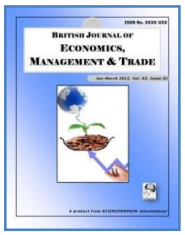

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Zimbabwe Stock Exchange ("ZSE")'s Exposure to Global Crude Oil Price Volatility

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Authors' contributions

This work was carried out in collaboration between all authors. Author WC designed the study, wrote the first draft of the manuscript. Author WC managed the literature searches, analyses of the study and interpretation of results. Author WG performed the econometric analysis. Author DJN collected data and analyzed volatility of the Zimbabwe Stock Exchange indices. Author RC performed analysis of crude oil price volatility. All authors read and approved the final manuscript.

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ABSTRACT

The major aim of this paper is to investigate Zimbabwe's Stock Exchange indices' exposure to global oil price volatility for the period 2009-2012.To determine the relationship between volatility of crude oil returns and volatility of stock returns of the ZSE indices using econometric GARCH models. Also to investigate the correlation of the global oil price in the form of Brent Crude oil prices index and Western Texas Intermediate (WTI) oil prices index with ZSE Industrial Index and the ZSE Mining index between 2009 and 2012. A GARCH approach is employed to analyse data from ZSE and Chicago Mercantile Exchange, OPEC and Datastream® Data. Daily data for crude oil prices and Zimbabwe stock exchange indices were collected for the period 2009-2012 and analysed. The variables of the Zimbabwe stock exchange are ZSE Industrial Index; and ZSE Mining index. Variables on Crude oil prices comprised of Western Texas Intermediate ("WTI") spot prices index;

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and Brent Crude oil spot prices index. Returns of stock on all the four indices were calculated. It was assumed that returns on stocks would mirror stock price movements. Volatility of returns on ZSE industrial index was very low with standard deviations ranging between -.01 to +.01. Volatility of returns on the ZSE Mining index was significant relative to the industrial index with standard between-0.1 to -0.1. Volatility of stock returns on Brent Crude spot price index was very high with standard deviations ranging between -0.6 to +0.6, while stock returns on Western Texas Intermediate ("WTI") spot prices index displayed high volatility, standard deviations ranged from -0.1 to +0.1. Standard deviation indicates the level of dispersion from the the mean. GARCH coefficients indicated that the mean of stock returns as represented by were generally negative for the two domestic stock indices while the means of global oil stock returns were positive. Parameters $\propto_i$ and β_j of the four indices were statistically significant. The β_j coefficients of all the indices were highly significant ranging between 0.6300 to 0.9300 indicating that volatility was persistent in the period under investigation and that volatility was to a large extend driven by the prices and values of the previous time period (past performance).There was a positive correlation between industrial index and Brent crude with a correlation coefficient of 0.505 as well as a positive correlation between the ZSE Industrial index and the WTI oil price index with a coefficient of 0.520. There was a negative correlation coefficient of -0.332 between the Mining index and the global Brent crude oil prices as well as a negative correlation coefficient of -0.201 between Mining index and WTI Crude. The results of the study confirmed the hypothesis that the ZSE stock markets are indeed exposed to significant exogenous risks emanating from rising global crude oil price movements. There are however, moderating factors as the standard deviations on ZSE stock returns are much lower compared to standard deviations of stock returns on the global oil indices. Also the correlation coefficients are on the low side. Increases in crude oil prices have the potential to subdue any favourable factors to share price increases.

Keywords: Volatility; global oil index; GARCH model; correlation; stock returns.

1. INTRODUCTION

This investigation seeks to ascertain the impact of global crude oil price volatility on the stock markets in Zimbabwe during the period 2009-2012. This is a period in which internal macroeconomic variables and political variables had a moderate influence on the Zimbabwe Stock Exchange. Politically, it was the period of Government of National Unity (GNU). There was not much change in terms of macroeconomic policy apart from dollarization. The period 2004 to 2008 was characterized by hyperinflation, high interest rates and depreciating Zimbabwe dollar. These were the variables that had a major impact on stock prices. It would have been difficult to isolate the impact of oil price change under extreme variability of these variables. The period from mid- 2013 to date 2014 was characterized by severe liquidity challenges, economic policy and political risk issues coming from the outcome of combined general elections. We therefore believe that the period under study provides valid and effective data for this research. The period tries to avoid structural breaks by avoiding two period of extreme variability in variables. We further believe limited research has been conducted in this area particularly in Zimbabwe. Brent Crude Oil Price Index and Western Texas Intermediate (WTI) Crude Oil Price Index would represent global oil price indices. The Zimbabwe stock market indices namely the industrial index and mining index would reflect price movements on the stock exchange. Daily data for the four indices were collected for the period 2009-2012 and analysed.

The research is expected to provide insights into the relationship between crude oil spot price volatility and the performance of the ZSE stock market indices. The relationship shall be utilized to forecast the impact future global oil spot prices changes would have on the stock market indices. Oil price movements are a factor affecting stock valuations in that the value of stock equals the discounted sum of expected future cash flows [1,2]. These cash flows are affected by macroeconomic events that can be directly influenced by oil prices. Since stock indices reflect the stock market's best estimate of future profitability of firms, oil price movements should have an impact on the stock market as they affect profitability of the firm through cost of production and distribution. The decline in profitability reduces dividend pay-outs to equity holders thus making equity investments less attractive to investors. However, this impact is not uniform for all stocks on the stock exchange.

Some companies are more exposed to oil price movements than others. Therefore to clearly see the impact of oil price movements on companies it was important to consider the effect of oil price volatility on separate stock market indices the ZSE Industrial Index and Mining Index.

The impact of oil price volatility on the stock market should be felt more on oil importing countries such as Zimbabwe. During the period under review the Zimbabwean economy experienced a high rate of economic growth with a consequential increase in oil and fuel consumption. Since 2009 the country's average daily fuel consumption increased steadily. The demand in fuel is expected to continue increasing because of the following factors:

- Liberalisation of trade which has seen a huge increase in the importation of relatively cheaper and affordable second hand vehicles particularly from Japan.
- The shift in company policies whereby most employees within managerial grades are accorded company vehicles as part of their employment packages.
- Growth in urban population due to rural urban migration which has put pressure on urban transport.
- The land reform programme has increased small scale farmers attempting to mechanize and indigenisation of the mining sector has seen small scale miners come on board who largely depend on diesel powered equipment.
- The growth of the urban elite class whereby some families have multiple vehicles which are utilized at the same time; and
- The persistent electricity shortages have led to the increase in demand for diesel and petrol power generators.

Zimbabwe imports 100% of its oil requirements hence fluctuations in oil prices would be a significant indicator of the country's exogenous risk.

