The relationship between oil prices and exchange rates in South Africa

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Abstract: The study examines the relationship between oil prices and exchange rates in South Africa for the period from 1970 to 2021. There is a problem of high oil prices and weak exchange rate of the South African Rand to the US Dollar. The study utilised annual time series data collected from the South African Reserve Bank. The study employed an ARDL model and performed Granger Causality test to analyse the relationships between the variables. The study found that there is a negative relationship between oil prices and exchange rates in South Africa. The study further revealed that there is a noncausality between oil prices and exchange rates in South Africa. The study therefore recommends that policies that reduce oil prices must be implemented to safeguard the value of the South African Rand against the US Dollar.

Keywords: Oil prices, exchange rate, SARB, South Africa

JEL Specification: *Q41, Q43, Q31, C22*

1. Introduction

In most cases, oil imports account for a significant portion of a country's trade balance. Oriavwote and Eriemo (2012), Shakibaei, Aflatouni et al. (2009), and Aziz and Bakar (2009) have all mentioned the potential impact of oil prices for exchange rate changes. In the case of a small open economy. Dawson (2004) shows that volatility in oil prices have a significant influence on the level values of the currency. While much has been written about the impact of oil prices on currency rates in oil-exporting nations, there is far less circumstantial evidence of energy-importing countries (Shakibaei, Aflatouni et al. 2009, Oriavwote and Eriemo 2012). As a result, this article utilizes the example of South Africa, a small open economy with exchange rate that is heavily reliant on brent crude oil prices, to demonstrate the volatility in oil prices and actual exchange rates. Oil prices are a major factor on economic growth around the world. As a result, governments must pay special attention to variations in oil prices to devise strategies to stabilize the volatility of the exchange rate.

International oil prices, as well as the dollar-rand exchange rate, impact local oil costs. South Africa imports oil in dollars. 95 octane fuel was expected to rise by R2.32/litre in April, based on current prices. In Gauteng, this will raise the price of 95 fuel to more than R23.90 per litre. A litre of petrol in Gauteng cost R16.32 a year ago. The rest of the month may see lower rises due to Rand strength and oil price weakening (Fin24 2022). The aftermath from Russia's invasion of Ukraine has sent oil prices rising. Russia is the world's third-largest crude oil producer, and the prospect of it being shut out of the market has pushed up oil prices. Traders are trying to secure oil supplies with Russia, with some of its commodities unable to be delivered owing to shipping and banking limitations. The United States declared on Tuesday that it will prohibit the purchase of Russian crude oil. The Brent crude oil price was pushed close to $140 a barrel because of this. Since then, it has dropped to roughly $124. This was not the only event that has resulted in oil prices fluctuating. The Coronavirus has also resulted in oil prices fluctuating due the effect it had on lowering the production of oil after heavy restrictions on working environment.

Overview of the study: The hybrid or interest rate differential model of exchange rate proposed by Frankel (1979) and Dornbusch (1980) states that because the exchange rate is the relative price of foreign and domestic money, it should be governed by the relative demand and supply of money, according to the monetary exchange rate model. This theory forms the basis of this study in which oil prices and exchange rates are incorporated to suit the study. Consumption of oil in South Africa is currently estimated to be around 20% of total energy utilization (EIA 2013). South Africa has no proven commercial oil resources, it should rely on imported crude oil to meet its energy needs (Nkomo 2009). According to available data, South Africa is heavily reliant on oil imports, accounting for 6% of total imports (EIA 2013). Furthermore, South Africa imports over 90% of its crude oil conditions required (Nkomo 2009). Because of its reliance on imported crude oil, South Africa is vulnerable to external shocks that destabilize or lead to higher oil prices, limiting economic growth and development. Another reason for concern is also that two of South Africa's core sectors, transportation, and agriculture, are strongly reliant on oil products, thus any change in oil prices will have a significant impact on the country. Crude oil is a crucial input in South African economy for the production cycle of consumer goods, is it a powerful factor in determining the price of goods. An unfavorable oil price fluctuation not only reduces revenue of companies but also raises production costs, resulting in higher inflation rate. It declines the economy's global competitiveness, which may lead to additional issues such as extreme depreciation of the domestic currency. Both dependence and market asymmetry approaches have been used in studies. Fowowe (2014) observes that an increase in oil prices causes the South African rand to depreciate.

The link between crude oil and exchange rates is theoretically supported by the law of one price, the wealth effect, and the terms of trade effect. Initially, the law of one price assumes that the similarity characteristics of crude oil clearly show that a depreciation of the US dollar lowers oil prices in the global oil market. Blomberg and Harris (1995) proposed that a depreciation of the US dollar would benefit foreigners by lowering oil prices, resulting in an increase in purchasing power and thus demand for oil. Second, the crude oil-exchange-rate connection resembles a wealth impact channel. Finally, trade terms indicate and identify the link between the oil price and the exchange rate based on the country's consumption of both traded and non-traded commodities. An unstable exchange rate is an enigma that has plagued South Africa for more than a decade. Given the considerable volatility of the exchange rate over the years, the following are the primary worries concerning the economy's performance in terms of exchange rate volatility: Is the rand impacted by the price of oil? What effect does the oil price have on the rand exchange rate? What are the ramifications of increased oil prices for the economy? As a result, the fundamental goal of this research is to investigate the relationship between oil prices and exchange rate of the South African Rand against the US Dollar and review the literature on the impact of oil prices on exchange rate and make recommendations based on statistical evidence.

The relationship between oil prices and exchange rates in South Africa has not been investigated sufficiently in the context of South African economy. There is a problem of high oil prices and weak exchange rate of the South African Rand against the US Dollar. Oil prices has been increasing for far too long and the exchange rate of the South African Rand against the US Dollar has been declining because of this since South Africa depends on oil imports. A shock in the international market has resulted in the Rand depreciating against the US Dollar. The significance of this study is to investigate the relationship between oil prices and exchange rate in South Africa by utilising nominal and real interest rates as intermittent variables. Oil prices represents the price of brent crude oil in US dollar, exchange rate refers to the exchange rate of the South African Rand against the US dollar, nominal interest rate refers to the interest before taking inflation into account and real effective interest rate refers to interest that accounts for inflation reflecting more accurate measure buying power.

