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The determinants of the exchange rate volatility: A case study for South Africa

**Mudau MP
(17011727)**

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**Supervisor: Doctor Nemushungwa AI
Co-Supervisor: Doctor Dagume MA**

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DECLARATION

I, Mudau Maria Phathutshedzo, hereby declare that the research project I am submitting for my master's degree in economics, titled "The determinants of the exchange rate volatility: A case study for South Africa", has never been submitted before for a degree at this university or any other university. I also declare that I am responsible for the design and execution of the project, and that all citations used in it have been properly acknowledged.

Signature: 

Date.....

Supervisor's signature:

DEDICATION

I dedicated this research to my late mother, Rengane Elisah Mudau, and my late grandmother, Thivhafuni Esther Nelutshindwi, siblings and friends.

ACKNOWLEDGEMENT

First and foremost, I would like to thank the Almighty God for being with me throughout this entire journey; without his everlasting love, I am not sure where I would be.

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LIST OF ABBREVIATIONS

SARB – South African Reserve Bank

NARDL – Nonlinear Autoregressive Distributed Lag

NEOM – New Open Economy Macroeconomics

GARCH – Generalized Autoregressive Conditional Heteroskedasticity

FMOLS – Fully Modified Ordinary Least Squares

ERV – Exchange Rate Volatility

PPP – Purchasing Power Parity

FPMM – Flexible Price Monetary Model

GDP – Gross Domestic Product

ADRL – Autoregressive Distributed Lag

REER – Real Effective Exchange Rate

ARCH – Autoregressive Conditional Heteroskedasticity

SOE – State-Owned Enterprise

RIR – Real Interest Rate

FMOLS - Fully Modified Ordinary Least Squares

CPIX – Consumer Price Index excluding mortgage interest costs

EM – Emerging Markets

OLS – Ordinary Least Squares

OECD – Organization for Economic Co-operation and Development

ADF – Augmented Dickey-Fuller

ERPT – Exchange Rate Pass-Through

VECM – Vector Error Correction Model

MPR – Monetary Policy Rate

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ABSTRACT

The dissolution of the Bretton Woods system in 1973 prompted numerous countries to shift from fixed to flexible exchange rate regimes, resulting in increased exchange rate volatility. In line with this global trend, South Africa adopted a free-floating exchange rate system in the mid-1990s and implemented an explicit inflation-targeting framework in the early 2000s. This policy transition, which emphasized the internal value of the rand, inadvertently led to increased exchange rate volatility. Excessive exchange rate volatility delays investment decisions, causing economic uncertainty and negatively impacting economic growth by impacting investment and investor confidence, productivity, consumption, international trade, and capital flows. Despite various factors suggested in the literature, there is no consensus on the primary causes of exchange rate volatility, making it a contentious issue. Notably, there is a paucity of studies examining this topic within the South African context. This study aims to contribute to the existing literature by analyzing the determinants of exchange rate volatility in South Africa, employing the Nonlinear Autoregressive Distributed Lag (NARDL) approach and utilizing quarterly data spanning from 2000 to 2023. The findings suggest that trade openness has a significant impact on exchange rate volatility, underscoring the need for policies that consider the complexities of trade integration and its impact on exchange rate stability. The findings suggest that trade openness has a significant impact on exchange rate volatility, underscoring the need for policies that consider the complexities of trade integration and its impact on exchange rate stability. Policymakers should advance trade liberalization, secure favorable agreements, and lower barriers to diversify export markets and reduce dependence on limited trading partners, thereby stabilizing the exchange rate.

Keywords: Fixed exchange rate regime, flexible exchange rate system, exchange rate volatility, NARDL approach, trade openness, South Africa

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Chapter One: Orientation of the Study

1.1 Background

The dissolution of the Bretton Woods system in 1973 prompted many countries to transition from fixed to floating exchange rate regimes, leading to increased exchange rate volatility (Kiliçarslan, 2018). South Africa followed this global trend by adopting a free-floating exchange rate regime in the mid-1990s and implementing an explicit inflation-targeting framework in the early 2000s. The South African Reserve Bank (SARB) set its primary objective as maintaining price stability, thereby focusing on protecting the internal value of the rand (Wolassa, 2015).

The transition to an inflation-targeting monetary policy framework in South Africa stabilised interest rates and enhanced their predictability. However, this shift also entailed the South African Reserve Bank (SARB) relinquishing its commitment to a specific exchange rate parity, allowing the rand to fluctuate freely in foreign exchange markets. Consequently, the SARB ceased interventions aimed at preserving the currency's external value, leading to a more volatile exchange rate environment (Mtonga, 2011).