During the period understudy the global economy was going through a period of weak growth. There were financial turbulences caused by excessive external debt levels particularly in Europe. At the aggregate level the knock-on effects of economic problems in developed markets have been minimal on the growth of emerging countries such as Zimbabwe and consequently on the stock exchange. Economic growth in Zimbabwe was largely underpinned by increased domestic demand and government expenditure.

Other external variables which could have had a significant impact on the stock exchange were volumes of trade by external investors, exchange rate and commodity prices. We believe these variables had a low to moderate influence on stock prices to subdue the relationship between oil price volatility and stock price volatility. Take inflation as an internal variable for example, during the period under study year on year inflation in Zimbabwe was at 3%. Inflation has since declined to the extent that analysts are now saying the economy is in a state of deflation. Commodity prices firmed during the period under study. This benefited exports in the mining sector the increases in mineral prices had the effect of increasing the mining stock prices. However, the increase in mineral prices did not subdue the negative relationship between increase in oil prices and mining stock prices. On agricultural commodities the local prices were much higher than international prices. Zimbabwe was not competitive in exporting agricultural commodities so the firming of international price of agricultural commodities did not have much influence on stock prices. Regarding exchange rates, assuming products in Zimbabwe are priced in US$ and looking at the major trading partners of Zimbabwe, from 2009 to 2012 there was an appreciation of the ZAR against the US$. Profitability should have increased for exporting companies and decreased for importing companies. Other things being constant stock prices for exporting companies should have increased during this period. There was alternating appreciation and depreciation of GDP and EURO against the US$ to the extent that no trend could be observed. Volumes of trade by external investors did have an influence in increasing stock prices and returns. Trading on the Zimbabwe stock exchange was dominated by high foreign inflows and foreign volumes while local traders were facing liquidity challenges. From the explanation of possible impact of other external variables on the stock market, the research will focus more on oil price volatility as a measure of exogenous risk exposures. Our analysis on the influence of exchange rates and dominance of foreign trading on stock returns and prices would be taken into account in the final conclusions.

2. LITERATURE REVIEW

There is a body of theory focused on the linkage between stock market indices and crude oil price

changes. In general, there is a consensus on the existence of a relationship between oil market volatility and stock price indices. This relationship can be explained through several economic canals. [3] Have shown the importance of oil resources in leading overall economic activity and suggested various theoretical links that may explain the interaction between oil prices and stock price indices. Based on the idea that stock prices are the discounted values of future cash flows, it has been suggested that net oil importing economies' response to crude oil price volatility can be explained via three canals which emanate from the hypothesis that the expected discount rate is composed of expected inflation and expected real interest rate. These two variables are jointly influenced by expected oil prices. Expected oil prices affect stock market indices through the discount rate. Indeed, because oil is a major resource in any net oil importing economy, increases in oil prices affect negatively the balance of payments, which in turn affects the foreign exchange rate and increases expected domestic inflation. A higher expected inflation rate is positively related to the discount rate and as a consequence is negatively related to stock market indices [3]. They showed that crude oil price volatility affects positively the expected costs and negatively the stock prices indices. However, according to the theories put forward by previous researchers, there seems to be no consensus among researchers when it comes to the relationship between stock spot prices and changes in global oil spot prices. Some theoretical results suggest a positive correlation between stock markets and oil spot price changes, while other results suggest negative correlation and yet others suggesting no significant relationship between the two variables.

Other authors suggested positive correlation between oil prices and stock market indices. This phenomenon is particularly evidenced in net-oil exporting economies. Expected oil prices increases reflect positive growth in demand which attracts investors to oil exporting countries in an effort to earn positive returns. This drives up stock prices and thus stock indices in oil exporting countries stock markets. In other words, increases in oil prices have a positive impact on the stock markets of oil exporting countries [4,5,6] discovered a negative reaction of US, Canadian, UK and Japanese stock prices to oil price increases by investigating the impact of oil price changes on real cash flows of listed companies. Their results suggested that an increase in global oil prices increased operating costs of listed companies (particularly those involved in production) which subsequently reduced the companies' real cash flows restricting the companies' ability to pay dividends hence making listed companies less attractive to investors. The result was a fall in stock prices and hence a subsequent decline in stock market indices. [7] Analysed the effect of oil price increases on stock prices by using the expected cost flows, the discount rate and the equity pricing model. They discovered that the direction of the stock price effect to oil price increases depends on whether a stock is a producer or a consumer of oil or oil-related products. As most companies in the world market are oil consumers, they discovered that the performance of the stock market indices is negatively correlated to oil price increases.

[8] Applied nonlinear cointegration analysis to examine the linkage between oil prices and stock markets in GCC countries. The empirical results indicated that oil prices movements have a nonlinear impact on stock price indices in GCC countries. [3] Argued that, in the short run, GCC stock market returns are dominated by the influence of non-observable psychological factors. In the long run, the effects of oil price changes are transmitted to fundamental macroeconomic indicators which in turn, affect the long run equilibrium linkages across markets. [9] Found a significant positive relation between oil prices volatility and the stock index of Qatar, Oman and UAE. Using a two-regime Markov-switching GARCH model, [10] examined the relationship between crude oil shocks and stock markets indices from December 1987 to January 2007. This study focused on two major crude oil markets, namely WTI and Brent, and three developed stock markets, namely France, UK and Japan. The results show that the net oil price increase variables play a significant role in determining the volatility of stock indices. [11] established that oil price shocks were a factor contributing to recession in the American economy. Several studies have been carried out on the impact of oil price on various macroeconomic activities. Findings reveal that there in a statistically significant influence of oil price shocks on macroeconomic activities in the G-7 [12,13], G-7 and Norway [14] and Asian countries [15].

Several authors such as [16,17,18,19,20] confirm the negative reaction of stock returns following an increase in oil prices. They developed models

that associate the stock returns to different variables including oil price, oil production, short-term interest rate and industrial production. Using an EGARCH-M model [21] investigated macroeconomic variables effect on both returns and volatility of the stock market returns. They use monthly data to analyse the impact of oil price shocks on 8 international stock markets over the period from January 1991 to September 2013. The countries included in the analysis are US, SWISS, FRANCE, CANADA, UK, AUSTRALIA, JAPAN and SINGAPORE. Evidence supported the negative connections between oil price changes and stock market returns for all selected countries with exception of the case of Singapore where the oil price shocks have no impact on stock price. The oil price changes exert significant positive effects on the volatility of stock returns for all selected countries with the exception to the cases of the France and the UK where there is no significant relationship between oil price shocks and the volatility of stock returns. Previous studies which revealed negative connection between oil prices and the stock returns document that oil price increases and volatility lead to rising inflation and unemployment and therefore depress macroeconomic growth and financial assets [20,22].