2. Literature Review

Theoretical literature: This study is based on the hybrid or interest rate differential model of exchange rate proposed by Frankel (1979) and Dornbusch (1980). Because the exchange rate is the relative price of foreign and domestic money, it should be governed by the relative demand and supply of money, according to the monetary exchange rate model. We begin by expressing the real money demand function in logarithmic notation in home and foreign country as follows:

Home country: $p = m - \alpha\gamma + \beta_i$ .... (1)

Foreign country: $p^* = m^* - \alpha\gamma^* + \beta_i^*$ .... (2)

Whereby, p and p^* represents home and foreign prices, respectively, m and m^* represents money demand in home and foreign country. γ and i represents output and interest rate for the other two countries. Assuming the purchasing power parity requirement remains in the long run, Equations 1 and 2 are combined to form Equation 3 below:

$$e = p - p^{*} = (m - m^{*}) - \alpha(\gamma - \gamma^{*}) + \beta(i - i^{*}) \quad (3)$$

Based on the two extra assumptions introduced in Frankel (1979) model, it differs from Equation 3 to some extent. The first assumption is that interest rate parity is linked to efficient markets in which various nation's bonds are ideal substitutes for each other as shown in the expression below:

$$z = i - i^{*} \quad (4)$$

The predicted rate of depreciation is a function of the difference between the current spot rate and an equilibrium rate, as well as the expected long run inflation disparity between the home and foreign countries, according to the second central assumption as shown below:

$$z = -\vartheta(e - \bar{e}) + \pi - \pi^{*} \quad (5)$$

Whereby, e is the log of the spot rate, π and π^{*} are the current rates of expected long run inflation at home and abroad, respectively. Taking equation 4 and 5 together, it gives us equation 6 below as follows:

$$e - \bar{e} = -\frac{1}{\vartheta}[(i - \pi) - (i^{*} - \pi^{*})] \quad (6)$$

Utilising bars to denote equilibrium values, Frankel (1979) argues further that when $-\bar{e}$, $i - i^{*} = \pi - \pi^{*}$ in the long run and equation 3 is now expressed as follows:

$$\bar{e} = \bar{p} - \bar{p}^{*} = \bar{m} - \bar{m}^{*} - \alpha(\bar{\gamma} - \bar{\gamma}^{*}) + \beta(\bar{\pi} - \bar{\pi}^{*}) \quad (7)$$

Furthermore, by substituting Equation 7 for Equation 6 and assuming that the current equilibrium money supply and income levels are determined by their present actual levels, a full equation for determining spot rates may be found below in Equation 8:

$$\bar{e} = \bar{p} - \bar{p}^{*} = \bar{m} - \bar{m}^{*} - \alpha(\bar{\gamma} - \bar{\gamma}^{*}) - \frac{1}{\vartheta}(i - i^{*}) + (\frac{1}{\vartheta} + \beta)(\bar{\pi} - \bar{\pi}^{*}) \quad (8)$$

Equation can be rewritten in a more stochastic way as given in Equation 9 below:

$$\bar{e} = \bar{p} - \bar{p}^{*} = \bar{m} - \bar{m}^{*} - \alpha(\bar{\gamma} - \bar{\gamma}^{*}) - \varphi(i - i^{*}) + \delta(\bar{\pi} - \bar{\pi}^{*}) + \varepsilon \quad (9)$$

Where, $\varphi(= -\frac{1}{\theta})$ is hypothesized negative and $\delta(= \frac{1}{\theta} + \beta)$ is hypothesized positive and greater than α in absolute value. Frankel (1979) offered an innovation that seeks to combine the Keynesian assumption of sticky prices with the Chicago assumption of secular rates of inflation. In contrast to the initial idea, the exchange rate is negatively connected to the nominal interest rate differential but positively related to the expected long-run inflation differential. In this work, the relationship between real exchange rates and real oil prices is experimentally investigated. We analyse whether the actual exchange rate is positively connected to the real oil price, as predicted by the model. We also investigate whether actual oil prices can be used to forecast the real exchange rate. The fundamental driver of real exchange rate movements is widely understood to be nonmonetary shocks. Several academics have looked at the link between oil prices and currency rates.

Studies that found positive relationship: Shakibaei, Aflatouni et al. (2009) conducted a study on the long run relationship between oil prices and exchange rates in the OPEC region for the period from 1995 M1 to 2006 M12. The study employed panel Random Effect model and revealed that oil prices are dominant source of exchange rate movements, and they have a long run relationship. Aziz and Bakar (2009) investigates the long run effects of real oil price and interest rate differential on real exchange rate on a panel of 8 countries for the period from 1980 to 2008. The study found positive statistically significant relationship between oil prices and exchange rates by employing PMG model. Oriavwote and Eriemo (2012) investigated the relationship between real oil prices and real exchange rate in Nigeria for the period from 1980 to 2010. The study employed a GARCH model and found the persistence of volatility between oil prices and real exchange rate. The researchers recommend that the government policies on tackling the impact of fluctuations in real oil prices are important source for stabilizing the movements in real exchange rate. Englama, Duke et al. (2010) investigated oil prices and exchange rate volatility in Nigeria by utilising monthly time series data spanning from 1991 M1 to 2009 M12. By employing a VECM model, the study found that oil prices have a positive effect on exchange rate volatility. The study recommends closely monitoring of exchange rate to move in tandem with the volatility in crude oil prices as Nigeria remains an oil-dependent economy.

Jain and Ghosh (2013) examines the cointegration and Granger causality among global oil prices, precious metal prices and exchange rate using daily data spanning from 2009 M1 to 2011 M12. By employing an ARDL model, the results revealed that the shocks in oil prices are transmitted to the Indian economy through exchange rates. Ferraro, Rogoff et al. (2015) found that oil prices are significant in forecasting exchange rates. Delgado, Delgado et al. (2018) analyses the relationships between oil prices, exchange rate and stock market index in Mexico utilising data spanning from 1992 M1 to 2017 M7. The study employed a VAR model and found that oil prices are statistically significant against the exchange rate, concluding that an increase in oil prices creates an appreciation of the exchange rate. Turhan, Hacihasanoglu et al. (2013) investigates oil prices and emerging market exchange rates using daily time series data spanning from 2003 3 January to 2010 2 June. The study employed a VAR model and revealed that a rise in oil prices leads to a significant appreciation of emerging economies' currencies against the US dollar. Their findings suggest that oil price dynamics changed significantly in the sample and the relationship between oil prices and exchange rates became more obvious after the 2008 financial crisis.