Between 2002 and 2013, South Africa experienced pronounced exchange rate volatility, with the rand exhibiting persistent fluctuations primarily driven by market shocks rather than fundamental economic indicators. During elevated interest rates, notably from 2000 to 2009, substantial foreign capital inflows led the rand to appreciate beyond its equilibrium level. This volatility was further exacerbated by the rand's status as one of the most traded emerging market currencies, rendering it particularly susceptible to global financial dynamics (Odhiambo, 2015).

South Africa has experienced significant episodes of currency depreciation, notably in 2001, January 2016, and June 2016. In the final quarter of 2001, the rand depreciated by 26% against the U.S. dollar. This decline was attributed to a combination of factors, including rapid growth in the money supply, increased bank credit expansion, and heightened investor concerns over emerging market risks, which collectively exerted downward pressure on the currency's value (South African Reserve Bank, 2001).

In January 2016, the rand experienced a sharp decline, falling by approximately 10% against the (USD) United States dollar. This depreciation was largely driven by concerns over China's economic slowdown, which impacted South Africa due to its strong trade ties with China, particularly in commodities such as iron ore and gold (Washington Post, 2016). On 24 June, 2016, following the United Kingdom's vote to exit the European Union (Brexit), the rand suffered its most substantial one-day loss since the 2008 financial crisis, dropping more than 8% against the U.S. dollar (Mukalayi, 2021). This decline was part of a broader sell-off in emerging market currencies triggered by global financial uncertainty stemming from the Brexit vote (Bloomberg, 2016).

In April 2020, a combination of factors, -including sovereign credit rating downgrades, the corona virus (COVID-19) pandemic, and a nationwide lockdown, led the rand to depreciate beyond R19 per US dollar. Such levels of depreciation have not been observed in recent history, and economic theory suggests that currency depreciation can, under certain conditions, boost export volumes (Ndou, 2020).

Both domestic and external shocks influence the rand's volatility. Domestically, significant economic disturbances have elevated the rand's volatility beyond global benchmarks like the VIX, a commonly used indicator of global uncertainty. Externally, the rand is often traded as a proxy for emerging market risks. Non-resident investors hold substantial shares of South African assets, amplifying the currency's sensitivity to global financial movements (Miyajima, 2019).

1.2 Problem Statement

Exchange rate volatility poses a significant risk to the financial industry, particularly in emerging markets like South Africa. Over the past decade, the rand has experienced considerable fluctuations, with annual volatility averaging 10–15% and spikes exceeding 20% during periods of economic or political stress, such as the global financial crisis and domestic policy uncertainty (South African Reserve Bank, 2023; Mpofu, 2016). This degree of volatility is high compared to other emerging markets, raising the risk premium for investors and increasing the cost of hedging for internationally engaged businesses.

Such instability introduces uncertainty into international trade and investment, discouraging exporters, delaying capital expenditure decisions, and undermining investor confidence. The resulting economic ripple effects can weaken productivity, dampen consumption, and disrupt capital flows (Nyandoro, 2020; Oaikhenan & Aigheyisi, 2015; Kiliçarslan, 2018). For example, during 2020, the rand depreciated by over 20% against the US dollar, coinciding with reduced foreign direct investment inflows and higher cost pressures for import-dependent industries, slowing economic recovery (National Treasury, 2021). From a policy perspective, excessive volatility complicates macroeconomic management, as it can trigger inflationary shocks that disrupt monetary policy frameworks such as the South African Reserve Bank's inflation targeting system, with adverse consequences for household welfare and business planning (SARB, 2023; Ajao, 2015).

Existing research identifies several potential determinants of exchange rate volatility, including trade openness, capital flows, economic growth rates, financial development, foreign reserves, external debt, and the exchange rate regime (Stancik, 2007; Oaikhenan & Aigheyisi, 2015; Kiliçarslan, 2018). However, the relative importance of these factors often varies across countries, time periods, and analytical methods, and there is little consensus on which dominate. Moreover, much of the literature focuses on the *effects* of exchange rate volatility on growth, trade, or investment, rather than its *causes*. In the South African context, studies examining the origins of volatility are scarce, with Mpofu (2016) among the few addressing this issue. Even then, the potential asymmetric impacts of macroeconomic variables on volatility remain largely unexplored.

This study addresses that gap by analysing the determinants of exchange rate volatility in South Africa, with a specific focus on the asymmetric effects of oil prices, inflation, trade openness, interest rate, and gross domestic price. Applying a Nonlinear Autoregressive Distributed Lag (NARDL) framework allows for distinguishing between the impacts of positive and negative changes in these variables over the short and long run. By shifting attention from outcomes to underlying drivers, the research provides deeper insight into the structural and policy-related forces shaping exchange rate dynamics. The findings aim to inform policymakers seeking to stabilise the exchange rate, enhance investor confidence, and promote sustainable economic

growth, while also making a meaningful contribution to academic discourse on exchange rate volatility in emerging markets.