The oil price changes affect substantially decisions made by producers and consumers in strategic planning and project appraisals. Secondly they determine investors' decision in oil-related activities, portfolio allocations as well as risk management [21,23] concluded that a rise in oil prices acts as inflation tax and lead therefore consumers to look for alternative energy sources from one hand andincreases risk and uncertainty from the other hand, and this affects seriously the stock price and reduce wealth. [24] Examined the effects of oil price shocks and oil price volatility on the real stock returns of the US and 13 European countries over the period from January 1986 to December 2005. Using a multivariate VAR model they found that oil price shocks exert a statistically significant impact on real stock returns in the same month or within one month.

Papapetrou [17] using 1989-1999 monthly data investigated effects of the oil price increases on of the Greek stock market. The results of his study show, in fact, that oil price forms an important component in explaining stock price movements, and the increases in oil price shocks induce serious depressions in real stock returns. Similarly, [19] test the long run relationship between the world price of crude oil and international stock markets. They used a Vector Error Correction model over the period spanning January 1971 to March 2008. The results for six OECD countries confirm a clear long-run connection between oil price and real stock market returns that means a negative reaction of real stock prices to the increase in oil prices. The negative reaction of real stock prices to the increase in oil price is attributed according several authors to the direct effects of this increase on cash flows and inflation. The result indicating that oil price increases lead to reduce stock returns is commonly shared by many authors such as [25] for US, UK and France, [24] for US and 12 European oil importing countries, and [16] for global industry indices (except for attractive industries).

Reboredo and Rivera-Castro [26] examined the connection between oil price and stock market returns using daily data that consists of the aggregate S&P 500 and Dow Jones Stoxx Europe 600 indexes and US and European industrial sectors (automobile and parts, banks, chemical, oil and gas, industrial goods, utilities, telecommunications, and technologies) over the period from 01 June 2000 to 29 July 2011. Based on wavelet multi-resolution analysis they found that oil price changes have not much effect on stock market returns in the pre-crisis period at either the aggregate as well as the sectoral level. [27] for a sample composed of the UK-listed oil and gas firms found out that changes in crude prices, the stock market condition as well as the exchange rate as risk factors exert significant impacts on oil and gas stock returns.

Zimbabwe Stock Market Indices 2009-2012

The Industrial index tracks daily price changes in the stocks of 74 listed companies drawn from various sectors of the economy ranging from Agro-Industry, Conglomerates, Financial services, Insurance, Property and Retail, while the Mining index tracks stock price movements of 4 listed companies involved in the mining industry. The indices performed well upon inception in 2009 with the Mining index reaching an annual high of 300.00 points while the Industrial Index rose to 150.00 points during the same year.

3. METHODOLOGY

3.1 Research Design

This investigation seeks to evaluate the contemporaneous and lagged time varying relationship between volatility of ZSE returns and volatility of global oil returns. Also to evaluate correlation between stock market indices and oil prices indices for a net oil importing country Zimbabwe. A GARCH approach is employed to analyse data from ZSE and Chicago Mercantile Exchange, OPEC and Datastream® Data. Daily data for oil prices indices and Zimbabwe stock exchange indices was collected for the period 2009-2012. The data was subjected to analysis using the GARCH method. The variables of the Zimbabwe Stock Exchange are ZSE Industrial Index and ZSE Mining index. Variables on Crude oil prices comprised of Western Texas Intermediate ("WTI") spot prices index and Brent Crude oil spot prices index. Returns of stock on all the four indices were calculated. It was assumed the returns on stock indices would mirror stock price movements and returns on oil indices would mirror oil price movements. The Brent crude oil price index is used in this investigation as it accounts for up to 60% of the trade in world oil daily production and Western Texas Intermediate accounts for up to 20% of global oil trades (Chicago Mercantile Exchange). Oil prices from both oil price indices are expressed in dollar terms and have been extracted from Datastream® Database. Further information and statistics included in this document was sourced from journals, and research papers about oil prices and stock markets. Microsoft Excel 2007, Matlab 7.60 (R2000a), RStudio and SPSS 13.0 were used in the analysis of the research data. The Phillips-Perron test was conducted to test for stationarity. The GARCH (p, q) model is used in the volatility analysis.

3.2 The GARCH (p, q) Model

The GARCH (p, q) model expresses the variance at time t, σ_t^2

Where, q stands for lags of the squared error and p stands for lags of the conditional variance.

$$\sigma_t^2 = \omega + \sum_{i=1}^{q} \propto_i \varepsilon_{t-1}^2 + \sum_{j=1}^{p} \beta_j \delta_{t-j}^2 \qquad (1)$$

$\omega, \propto_i$ and β_j are the parameters to be estimated.

The GARCH estimation model consists of two equations, $\sum_{i=1}^{q} \propto_i \varepsilon_{t-1}^2$ for the mean which is a simple autoregressive AR (1) model and the other $\sum_{j=1}^{p} \beta_j \delta_{t-j}^2$ for the variance which is identified by a particular ARCH specification, i.e. GARCH (1, 1). Where $\omega > 0$, $\propto_i > 0$, $\beta_j > 0$, and $\beta_1 + \propto_i < 1$, so that the next period forecast of variance σ_t^2 is a blend of last period forecast and last period's squared return.

Where $\boldsymbol{\omega}$ is the constant representing the intercept.

μ is the mean estimate of the time series data.

$\propto$ is the coefficient of previous day forecast.

β is the coefficient of previous day squared error.

3.3 Correlations

For measuring the correlation between stock markets and oil price volatility the following formula was used. The correlation coefficient $\mathbf{r_{X,Y}}$ between the ZSE Industrial Index**(X)** and Brent crude oil prices **(Y)** with expected values **μX** and **μY** and standard deviations **σX** and **σY** is their covariance normalized by their standard deviations, as follows;

Since $\mu X = E(X)$, $\sigma X^2 = E(X^2) - E^2(X)$, and likewise for **Y,**

Then correlation coefficient ($\mathbf{r_{X,Y}}$) is given by;

$$\frac{E(XY) - E(X)E(Y)}{\sqrt{E(X^2) - E^2(X)}\sqrt{E(Y^2) - E^2(Y)}} = r_{x,y} \qquad (2)$$

Therefore the inputs for the coefficient correlation are

E(X) is the expected value of the global crude oil prices namely:

- Brent Crude Oil Prices 2009-2012
- Western Texas Intermediate oil prices 2009-2012

E(Y) is the expected value of the ZSE stock market indices namely:

- ZSE Industrial Index daily closing values 2009-2012
- ZSE Mining Index daily closing values 2009-2012

E(XY) is the expected value of product of the of ZSE stock index closing value and the corresponding Brent/WTI oil price:

E($X^{2)}$ is the expected value of the square of the Brent/WTI crude oil price

E (Y2) is the expected value of the square of ZSE stock market indices either Industrial/ Mining index

Correlation coefficients will be used to measure the strength of the correlation between the following results:

- Correlation between the ZSE Industrial Index and Brent crude oil prices;
- Correlation between the ZSE Industrial Index and WTI crude oil prices;
- Correlation between the ZSE Mining Index and Brent crude oil prices; and
- Correlation between the ZSE Mining Index and WTI crude oil prices.