Mukhtarov, Mammadov et al. (2019) investigates the impacts of oil prices on inflation in Azerbaijan utilising data spanning from 1995 to 2017. The study employed a VECM model and found that oil prices and exchange rates have positive statistically significant impact on inflation in the long run. The results further reveal that the impact of exchange rate such that the drop in oil prices in 2014 caused devaluation of national currency. Narayan, Falianty et al. (2019) investigates the influence of oil prices on Indonesia's exchange rate for the period from 1986 to 2017. The study employs an ARDL model and found that long-run cointegration relation between oil prices and the real exchange rate is sensitive to different exchange rate regimes in Indonesia. Abraham (2016) examine the exchange rate policy and falling crude oil prices on the Nigerian stock market. By employing an ARDL model, the study found that oil prices are positively related with the performance of the Nigerian stock market thus would drag the market down in times of turmoil. The study further stress that devaluation of the Naira is found to be effective in cushioning the effect of crude oil price decline on the stock market. Duan, Khurshid et al. (2021) investigates how geopolitical risk drives exchange rate and oil prices using a wavelet-based analysis in Venezuela. The study found that bidirectional causality between oil prices and exchange rate.

Beckmann, Czudaj et al. (2020) reviews the existing theoretical and empirical research on the relationships between oil prices and exchange rates. The theoretical transmission channels point out to bidirectional causality while empirical literature shows strong links between exchange rates and oil prices frequently observed over the long run. Wen, Liu et al. (2020) employed a Granger causality model and found that risk spill overs are stronger from exchange rates to crude oil than those from oil to exchange rate markets.

Gomez-Gonzalez, Hirs-Garzon et al. (2020) explore predictive causality between oil prices and exchange rates. The study employed a VAR model and revealed that oil prices are net spill over receivers from exchange rate markets. The results also show bidirectional Granger causality which is detected for longer periods from exchange rates to oil prices. Devpura (2020) employs Westerlund and Narayan predictive regression model on data spanning from 1 June 2019 to 4 September 2020. The study found limited evidence that oil prices predict the Yen in Japan. Qiang, Lin et al. (2019) analyses the literature on oil prices and exchange rate and found that most of the studies focus on causality, nonlinear structure, and volatility spill over effects. Zankawah and Stewart (2020) examines shock and volatility spill over effects from crude oil prices to Ghana's exchange rate and stock market utilising monthly data spanning from January 1991 to December 2015. The study employs a multivariate GARCH BEKK and TBEKK models and found that oil prices have significant spill over effects on exchange rates. Mofema and Mah (2021) found that interest rates have a positive impact on oil prices using a GARCH model for the data spanning from 2000 to 2020 in South Africa. Obansa, Okoroafor et al. (2013) investigated the relationship between economic growth, interest rates and exchange rates by employing a VAR model in Nigeria for the period from 1970 to 2010 and found the positive relationship between the variables.

Studies that found inverse relationship: Brahmasrene, Huang et al. (2014) examines the short and long run dynamic relationships between the US imported crude oil prices and exchange rates utilising data spanning from 1996 M1 to 2000 M12. By employing a VAR model and Granger causality tests, the study found that crude oil prices granger cause exchange rate in the long run while exchange rate shock has a negative statistically significant impact on crude oil prices. Turhan, Sensoy et al. (2014) conducted a comparative analysis of the dynamic relationship between oil prices and exchange rates in G20 members. The study employed a Dynamic Conditional Correlation (DCC) model and found that for each pair of oil price-exchange rate, the empirical evidence confirms of a strengthening negative correlation in the last decade. Mendez-Carbajo (2011) conducted a study on the impact of energy dependence, oil prices and exchange rates in the Dominican economy for the period from 1990 to 2008. The study employed a VECM model and found that there is a negative relationship between the variables, that is, an increase in the price of oil leads to the depreciation of the peso and that causality runs from oil prices to exchange rate.

Anjum (2019) examines volatility dynamics of oil prices and the US dollar exchange rate using univariate and bivariate GARCH models on data spanning from 2 January 2000 to 31 December 2015. The results revealed no evidence of volatility transmission between oil prices and the US dollar exchange rate if structural breaks are ignored and significant volatility transmission when structural breaks are accounted for. Singhal, Choudhary et al. (2019) found that oil price negatively influences exchange rate in the long run in Mexico by employing an ARDL model on data spanning from January 2006 to April 2018. Mukhtarov, Aliyev et al. (2020) investigates the effect of oil prices on macroeconomic variables in Azerbaijan for the period spanning from January 2005 to January 2022. The study employed a VECM model and found that oil prices have a negative impact on exchange rate. The study recommends that researchers and policy makers to comprehend the role of oil price shocks on economy in the case of Azerbaijan and other developing oil-rich countries. Villarreal-Samaniego (2020) using the ARDL model found that there is an inverse relationship between the exchange rate and the movements in oil prices. Dash (2012) conducted on the relationship between exchange rates and interest rates in India. The study employed a VECM model on time series data spanning from April 1993 to March 2003 and found that there is a negative relationship between interest rates and exchange rates in India for the period understudy.

Studies that found no relationship: Sari, Hammoudeh et al. (2010) examines the dynamics of oil prices, precious metals, and exchange rate by utilising data spanning from 1994 M1 to 2007 M10. The study employed a VAR model and revealed that changes in exchange rate and oil prices return do not have considerable linkages with each other, neither in the short nor long run period. Tiwari, Mutascu et al. (2013) investigates the influence of international oil prices on the real effective exchange rate in Romania in a wavelet transform framework. By employing Granger causality, the results reveal that oil prices have no influence on the real effective exchange rate in the short and long run period. Reboredo (2012) modelled oil price and exchange rate co-movements for European countries, Australia, Canada, United Kingdom, Japan, Norway, and Mexico by utilising daily data spanning from 4 January 2000 to 15 June 2010. By employing a TGARCH model, results revealed that an increase in oil prices is weakly associated with USD depreciation and almost independent of each other.

