | -8.508621 |
| 3 | 835.6992 | 4.384229 | 6.57E-07 | -8.559367 | -8.321841 | -8.463167 |
| 4 | 841.493 | 11.04436 | 6.45E-07 | -8.578052 | -8.272661 | -8.454366 |
| 5 | 843.467 | 3.721897 | 6.59E-07 | -8.556948 | -8.183693 | -8.405777 |
| 6 | 844.6915 | 2.283221 | 6.79E-07 | -8.528037 | -8.086918 | -8.34938 |
| 7 | 853.2239 | 15.73150* | 6.47E-07 | -8.575249 | -8.066265 | -8.369106 |
| 8 | 855.0983 | 3.416999 | 6.62E-07 | -8.553108 | -7.976259 | -8.31948 |
| 9 | 859.8363 | 8.53827 | 6.57E-07 | -8.560795 | -7.916082 | -8.299682 |
| 10 | 862.2427 | 4.286347 | 6.69E-07 | -8.544195 | -7.831618 | -8.255596 |
| 11 | 863.9221 | 2.956514 | 6.85E-07 | -8.520022 | -7.739581 | -8.203938 |
| 12 | 865.2988 | 2.394863 | 7.05E-07 | -8.492696 | -7.64439 | -8.149126 |

VAR Lag Order Selection Criteria
Endogenous variables: RBPR EXRVOL
Exogenous variables: C
Date: 03/06/17 Time: 00:42
Sample: 2000M01 2016M12
Included observations: 67

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 278.1932929 | NA | 9.00E-07 | -8.244576 | -8.178764 | -8.218534 |
| 1 | 327.4596803 | 94.12086* | 2.33e-07* | -9.595811* | -9.398376* | -9.517686* |
| 2 | 329.8980074 | 4.512725 | 2.44E-07 | -9.549194 | -9.220136 | -9.418985 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | 334.9975471 | 9.133504 | 2.37E-07 | -9.582016 | -9.121334 | -9.399723 |
| 4 | 338.4136294 | 5.914411 | 2.41E-07 | -9.564586 | -8.97228 | -9.330209 |
| 5 | 342.8182437 | 7.362937 | 2.39E-07 | -9.576664 | -8.852735 | -9.290204 |
| 6 | 343.5453041 | 1.171978 | 2.65E-07 | -9.478964 | -8.623412 | -9.14042 |
| 7 | 347.2226585 | 5.708132 | 2.69E-07 | -9.469333 | -8.482157 | -9.078705 |

VAR Lag Order Selection Criteria
Endogenous variables: WEZR EXRVOL
Exogenous variables: C
Date: 03/06/17 Time: 00:45
Sample: 2000M01 2016M12
Included observations: 125

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 397.2429194 | NA | 6.15E-06 | -6.323887 | -6.278634 | -6.305503 |
| 1 | 516.5948095 | 232.9749 | 9.71e-07* | -8.169517* | -8.033758* | -8.114365* |
| 2 | 517.6163087 | 1.961278 | 1.02E-06 | -8.121861 | -7.895596 | -8.029941 |
| 3 | 521.3033678 | 6.961167 | 1.02E-06 | -8.116854 | -7.800083 | -7.988166 |
| 4 | 526.6517888 | 9.926669* | 1.00E-06 | -8.138429 | -7.731151 | -7.972973 |
| 5 | 527.6380495 | 1.79894 | 1.05E-06 | -8.090209 | -7.592426 | -7.887986 |
| 6 | 529.6406891 | 3.58873 | 1.09E-06 | -8.058251 | -7.469962 | -7.81926 |
| 7 | 532.4572496 | 4.957146 | 1.11E-06 | -8.039316 | -7.360521 | -7.763557 |
| 8 | 535.4460035 | 5.164567 | 1.13E-06 | -8.023136 | -7.253835 | -7.71061 |

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

## 8.5 Appendix 5 – Additional Regressions

The additional regression was a simple OLS test, $R_{it} = \vartheta + \emptyset_i BCOM_t + \epsilon_t$ which involved regressing the mining firms hare returns with BCOM[3] commodity index to establish the relationship between the dependent and independent variable.

[3] "BCOM - The Bloomberg Commodity Index (BCOM) is a broadly diversified commodity price index distributed by Bloomberg Indexes" (Bloomberg, 2017)

| | Constant ($\vartheta$) | Coefficient ($\emptyset_i$) | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|---|
| AMS | 0.001760 | -0.084014 | 0.178643 | -0.470288 | 0.638659 |
| ANG | 0.000299 | -0.332870 | 0.175667 | -1.894892 | 0.059542 |
| ARI | 0.003017 | 0.009778 | 0.181983 | 0.053728 | 0.957206 |
| ASR | 0.017566 | 0.010435 | 0.163575 | 0.063793 | 0.949198 |
| EXX | 0.013873 | -0.058045 | 0.177036 | -0.327868 | 0.743392 |
| IMP | 0.001041 | -0.165391 | 0.178577 | -0.926165 | 0.355471 |
| KIO | 0.002510 | -0.035412 | 0.248429 | -0.142545 | 0.886889 |
| NHM | 0.007501 | 0.336491 | 0.183346 | 1.835280 | 0.067900 |
| RBP | -0.007802 | 0.023795 | 0.256240 | 0.092864 | 0.926270 |
| WEZ | -0.008220 | 0.252813 | 0.297319 | 0.850309 | 0.396705 |