3.4 Pairwise Granger Causality Tests

We test for causality, in the Granger sense, by using F-tests to test whether lagged information on a variable Y provides any statistically significant information about a variable X in the presence of lagged X. If not, then Y does not Granger-cause X. A variable Y is said not to Granger-cause a variable X if the distribution of X, conditional on past values of X alone, equals the distribution of X, conditional on past realizations of both X and Y. If this equality does not hold, Y is said to Granger-cause X. If Y can predict future X, over and above what lags of X itself can, then Y Granger causes X. We test for Granger causality by estimating the following VAR models for each pair-wise combination of returns series:

$$X_t = \mu_1 + \sum_{i=1}^{p} \alpha_{1,i} Y_{t-i} + \sum_{i=1}^{p} \beta_{1,i} X_{t-i} + \varepsilon_{1,t} \quad (3)$$

If the null hypothesis:

$H_0 : \sum_{i=1}^{p} \alpha_{1,i} = 0$ is rejected then Y is said to Granger cause X.

$$Y_t = \mu_2 + \sum_{i=1}^{p} \alpha_{2,i} X_{t-i} + \sum_{i=1}^{p} \beta_{2,i} Y_{t-i} + \varepsilon_{2,t} \quad (4)$$

If the null hypothesis:

$H_0 : \sum_{i=1}^{p} \alpha_{2,i} = 0$ is rejected then X is said to Granger cause Y.

If the null hypothesis is rejected from both cases, it is said that there is a feedback relationship between X and Y.

3.5 Calculating Net Returns

Let ***Pt*** be the price of an asset at time *t*. Assuming no dividends, the ***net return*** $\boldsymbol{R_t}$ over the holding period from time ***t-1*** to time ***t*** is given by;

$$\mathbf{Netreturn} = \mathbf{R_t} = \frac{\mathbf{P_t}}{\mathbf{P_{t-1}}} - \mathbf{1} = \frac{\mathbf{P_t - P_{t-1}}}{\mathbf{P_{t-1}}} \quad (5)$$

The numerator $\boldsymbol{P_t - P_{t-1}}$ is the revenue or profit during the holding period, with a negative profit meaning a loss. The denominator $\boldsymbol{P_{t-1}}$ was the initial investment at the start of the holding period. Therefore, the net return can be viewed as the relative revenue or profit rate.The numerator

4. RESULTS AND DISCUSSION

4.1 Data Specification

Data on the ZSE Industrial and Mining Indices as well as the Brent crude oil price index and WTI crude oil price index was prepared for analysis by creating the respective time series data in the form of a csv files that were imported for analysis in RStudio. Returns of the Industrial index, Mining Index, Crude oil price index and WTI price index were calculated and the respective time series were generated. The Table 1 below gives the results of a descriptive statistical tests carried out on the time series data of the four respective indices to determine the key statistical characteristics of the data. From the results it can be seen that the mining index time series data had the maximum values of mean and standard deviation while the WTI price index exhibited the lowest values for mean and standard deviation.

4.2 Phillips-Perron Stationarity Test

According to the Phillips-Perron test, the null hypothesis is that X is non-stationary. The results in Table (2) below show that Phillips-Perron test statistics proved to be sufficiently negative, a result which means that the null hypothesis is rejected. The respective time series data of the indices was stationary.

4.3 Industrial Index Volatility of Returns under GARCH (1, 1) Plot

Fig. 1 is a graphical representation of the results showing the volatility of Industrial Index returns. During the first trading months after dollarization on the ZSE, the returns on the Industrial index exhibited a greater degree of volatility. This phenomenon however persisted for over a year as the market battled to correct the stock price distortions emanating from the transition from Zimbabwe dollar to United States dollar. The results of the conditional standard deviation also confirm the existence of wide deviations in industrial stock index returns during the initial dollarization phase. The degree of deviation subsided in the subsequent years and eventually became relatively constant. During the initial stages deviations reached a peak of + 0.12 to -0.12 but at the close of 2012 deviations were in the region of below +0.01to -0.01. This result is consistent with the decline in volatility during the same period of time.

Fig. 2 below shows the movement and trends in the Industrial Index price since the inception of dollarization;

4.4 Mining Index Volatility of Returns under GARCH (1, 1) Plot

The results of the Mining index returns time series showed a more persistent level of variability (Fig. 3) below. The plot above shows alternating periods of high volatility and periods of relatively low volatility. The index showed clusters of deviations ranging fron-0.2 to +0.2 indicating a high degree of persistent volatility throughout the period under study. The Mining index time series data both and proved to be significant and the volatility of the mining index was largely dependent on the GARCH component.

As Fig 4 indicates the ZSE mining index initially kicked off the year 2009 in a bullish mode rising from below 100.00 points to move beyond the 250.00 points as investors regained confidence in ZSE mining counters after the dollarization. It then started sliding down. The bearish trend continued until September 2010 were the index rebounded to register a high of 260.00 points before retreating again in late 2011.

4.5 Brent Crude Oil Price Index Volatility of Returns Under GARCH (1,1) Plot

The Brent crude index showed the highest degree of persistent volatility indicating global oil price uncertainty (Fig. 5). The frequency of very high and very low peaks was persistent throughout the period. The range of deviations was between -0.6 and +0.6. There were frequent periods of high volatility intensity. The results confirm that global oil returns reflect the forces of demand and supply of the precious commodity and also capture future expectations of supply and availability.

According to Fig. 6, Brent crude oil prices have shown a sustained growth trend since 2009. Brent crude initially traded at below US$50/ barrel in 2009 and had risen by100% in 2011. Brent crude oil prices moved beyond US$120/barrel before meeting resistance just below US$130/barrel. Brent crude oil prices did however decline significantly in 2011 falling to below US$90/ barrel representing a 25% decline in crude oil prices. Prices have been fluctuating at about the US$100/barrel since late 2012.