Reboredo and Rivera-Castro (2013) conducted a wavelet decomposition approach to crude oil price and exchange rate dependence. By employing a wavelet multi-resolution analysis, the study found that oil prices and exchange rates were not dependent in the pre-crisis period. The results further show that oil prices led exchange rates in the crisis period and recommend monetary policies to control oil inflationary pressures and fiscal policy in oil-exporting countries. Chang, Huang et al. (2013) investigates the interactive relationships between crude oil prices, gold prices, and the NT-US dollar exchange rate in Taiwan for the period spanning from 3 September 2007 to 28 November 2011. The study employed VAR model and Granger causality test and found that oil prices and exchange rates remain independent from one another, meaning that policy makers should consider the separation of energy and financial policies. Wilson and Sheefeni (2014) conducted a study on the relationship between interest rates and exchange rate in Namibia for the period from 1993 to 2012. By utilising quarterly data, the study employed a VAR model and found that there is a negative relationship between interest rates and exchange rates in Namibia and recommend that studies in the future should consider utilising a different model and adding more variables.

Studies that found nonlinear relationship: Ji, Liu et al. (2019) analyses the dynamic dependence between WTI crude oil and the exchange rate of the United States and China, taking structural changes of dependence into account by using six time-varying copula models. The dependence between crude oil and the RMB exchange rate is faintly positive with lower tail dependence, while the dependence between crude oil and the US dollar index is significantly negative with lower-upper and upper-lower tail dependence. The CoVaRs results show significant asymmetry risk spill over from crude oil to Chinese and the US exchange rate markets. Balcilar, Hammoudeh et al. (2015) conducted a regime-dependent assessment of the information transmission dynamics between oil prices, precious metal prices and exchange rates. The study employed a Bayesian Markov-Switching Vector Error Correction model on daily data spanning from 1987 to 2012 and found that there is asymmetric relationship between oil prices and exchange rate volatility. Saenong, Adam et al. (2020) conducted a symmetric and asymmetric effect of crude oil prices and exchange rate on bond yields in Indonesia utilising monthly data spanning from 2007 M1 to 2019 M4. The study employed ARDL and NARDL models and discovered that neither oil prices nor exchange rate has symmetric relationships to bond yields in the long run and vice versa in the short run. Zhu and Chen (2019) explores the symmetric effects of oil prices and exchange rates on China's industrial prices utilising monthly data spanning from 2000 M1 to 2019 M7. The study employed an NARDL model and found the inconsistency between the practice of oil price and exchange rate transmissions in China and the active roles of China's oil product mechanism and exchange rate policy reforms in mitigating transmission distortions.

Jammazi, Lahiani et al. (2015) conducted a wavelet based NARDL model for assessing the exchange rate pass-through to crude oil prices for 18 countries. The results found the evidence of significant and asymmetric pass-through of exchange rates to oil prices in both the short and long run period. The study suggests that denoising the crude oil and exchange rate data is effective and necessary before their interactions can be analysed. Aloui, Aïssa et al. (2013) study the conditional dependence structure between crude oil prices and the US dollar exchange rates using a copula-GARCH model. By utilising data spanning from 2000 to 2011, the study found evidence of significant and symmetric dependence for almost all the oil-exchange rate pairs, and the rise in oil prices is associated with depreciation of the dollar. Chou and Tseng (2016) conducted a study on oil prices, exchange rate, and price asymmetry in the Taiwanese retail gasoline market. The study employed an NARDL model and found that oil prices responses to the exchange rate shocks were slow and complex and exhibited reverse adjustments during periods of initial exchange rate depreciation. Mohammadi and Jahan-Parvar (2012) investigates the oil prices and exchange rates in oil-exporting countries. By employing the TAR and M-TAR models, the study found that there is no evidence of short run causality, exchange rates adjust faster to positive deviations from equilibrium and that oil prices have a long run effect on the exchange rates.

Kumar (2019) examines the asymmetric impact of oil prices on exchange rate and stock prices using monthly data spanning from 1994 M1 to 2015 M12. The study employed a nonlinear Granger causality and NARDL models and found that the previous month positive and negative shocks in oil prices have positive and negative significant impact on exchange rate and stock prices. Kisswani, Harraf et al. (2019) conducted an asymmetric analysis of the effects of oil prices on exchange rate in the ASEAN countries using quarterly data spanning from 1970 Q1 to 2016 Q4. The study employed an NARDL model and found long run asymmetry for Indonesia and Malaysia and mixed bidirectional causality oil prices and exchange rate. Baek and Kim (2020) examines the relationship between crude oil prices and exchange rates in Sub-Saharan Africa employing an NARDL model and found strong evidence that changes in oil prices have asymmetric effects on the real exchange rates in the long run, that is, the movements in real exchange rates in selected countries appear to respond mostly more to oil price increase than to a decrease. Xu, Han et al. (2019) explore a nonlinear relationship between crude oil prices and exchange rates from a quantitative and structural perspectives, employing a bivariate normal mixture model. The study found structural heterogeneity during economic expansion while little evidence of heterogeneity in recession.

Khraief, Shahbaz et al. (2021) examines the nonlinear movements of oil prices and exchange rates in China and India. The study employed an NARLD model and found that only long run asymmetric effects of oil prices on exchange rates for both countries, however, after time-series noise removal, the asymmetric long-run effect becomes symmetric for India. Fasanya, Oyewole et al. (2021) model the relationship between oil price and exchange rate for Nigeria using monthly data from 1997 M1 to 2019 M12. The study employed ARDL and NARDL model and found that an increase in oil prices leads to depreciation of the Naira relative to the US dollar and oil price asymmetries seem to matter both in the short and long run period. Capasso, Napolitano et al. (2019) investigated the long run relationship between interest rates and exchange rates in Mexico by employing a nonlinear ARDL model for the period from 1996 to 2017. The study found that there is a positive relationship between interest rates and exchange rates in Mexico.

From the literature review above, majority of the studies employed nonlinear models and VECM model to analyse the relationship between oil prices and exchange rates. This study identified the gap in the model and adopts the ARDL model to analyse short and long run relationships between the variables. There is insufficient to limited studies on the relationship between oil prices and exchange rates in South Africa. Majority of the studies that has been conducted were focusing on other countries but not in South Africa. Due to the identified gap in methodology, this study therefore investigates the relationship between oil prices and exchange rates in South Africa to discover the nature of relationship that exists in the short and long run period and contribute to existing literature.

3. Methodology

Data sources: The study utilises annual time series data spanning for the period from 1970 to 2021 for exchange rate and oil prices in US Dollar by utilising real and nominal interest rates as intermittent variables. This data was sourced from online secondary source that is the South African Reserve Bank. Oil price (OP) represents brent crude oil price in US Dollar and exchange rate (EXC) represents foreign exchange rate: SA cent per USA dollar middle rates (R1 = 100 cents), nominal interest of which is interest before inflation and real interest rate which is interest rate after considering the effect of inflation. Based on the theoretical and empirical literature given in Section 2, the conceptual framework of this study can be represented algebraically as given below:

Exchange rate = f(oil prices, nominal interest rate, real effective interest rate)

Model estimation: To study the exchange rate volatility and oil prices in South Africa, this study utilises exchange rate and oil prices to formulate multivariate model. The variables are transformed into logarithms to have the same unit of measurement. The model that will be used in this study can therefore be specified as given below:

$$LEXC_t = \alpha_1 + \alpha_{LOP} LOP_t + \alpha_{LRI} LRI_t + \alpha_{LNI} LNI_t + \varepsilon_t \quad \ldots\ldots (10)$$

Whereby, LEXC is the logarithm of exchange rate, LOP is the logarithm of oil prices, LRI is the logarithm of real interest rates, LNI is a logarithm of nominal interest rate, α_1 is the constant and ε_t is an error term.

Data analysis: To evaluate the short- and long-term association among the variables under examination, the study uses the ARDL model established by Pesaran, Shin et al. (2001). Abraham (2016) provided the ARDL model that was employed in this investigation. The variables in this model must be stationary or integrated of I(0) or I(1), or a mixture of I(0) and I(1), but no variable should be stationary at the second difference, which is integrated of I(0) and I(1) (2).

Estimating long run relationship: Following the discovery of cointegration in the model, the study applies the ARDL levels equation that shows long run relationship, as specified in equations 11–14 below.

$$LEXC_t = \alpha_{01} + \sum_{i=1}^{p} k_{11}\, LEXC_{t-i} + \sum_{i=0}^{q} k_{21}\, LOP_{t-i} + \sum_{i=0}^{q} k_{31}\, LRI_{t-i} + \sum_{i=0}^{q} k_{41}\, LNI_{t-i} + \varepsilon_t \ldots\ldots \quad (11)$$

$$LOP_t = \alpha_{02} + \sum_{i=1}^{p} k_{12}\, LOP_{t-i} + \sum_{i=0}^{q} k_{22}\, LEXC_{t-i} + \sum_{i=0}^{q} k_{32}\, LRI_{t-i} + \sum_{i=0}^{q} k_{42}\, LNI_{t-i} + \varepsilon_t \ldots\ldots \quad (12)$$

$$LRI_t = \alpha_{03} + \sum_{i=1}^{p} k_{13}\, LRI_{t-i} + \sum_{i=0}^{q} k_{23}\, LOP_{t-i} + \sum_{i=0}^{q} k_{33}\, LEXC_{t-i} + \sum_{i=0}^{q} k_{43}\, LNI_{t-i} + \varepsilon_t \ldots\ldots \quad (13)$$

$$LNI_t = \alpha_{04} + \sum_{i=1}^{p} k_{14}\, LNI_{t-i} + \sum_{i=0}^{q} k_{24}\, LRI_{t-i} + \sum_{i=0}^{q} k_{34}\, LOP_{t-i} + \sum_{i=0}^{q} k_{44}\, LEXC_{t-i} + \varepsilon_t \ldots\ldots \quad (14)$$

Estimating short run relationships: The short run dynamic ARDL error correction model may thus be generated from the previous ARDL models while approximating the long run connection using Pesaran, Shin et al. (2001) simple linear transformation. An unrestricted ARDL error correction model with an ECT the error correction term that can be positive or negative but should be statistically significant incorporates dynamic short run with long run equilibrium. Δ represents a differencing operator and an ε_t represents an error term. The unrestricted ARDL error correction model can therefore specified as shown in equation 15 to 18 below:

$$\Delta LEXC_t = \alpha_{01} + \sum_{i=1}^{p} \alpha_{11}\, \Delta LEXC_{t-i} + \sum_{i=0}^{q} \alpha_{21}\, \Delta LOP_{t-i} + \sum_{i=0}^{q} \alpha_{31}\, \Delta LRI_{t-i} + \sum_{i=0}^{q} \alpha_{41}\, \Delta LNI_{t-i} + \lambda ECT_{t-1} + \varepsilon_t \ldots\ldots \quad (15)$$

$$\Delta LOP_t = \alpha_{02} + \sum\nolimits_{i=1}^{p} \alpha_{12}\, \Delta LOP_{t-i} + \sum\nolimits_{i=0}^{q} \alpha_{22}\, \Delta LEXC_{t-i} + \sum\nolimits_{i=0}^{q} \alpha_{32}\, \Delta LRI_{t-i} + \sum\nolimits_{i=0}^{q} \alpha_{42}\, \Delta LNI_{t-i} + \lambda ECT_{t-1} + \varepsilon_t \dots \dots \dots (16)$$

$$\Delta LRI_t = \alpha_{03} + \sum\nolimits_{i=1}^{p} \alpha_{13}\, \Delta LRI_{t-i} + \sum\nolimits_{i=0}^{q} \alpha_{23}\, \Delta LOP_{t-i} + \sum\nolimits_{i=0}^{q} \alpha_{33}\, \Delta LEXC_{t-i} + \sum\nolimits_{i=0}^{q} \alpha_{43}\, \Delta LNI_{t-i} + \lambda ECT_{t-1} + \varepsilon_t \dots \dots \dots (17)$$

$$\Delta LNI_t = \alpha_{04} + \sum\nolimits_{i=1}^{p} \alpha_{14}\, \Delta LNI_{t-i} + \sum\nolimits_{i=0}^{q} \alpha_{24}\, \Delta LRI_{t-i} + \sum\nolimits_{i=0}^{q} \alpha_{34}\, \Delta LOP_{t-i} + \sum\nolimits_{i=0}^{q} \alpha_{44}\, \Delta LEXC_{t-i} + \lambda ECT_{t-1} + \varepsilon_t \dots \dots \dots (18)$$

Diagnostic tests: Breusch-Godfrey Serial Correlation LM test is used to determine the model's serial correlation. The Breusch Pegan Godfrey test is used to determine whether the condition of heteroskedastic exists in the model. The Jarque-Berra test is used to determine if the residuals in the model are normally distributed or not. The parameter's stability is assessed using the cumulative sum (CUSUM), cumulative sum of squares (CUSUMSQ), and RAMSEY RESET tests.