Table 1. Results of descriptive statistics

Index	N	Minimum	Maximum	Mean	Std. deviation
Mining	927	63.4100	297.6300	157.593862	58.9410603
Brent	927	48.2900	128.1400	94.262913	20.1204636
WTI	927	45.8200	113.3900	85.305566	12.7314852
Industrial	927	51.4100	173.2100	142.110734	20.7500471
Valid N	927				

N = Data points

Table 2. Results of stationarity tests

Index	Phillips-perrontest statistic	Critical value at 5%	p-Value	Conclusion
Industrial index	-26.63855	-2.864452	0.0000	Stationary
Mining index	-27.69714	-2.864452	0.0000	Stationary
Brent crude	-30.14404	-2.864452	0.0000	Stationary
WTI	-16.63428	-2.864452	0.0000	Stationary

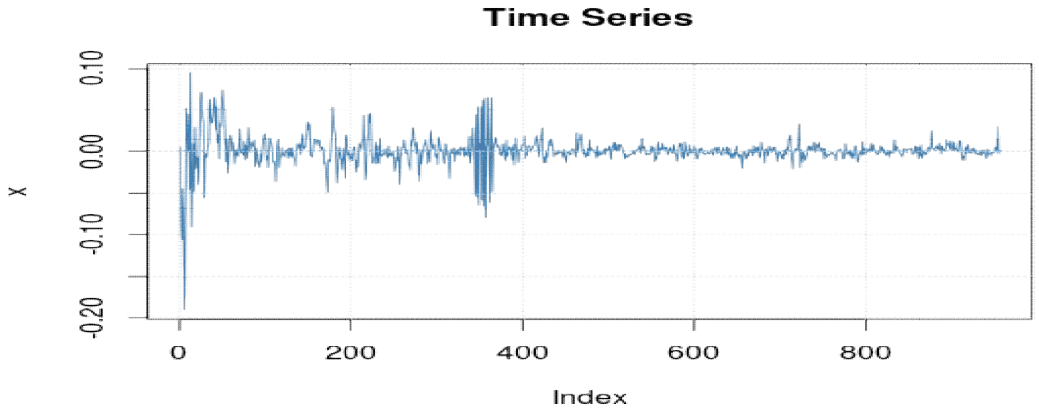

Fig. 1. Industrial index time series

Where x= the return on the ZSE Industrial index, Index= the number of days since 1 January 2009