4. Results and Interpretations

Table 1: Augmented Dickey-Fuller and Phillip-Perron unit root test

Variables	**ADF unit root**				**PP unit root**			
	Constant		**Trend & Intercept**		**Constant**		**Trend & Intercept**	
	Level	Δ	Level	Δ	Level	Δ	Level	Δ
LEXC	-0.6377	-5.6158 ***	-2.3981	-5.5663 ***	-0.6501	-5.0722 ***	-1.8260	-5.0023 ***
LOP	-8.5152 ***	-10.429 ***	-8.3410 ***	-160.311 ***	-8.5152 ***	-44.963 ***	-8.3410 ***	-43.691 ***
LRI	-2.1982	-6.3422 ***	-3.8051 **	-6.2738 ***	-2.3228	-6.6393 ***	-3.3163 *	-6.5427 ***
LNI	-0.9851	-5.5458 ***	-1.3383	-5.5626 ***	-0.9656	-5.4178 ***	-1.3383	-5.3724 ***

Source: Author's own computation

The study performed the ADF, and the PP unit root test and the results are presented in Table 1 above. From Table 1, the variables LEXC, LRI and LNI are stationary at first difference according to the ADF and PP unit root test. LOP is stationary at level form, this means it is integrated of I(0). This means the variables are integrated of order zero and one, that is, I(0) and I(1) and this makes it suitable to deploy the ARDL model to estimate short and long run relationships. The study therefore continues to estimate the optimal lag length that can be used in this study as shown in Table 2 below.

Table 2: VAR optimal lag length criterion

Lag	LogL	LR	FPE	AIC	SC	HQ
0	391.8415	NA	7.99e-13	-16.50390	-16.34644*	-16.44464
1	418.9114	48.38019*	5.00e-13*	-16.97495*	-16.18766	-16.67869*
2	429.2190	16.66767	6.48e-13	-16.73273	-15.31559	-16.19945
3	441.1212	17.22014	8.03e-13	-16.55835	-14.51138	-15.78806
4	447.1087	7.643554	1.33e-12	-16.13228	-13.45547	-15.12498

Source: Author's own computation

The study performed the VAR optimal lag length criteria to determine the number of lags that can be utilised in the model. As shown in Table 2 above, the study will be utilising 1 lag as selected by the LR, FPE, AIC and HQ criterion. The SC criterion selected zero lags, however, for the purpose of this study, we will be deploying 1 lag as selected by majority of the criterions. The study therefore continues to perform the ARDL Bounds test to cointegration to determine if there are long run relationships between the variables in the model as shown in Table 3 below.

Table 3: ARDL Bound test for cointegration

ARDL F-Bounds and t-Bounds Test **Null Hypothesis: No levels relationship**				
Test Statistic	**Value**	**Significance**	**I(0)**	**I(1)**
F-statistic	7.612341	10%	2.72	3.77
k	3	5%	3.23	4.35
		2.5%	3.69	4.89
		1%	4.29	5.61
t-statistic	-5.703109	10%	-2.57	-3.46
		5%	-2.86	-3.78
		2.5%	-3.13	-4.05
		1%	-3.43	-4.37

Source: Author's own computation

The study performed the ARDL F-Bounds and t-Bounds test to determine if there are long run relationships between the variables in the model. The f-statistic on the F-Bounds is 7.612341 that is greater than the critical values at 10%, 5%, 2.5% and 1% on both I(0) and I(1). The t-statistic on the t-Bounds test is -5.703109 that is smaller than all the critical values at 10%, 5%, 2.5% and 1% on both I(0) and I(1). The results from both the F-Bounds and t-Bounds reveal presents of cointegration in the model and therefore the study will estimate both the ARDL ECM model for short run relationships and the ARDL Levels equation for long run relationships. The study therefore continues to perform the Unrestricted ARDL ECM regression as shown in Table 4 below.

Table 4: Unrestricted ARDL ECM model and short run relationships

Unrestricted ARDL ECM model				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
D(LEXC(-1))	0.339295	0.141777	2.393162	0.0210
D(LOP(-1))	-0.262493	2.191931	-0.119754	0.9052
D(LRI(-1))	-0.216794	0.337681	-0.642007	0.5242
D(LNI(-1))	-0.833977	0.073826	-11.29659	0.0000
C	3.558950	0.624140	5.702171	0.0000
ECT(-1)	-0.660705	0.115850	-5.703109	0.0000
R-Squared	0.853194			
Adjusted R-squared	0.846947			
Prob(F-statistic)	0.000000			

Source: Author's own computation

The study performed the ARDL ECM regression as shown in Table 4 above. The R-squared is 0.853194, which explains that the data is a good fit for this regression model, meaning that 85.32% of the variation in the exchange rate is explained by oil prices, real interest rates and nominal interest rates. The adjusted R-squared is 0.846947, meaning 84.69% is adjusted for the degrees of freedom, meaning that additional variables in the model improves the predictive power of the model. The error correction term, ECT(-1) is -0.660705 that is negative and statistically significant with a p-value of 0.0000, meaning that 66.07% of the deviation in exchange rate is adjusted annually towards long run equilibrium.

There is a negative statistically insignificant short run relationship since the p-value is 0.9052 that is above the 1%, 5% and 10% level of significance between oil prices and exchange rates in South Africa. A 1% increase in oil prices in the short run in South Africa, will insignificantly result in the exchange rate declining by 0.26%, ceteris paribus. These results are consistent with the studies conducted by Brahmasrene, Huang et al. (2014), Turhan, Sensoy et al. (2014) and Anjum (2019). This means that though the results are insignificant, oil prices have been not good on the exchange rate of the South African Rand to the US Dollar, in other words, the increase in oil prices result in depreciation of the Rand. This entails that, policies that result in oil prices decreasing in South Africa must be promoted to safeguard the value of the rand against the US dollar.

There is a negative statistically insignificant short run relationship between real interest rates and exchange rate in South Africa in the short run since the p-value is 0.5242 that is above the 0.1, 0.05 and 0.01 critical values. A 1% increase in real interest rates in the short run in South Africa will insignificantly result in exchange rates declining by 0.22%, ceteris paribus. This means that real interest rates are not good on the exchange rates of the South African Rand to the US Dollar. Therefore, policies that favours decrease in real interest rates must be promoted in the short run to safeguard the value of the rand against the US dollar. These results are consistent with the study conducted by Dash (2012) and Wilson and Sheefeni (2014).

There is a negative short run statistically significant relationship between nominal interest rates and exchange rates in South Africa since the p-value is 0.0000 that is less than the 0.01, 0.05 and 0.1 critical values. A 1% increase in nominal interest rates will result in exchange rates declining by 0.83% in the short run period in South Africa, ceteris paribus. This means that increase in nominal exchange rates in the short run is not good for the value of the South African Rand against the US Dollar. This entails those policies that result in the nominal exchange rates declining must be promoted to safeguard the value of the Rand against the Dollar. These results are consistent with the study conducted by Wilson and Sheefeni (2014) and Dash (2012). The study continues to perform the long run relationships among the variables as shown by the results in Table 5 below.

Table 5: Unrestricted ARDL Levels Equation and long run relationship

Unrestricted ARDL Levels Equation				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
LOP	-0.397293	3.326610	-0.119429	0.9055
LRI	-0.328125	0.507051	-0.647124	0.5209
LNI	-0.508379	0.349615	-1.454111	0.1530

Source: Author's own computation

The study performed the long run estimations by employing the Unrestricted ARDL Levels equations as shown in Table 5 above. There is a negative statistically insignificant relationship between oil prices and exchange rates in South Africa since the p-value is 0.9055 that is above the 0.01, 0.05 and 0.1 critical values. A 1% increase in oil prices will insignificantly result in exchange rate declining by 0.40% in the long run period in South Africa, ceteris paribus. These results are inconsistent with the studies conducted by Delgado, Delgado et al. (2018) and Turhan, Hacihasanoglu et al. (2013). This means that increase in oil price is not good for the value of the South African Rand against the US Dollar since it leads to depreciation in the exchange rates. Therefore, policies that favours a decrease in oil prices must be promoted to safeguard the value of the South African Rand against the US Dollar.

There is a negative statistically insignificant relationship between real interest rates and exchange rates in South Africa in the long run since the p-value is 0.5209. A 1% increase in real interest rates will insignificantly result in exchange rate declining by 0.33% in the long run, ceteris paribus. This means that real interest rate increases are not good for the value of the South African Rand against the US Dollar in the long run. Therefore, policies that result in decrease in real interest rates must be promoted for appreciation of the South African Rand against the US Dollar. These results are consistent with the study conducted by Dash (2012) and Wilson and Sheefeni (2014).

There is a negative statistically insignificant long run relationship between nominal interest rate and exchange rate in South Africa since the p-value is 0.1530 that is above the 0.01, 0.05 and 0.1 critical value. A 1% increase in nominal interest rates in the long run in South Africa, will insignificantly result in exchange rate declining by 0.51%, ceteris paribus. This means that increases in nominal interest rate is not good for the value of the South African Rand since it results in depreciation of the exchange rate. Therefore, policies that result in decline in nominal interest rates must be promoted to safeguard the value of the rand and avoid the overheating of the South African economy. These results are consistent with the studies conducted by Wilson and Sheefeni (2014) and Dash (2012). The study therefore continues to perform the Granger Causality tests as shown in Table 6 below to check for causal relationships among the variables.

Table 6: Granger Causality Test

Pairwise Granger Causality Tests Lags 1 Sample: 1970 - 2021		
Null Hypothesis	**F-Statistic**	**Probability**
LOP does not Granger Cause LEXC	0.00074	0.9784
LEXC does not Granger Cause LOP	1.88758	0.1760
LRI does not Granger Cause LEXC	2.94571	0.0927
LEXC does not Granger Cause LRI	0.73123	0.3968
LNI does not Granger Cause LEXC	8.24807	0.0061
LEXC does not Granger Cause LNI	5.20099	0.0272
LRI does not Granger Cause LOP	2.79904	0.1010
LOP does not Granger Cause LRI	0.09583	0.7583
LNI does not Granger Cause LOP	1.33437	0.2539
LOP does not Granger Cause LNI	0.11537	0.7356
LNI does not Granger Cause LRI	5.37939	0.0248
LRI does not Granger LNI	1.57346	0.2159

Source: Author’s own computation

The study performed the Granger Causality Test as shown in Table 6 above to check for causality relationships among the variables. The results revealed noncausality between oil prices and exchange rate of the South African Rand against the US Dollar. These results are consistent with the study conducted by Tiwari, Mutascu et al. (2013) and Chang, Huang et al. (2013). There is unidirectional causality running from real interest rates to exchange rates at 10% level of significance since the p-value is 0.0927. This means policies that affect real interest rates will have a causal effect on exchange rate of the Rand to the Dollar in South Africa. There is bidirectional causality between nominal interest rates and exchange rates in South Africa at 5% level of significance. This means that policies that affect nominal interest rates will have an impact on exchange rate and the policies that affect exchange rate will also have a causal effect on nominal interest rates in South Africa. There is unidirectional causality running from nominal interest rates to real interest rates in South Africa. This means that policies that affect nominal interest rates will have a causal effect on real interest rates. There is also causal effect of real interest rates and nominal interest rates on oil prices in South Africa as shown by the probabilities that exceed the 0.01, 0.05 and 0.1 critical values. The study therefore continues to perform the residuals diagnostic tests as shown in Table 7 below to check how well are these results reliable and valid for policy recommendations in South Africa.