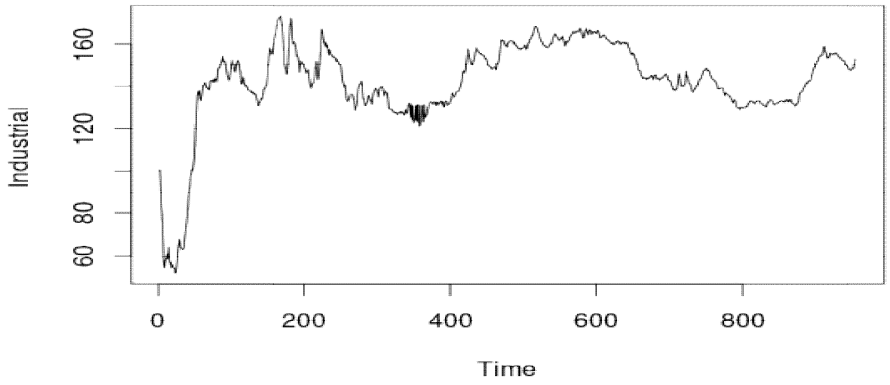

Fig. 2. ZSE Industrial Index price movements since 2009

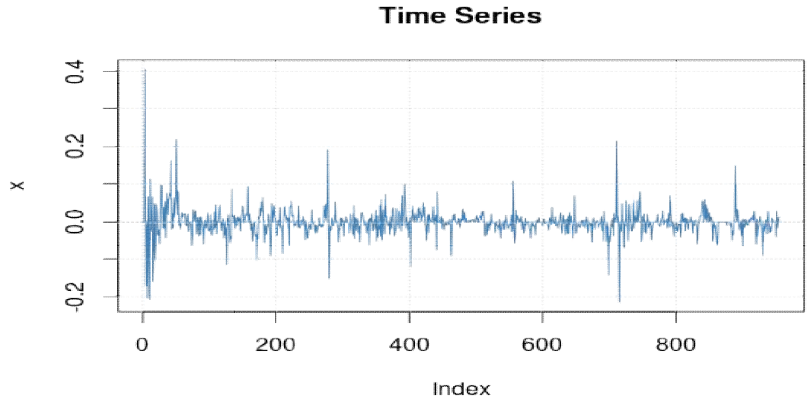

Fig. 3. Mining index returns time series plot

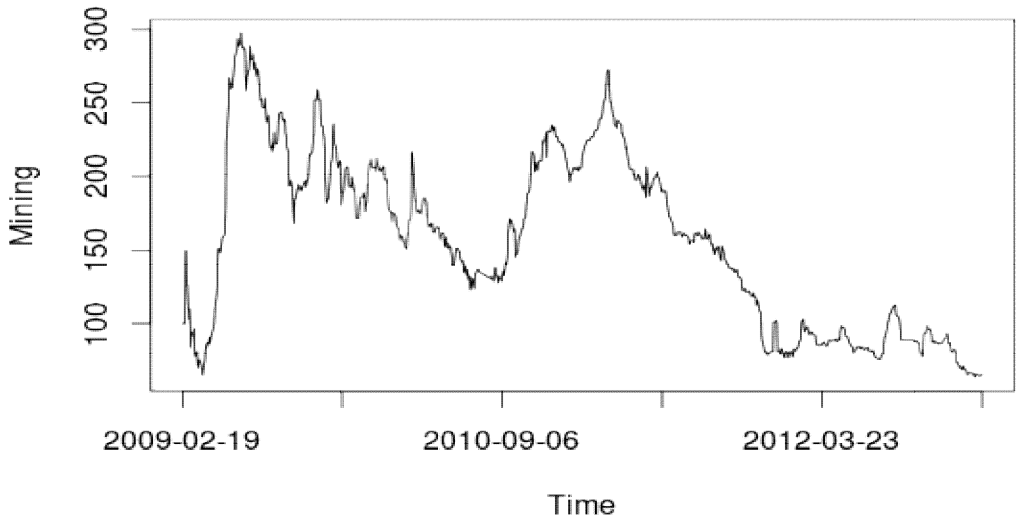

Fig. 4. ZSE Mining Index price movements for the duration 2009-2012

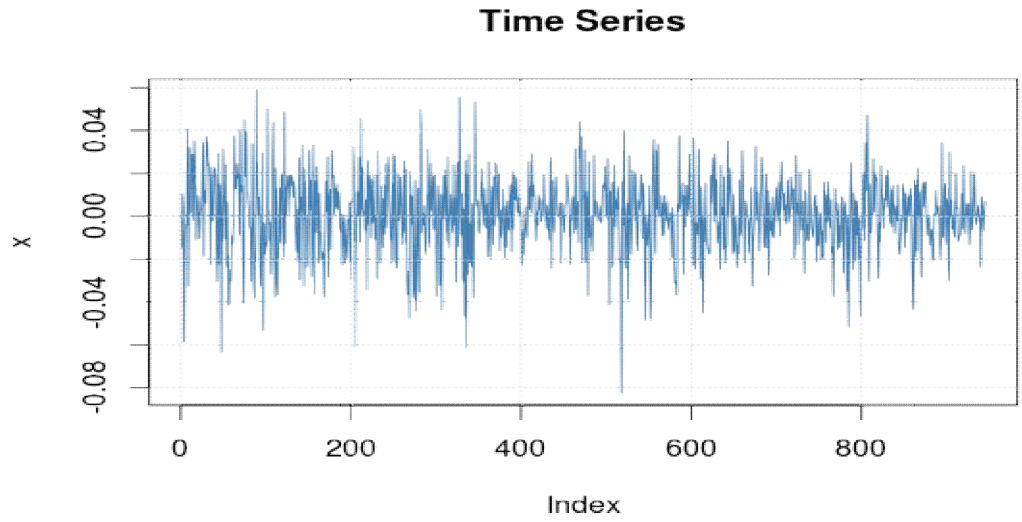

Fig. 5. Brent Crude price index returns time series plot

4.6 WTI Crude Oil Price Index Volatility of Returns Plot under GARCH (1, 1)

As shown in Fig. 7 below the WTI crude oil price index exhibited relatively less volatility compared to the Brent index. The WTI oil price index returns also exhibited significant levels of persistent volatility throughout the period under investigation. The index showed sustained periods of high levels of standard deviation. The results confirm that global oil prices are highly volatile, as the WTI oil price index returns also exhibited significant levels of persistent volatility.

Global oil prices as represented by the WTI price index were generally on a sustained growth trend during the period 2009-2012 as shown in Fig. 8. Crude oil prices on the WTI index commenced the year 2009 trading below US$50/barrel. Crude oil prices soared to register a period high of US$110/barrel which represented a 100% leap in oil prices. Crude oil prices retreated significantly thereafter declining to US$70/ barrel. The decline was however followed by another period of crude oil price firming. Global oil prices rallied in 2011 to trade past the US$100/barrel mark.

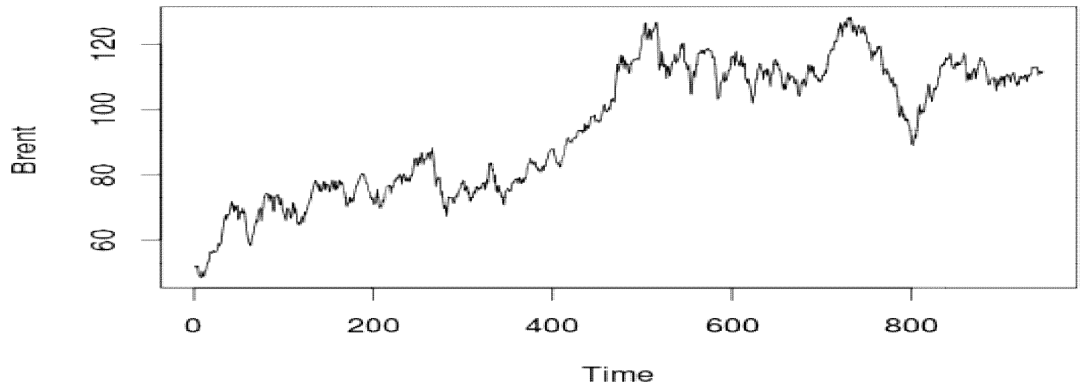

Fig. 6. Brent global crude oil price index performance 2009-2012

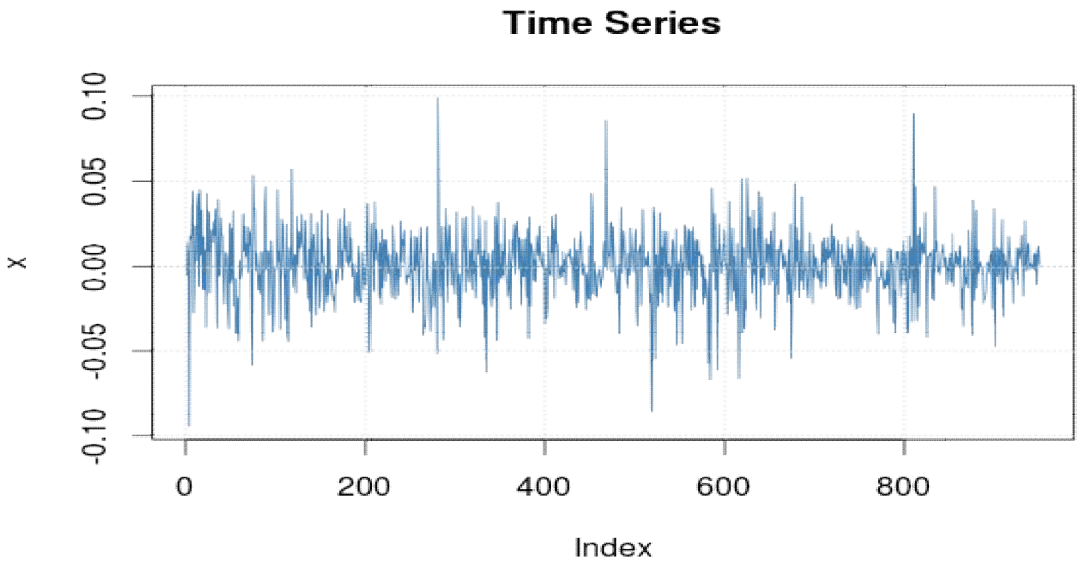

Fig. 7. WTI Crude price index returns time series

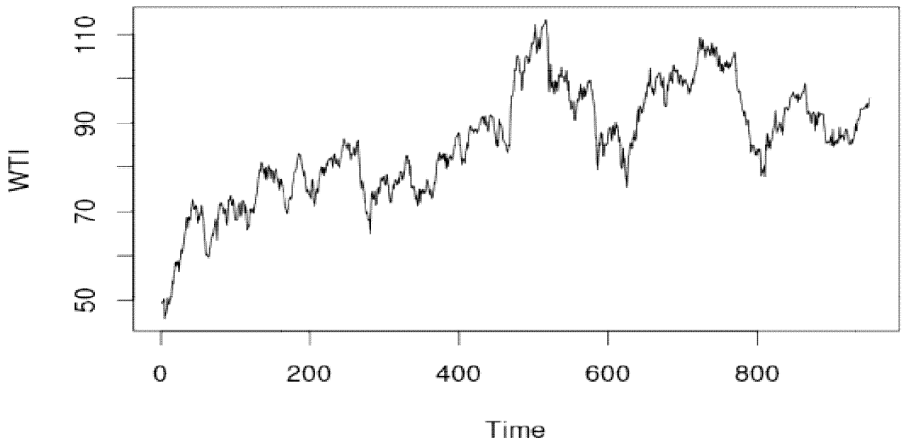

Fig. 8. WTI global crude oil price index performance 2009-2012

4.7 Measuring Volatility Using GARCH (1, 1)

4.7.1 The background

The justification of using GARCH (1, 1) in practice is that GARCH (1, 1) is often the best model characterising financial data series volatility. The idea is to calculate the mean and variance of a time series data set so as to determine the volatility of the data set. Using RStudio the GARCH (1, 1) specification includes the mean equation shown below.

Mean equation.

$$\boldsymbol{\mu} = \emptyset z_{t-1} + \boldsymbol{\varepsilon_t} \quad (6)$$

Where $\boldsymbol{\varepsilon_t} \sim \boldsymbol{N}(\mathbf{0}, \boldsymbol{h_t})$ and $\emptyset$ is the parameter to be estimated using **GARCH (1, 1)** model

RStudio **GARCH (1, 1)** package specifies the following variance equation;

Variance equation

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1} + \beta_1 h_{t-1} \quad (7)$$

Where and are parameters to be estimated using the GARCH (1, 1) model

The persistence of the time series data under RStudio GARCH (1, 1) package is given by;

Persistence parameter

$$\text{persistance} = \propto_{\mathbf{1}} + \beta_{\mathbf{1}} \quad (8)$$

Before applying GARCH (1, 1) process on a given time series data set, the data should be stationary. Section 4.2 of this document proves that the time series data used in this investigation was sufficiently stationary. RStudio GARCH (1, 1) package verifies that a given data set meets the stationarity conditions by specifying the following condition;

Stationarity condition

$$\sum_{i=1}^{p} \propto_i + \sum_{j=1}^{q} \beta_q < 1 \quad (9)$$

Furthermore the RStudio package "fGarch" function `garchFit' was used to simultaneously fit ARMA and GARCH models into the system. The RStudio package "tseries" function `garch' was used to import the time series data into the ARMA and GARCH models. The above description highlights the preliminary steps in applying the time series data to fit the GARCH model. The following are the output results of applying the GARCH (1, 1) model to the respective time series data using the following GARCH (1, 1) equation;

GARCH (1, 1) equation

$$\sigma_t^2 = \omega + \sum_{i=1}^{q} \propto_i \varepsilon_{t-1}^2 + \sum_{j=1}^{p} \beta_j \delta_{t-j}^2 \quad (10)$$

Where $\omega > 0$, $\propto_i > 0$, $\beta_j > 0$, and $\beta_1 + \propto_1 < 1$, so that our next period forecast of variance σ_t^2 is a blend of our last period forecast and last period's squared return. Hence the results of the GARCH (1, 1) model estimate coefficients of the GARCH parameters namely ω, $\propto_i$ and β_j where $\boldsymbol{\omega}$ is the constant representing the intercept. The RStudio GARCH package also estimates the mean of the time series data given by μ which is also presented in the results as the weighted average of the time series data. Therefore using R Studio GARCH (1, 1) package estimates the mean and variance coefficients and specifies conditional distribution as a standard normal distribution as well as calculated the standard errors of the parameters using the Hessian matrix.

4.7.2 Table 3 Summary of GARCH (1, 1) coefficients

According to Table 3 below the means of the returns as represented by were generally negative for the two domestic stock indices while the means of global oil returns were positive over the period 2009-2012. This could reflect an underlying negative correlation. It therefore means that the ZSE stock market returns were on average bearish (declining) while oil returns were increasing during the same period. Both coefficients $\propto_i$ and β_j were statistically significant. The β_j coefficients of all the four indices were highly significant. This showed persistent volatility clustering. The Brent crude returns exhibited the highest degree of volatility of all the indices investigated.

4.8 Results of Pearson Correlations

4.8.1 Industrial index, mining index versus Brent crude oil, WTI crude oil index

The industrial index and Brent crude results show a positive correlation of 0.505. Industrial index counters maintained profitability during the period 2009-2012 despite sustained increases in

oil prices. The correlation of the ZSE Industrial index and the WTI oil price index was also positive with a correlation coefficient of 0.520. This implies that the ZSE Industrial Index generally increased during the period under review in tandem (same direction) with increases in Brent global oil prices and WTI oil prices. The positive correlation can be attributed to the general increase in the country's productivity and oil consumption which was largely seen by investors as a positive sign of future growth prospects in Zimbabwe. That coupled with the general macroeconomic stability made ZSE Industrials stock counters attractive investments. That drove stock prices upwards hence resulting in a bullish (increasing) Industrial Index. The correlation coefficients were all significant at the 0.01 level (2-tailed).

4.8.2 Mining index and BRENT crude, WTI crude correlation

There was a negative correlation of -0.332 between the Mining index and the global Brent crude oil prices. An overall increase in global Brent crude oil prices negatively affected the ZSE Mining index. The results also show a negative correlation of -0.201 between Mining index and WTI Crude. The correlation is rather weak. The results support the hypothesis that stock market indices (in this case ZSE Mining index) are negatively correlated to global crude oil price volatilities. This can be attributed to the fact that mining is largely an oil intensive sector thus oil price increases tend to increase production costs which subsequently negatively affects the bottom line (profitability) of ZSE mining counters thus making them less attractive to investors resulting in falling stock price and thus resulting in a bearish (declining) ZSE Mining Index. The correlation coefficients were all significant at the 0.01 level (2-tailed). The Granger causality tests to a large extend confirmed Pearson correlations as indicated in Table 4.