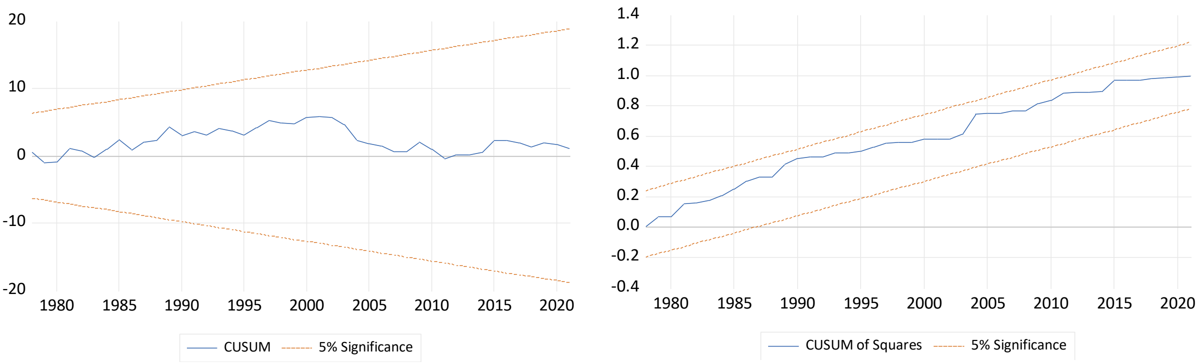
Table 7: Residual Diagnostic Tests

Residual Diagnostic Test	**Probability**
Breusch-Godfrey Serial Correlation LM Test	0.7632
Breusch-Pagan-Godfrey Heteroskedasticity Test	0.2006
Ramsey RESET test	0.3472
Jarque-Berra	0.9506

Source: Author's own computation

The study performed the residual diagnostic tests as shown in Table 7 above. The results of the Breusch-Godfrey Serial Correlation have a p-value of 0.7632 that is above the 0.05 critical value. This means that we fail to reject the null hypothesis that states that the residuals do not suffer from serial correlation up to 1 lag and conclude that there is no serial correlation in the model. The Breusch-Pagan-Godfrey heteroskedasticity test have a p-value of 0.2006 that is above the 0.05 critical value. This means that we fail to reject the null hypothesis that states that the residuals are homoscedastic and conclude that there is no heteroskedasticity in the residuals in the model. The Jarque-Berra has a probability value of 0.9506 that is above the 0.05 critical value meaning that we fail to reject the null hypothesis that the residuals are normally distributed and conclude that there are not problems of nonnormal residuals in the model. The Ramsey RESET test has a probability value of 0.3472 that is above the 0.05 critical value. This means that we fail to reject the null hypothesis that states that the model is correctly specified and conclude that the model does not suffer from any misspecification. The study therefore continues to perform the CUSUM and CUSUM of Squares as shown in Figure 1 below.

Figure 1 CUSUM and CUSUM of Squares



Source: Author's own computation

The study performed the CUSUM and CUSUM of Squares as shown in Figure 1 above to check for stability of the model. The blue line drifts between the 5% critical boundaries indicated by the yellow line from 1960 to 2021 meaning that the model is stable throughout the period under investigation. This means the results of the study are valid for policy recommendations and the recommendations are reliable based on statistical evidence. The study therefore continues to provide the conclusion and policy recommendation as shown in Section 5 of the study below.

5. Conclusion and Recommendations

The study investigates the relation between oil prices and South African exchange rates from 1970 through 2021 using annual time series data from the South African Reserve Bank. Nominal and real interest rates were used as intermittent variables in the study. The Autoregressive Distributed Lag Model and the Granger Causality tests were used in the inquiry. The research proposed various policy implications that needed to be considered. The relationship between oil prices and exchange rate has been found to be negative both in the short and long run period in South Africa though it is insignificant. The Granger Causality test confirmed that there is no evidence of causality between oil prices and exchange rates. These results entail that, ceteris paribus, an increase in oil prices will result in depreciation of the South African Rand against the US Dollar exchange rates both in the short and long run period. The policy implications of these results are therefore as follows:

Firstly, there is a negative relationship between oil prices and exchange rates of the South African Rand against the US Dollar both in the short and long run period. The government and policy makers must implement policies that results in an increase in demand of the South African Rand for it to appreciate against the US Dollar. This will enable oil prices to be cheaper against the strengthening Rand to the US Dollar exchange. The government can also safeguard oil prices by making sure that they have built enough buffer stock of crude oil to smooth effects of external shocks in the oil market. The government must also increase investment in offshore drilling and projects that are extracting crude oil in South Africa to reduce dependency on oil imports. The department of energy must also embark on initiatives that seeks to keep oil prices low in South Africa.

Secondly, there is a negative relationship between real interest rates and the exchange rates of the South African Rand against the US Dollar in both the short and long run period. This was validated by the unidirectional causality running from real interest rates to exchange rates. This calls for the government and policy makers to reduce real interest rates by revising the monetary policy. Lower real interest rates will result in an increase in aggregate demand transforming into higher economic growth and appreciation of the Rand against the US Dollar. However, this must be implemented with great care since lower interest rates will likely result in higher imports that worsen the current account.

Thirdly, there is a negative relationship between nominal interest rates and exchange rates in South Africa both in the short and long run period, except that the relationship is statistically insignificant in the long run. These results were validated by the bidirectional causality between nominal interest rates and exchange rates of the South African Rand against the US Dollar. This calls for the government, monetary authorities, and policy makers to implement policies that reduce nominal interest rates. This will help with cheaper borrowing costs and making South African exports more competitive and imports expensive thereby reducing heavy dependency on oil imports. This will transform into higher economic growth in South Africa thereby solving challenges of low economic growth.

In conclusion, the study investigated the relationship between oil prices and exchange rates in South Africa from 1970 to 2021 and has found that oil prices contribute negatively on the exchange rates of the Rand against the US Dollar. Real interest rates and nominal interest rates were also found to contribute negatively to exchange rate of the South African Rand to the US Dollar. Oil prices has been increasing and the exchange rate of the South African Rand against the US Dollar has been depreciating through out the period understudy. This has resulted in an increase in petroleum prices in South Africa also leading to the increase in the cost of living. We need the government to safeguard oil prices so that they are not easily affected by external shocks in the oil market by maintaining sufficient buffer stocks. Research in the future must consider increasing variables in the model such as inflation, balance of trade and political stability when investigating the relationship between oil prices and exchange rates. From this study, it can be suggested that in future research should consider using other models when investigating the relationship between oil prices and exchange rates to discover different results.

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