Fig. 9 below gives a graphical representation of the correlation based on the trend of the respective indices. During 2009-2012 the mining index can be seen to be largely declining while during the same period both the Brent Crude and WTI crude oil price indices were largely on a positive growth trend. The ZSE mining index graph can be seen to intersect both the WTI and Brent crude graphs. This is classical illustration of a negative correlation in the long term [19]. The negative correlation of the Mining index and the two oil price indices was more pronounced in the later stages of 2012 thus explaining the low value of the correlation coefficient. In the same regard the industrial index can be seen to move in tandem with both the Brent Crude and WTI crude oil price indices. This shows positive correlation and for the entire duration of the investigation period the 3 graphs moved to a large extend in the same direction thus explaining the high correlation coefficient between the variables.

Table 3. Summary of GARCH coefficients

Index			i	β_j
Industrial	-0.00036567	0.000005887	0.305670	0.68201
Mining	-0.00150250	0.000042307	0.079480	0.87865
Brent crude	0.00083763	0.000006520	0.053106	0.92677
WTI	0.00075793	0.000094626	0.143120	0.62473

Table 4. Results of Pairwise Granger causality tests

Pairwise hypothesis	F-statistic	P-value	Decision	Type of causality
Brent ↘ Industrial	0.23256	0.79255	DNR H_0	No causality
Industrial ↘ Brent	0.17494	0.83954	DNR H_0	No causality
Brent ↘ Mining	4.62264	0.01006	Reject H_0	Uni-directional causality
Mining ↘ Brent	0.70832	0.49274	DNR H_0	Uni-directional causality
WTI ↘ Industrial	0.48735	0.61441	DNR H_0	No causality
Industrial ↘ WTI	0.08777	0.91598	DNR H_0	No causality
WTI ↘ Mining	3.76807	0.02345	Reject H_0	Uni-directional causality
Mining ↘ WTI	1.14365	0.31911	DNR H_0	Uni-directional causality

Alpha (α) = 0.05, Decision rule: reject H if P-value < 0.05, Key: DNR = Do not reject, = does not Granger cause

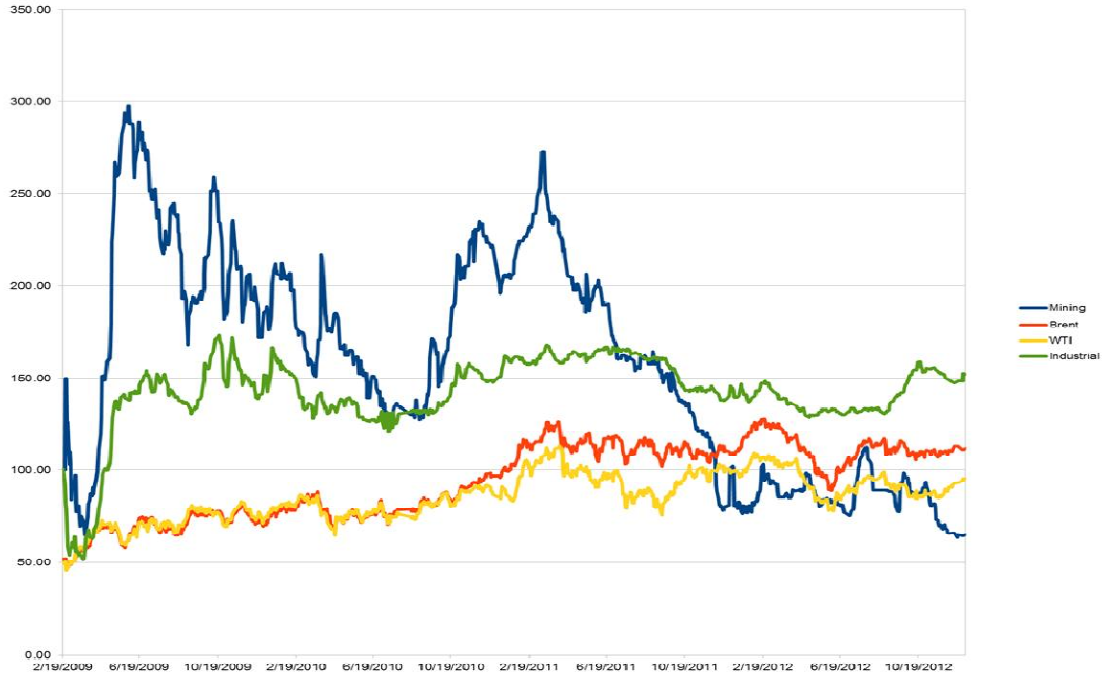

Fig. 9. ZSE stock market indices and global oil prices correlation summary

5. CONCLUSION

The low volatility of the stock returns on Zimbabwe Stock Exchange indices compared to the relatively high volatility of stock returns on the global oil indices indicates the presence during this period of cushioning factors that tend to reduce the impact of adverse crude oil price movements on the ZSE indices. It is also important to note that volatility was less dependent on the current price of the oil or stock markets. Volatility was to a large extend driven by the prices and values of the previous time period (past performance) as represented by significant β coefficient . ZSE stock market indices are influenced by historical oil price movements. There is a time lag ranging from 9 to 30 days before impact of oil price changes affects the economy. The range depends on the level of strategic reserves of fuels. Zimbabwe with low inflows of foreign currency should have short periods to feel the price increase effect. This result is supported by [24]. There is an underlying negative relationship between the two domestic stock indices and the global oil price indices as reflected by the negative (means) of stock returns on ZSE indices and the positive (means) of global oil indices.

With respect to correlation investigations the ZSE Mining Index was found to be negatively correlated to global oil prices indices. Increases in global oil prices would induce a fall in the ZSE Mining Index. This would be through increased production costs of mining companies. This was also supported by the Granger causality test. On the other hand the results of this study revealed evidence of beneficial effects of global oil price movements on the ZSE Industrial index. The Industrial index is positively correlated to the global crude oil price movements. The Granger causality tests showed no causal relationship. The expected negative relationship between share price movement and oil price movements was outweighed by factors favourable to share price rises such as a favourable exchange rate and high levels of trading by foreign investors. Furthermore, the ZSE Industrials index is comprised of counters from a wide spectrum of sectors some of which may have limited direct exposure to crude oil prices. This is supported by the findings of [26,21] in the cases of Singapore, France and United Kingdom.

The results of the study confirmed the hypothesis that the ZSE mining stocks are indeed exposed to significant exogenous risks emanating from rising global crude oil price movements. This is supported by most of the authors referenced in

the literature review [16,17,18,19,20]. While the ZSE industrial stocks appear to be exposed to exogenous factors due to movements in global oil prices. There are however moderating factors. These increases in crude oil prices have the potential to subdue any favourable factors to share price increases.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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