1.3 Objectives of the Study

1.3.1 Main Objective

This study's primary aim is to analyse the determinants of exchange rate volatility in South Africa from 1990 to 2023.

1.3.2 Specific Objectives

The study seeks to:

- Empirically investigate the existence of a long-run relationship between exchange rate volatility and its potential determinants.
- Examine the short-run dynamics among exchange rate volatility and its explanatory variables.

1.4. Research Hypotheses

Hypothesis 1: Long-Run Relationship

- **Null Hypothesis (H_0):** There does not exist statistically significant long-run relationship between exchange rate volatility and its determinants
- **Alternative Hypothesis (H_1):** There exists a statistically significant long-run relationship between exchange rate volatility and its determinants.

Hypothesis 2: Short-Run Dynamics

- **Null Hypothesis (H_0):** There are no significant short-run dynamics among exchange rate volatility and its explanatory variables in South Africa.
- **Alternative Hypothesis (H_1):** There are significant short-run dynamics among exchange rate volatility and its explanatory variables in South Africa.

1.5 Significance of the Study

Exchange rate volatility poses significant challenges to economic stability, particularly in trade-dependent economies like South Africa. Fluctuations in exchange rates can deter exporters from engaging in international trade due to increased risk, leading to reduced export earnings and potential current account deficits, which may culminate

in balance of payment crises (Agboola, Tchokote, & Uche, 2015; Nyandoro, 2020). The exchange rate is one of the most closely monitored economic indicators by policymakers, financial market participants, and industries involved in international trade. It reflects a country's competitiveness in international markets and has a major influence on economic activity, mainly through the external sector (Khomu, 2018).

This study aims to provide valuable insights into the drivers of exchange rate volatility in South Africa. By analysing the determinants of such volatility, the research contributes to a deeper understanding of the economic dynamics affecting the exchange rate. The findings can assist policymakers in formulating more effective strategies to promote stability and mitigate adverse impacts on businesses and the overall economy.

The novelty of this study lies in its comprehensive analysis of the asymmetric effects of key macroeconomic variables, specifically oil prices, inflation, and trade openness, on exchange rate volatility in South Africa, using the Nonlinear Autoregressive Distributed Lag (NARDL) model. Unlike prior research that often treats these relationships symmetrically, this approach captures nonlinear dynamics and reveals how positive and negative shocks impact exchange rate volatility differently. Furthermore, the study highlights the critical role of trade openness in reducing volatility, an area that has been underexplored in the South African context. These insights provide a more nuanced and comprehensive framework for understanding the complex interplay between macroeconomic variables and exchange rate volatility, offering valuable policy implications for stabilizing the exchange rate and promoting sustainable economic growth.

Despite the existing literature on exchange rate volatility, limited research addresses the asymmetric impacts of these macroeconomic determinants within South Africa's unique economic environment. By filling this gap, the study makes a significant contribution to both academic knowledge and practical policy formulation. Additionally, it overcomes limitations of earlier studies by employing advanced econometric techniques to capture nonlinearities and direction-specific effects that traditional models may overlook.

1.6 Delimitations of the Study

This study focuses on identifying and analyzing quantifiable macroeconomic determinants of exchange rate volatility in South Africa. Specifically, it examines variables such as interest rate differentials, inflation rate differentials, economic growth (GDP), trade openness, and oil prices. These factors have been identified in prior research as significant contributors to exchange rate volatility.

1.7 Operational definitions

- **Exchange Rate Volatility**

According to Yensu et al. (2022), exchange rate volatility encompasses the unpredictable exchange rate changes over time, which pose risks to economic activities such as trade and investment. Similarly, Morina et al. (2020) define exchange rate volatility as the short-term fluctuations of nominal or real exchange rates around their longer-term trends, highlighting its impact on economic stability.

These fluctuations can have profound effects on international trade, investment decisions, and overall economic growth. For instance, increased exchange rate volatility can deter foreign investment due to the heightened risk of currency value changes, while stable exchange rates can promote economic confidence and growth.

- **Trade Openness**

Definition: Trade openness refers to the extent to which a country allows free trade with other nations, typically measured by the ratio of the sum of exports and imports to the country's gross domestic product (GDP).

Trade openness is often quantified as the trade-to-GDP ratio, indicating the degree of a country's integration into the global economy (Sowrov, 2024).

- **Gross Domestic Product (GDP)**

Definition: GDP is the total monetary value of all finished goods and services produced within a country's borders in a specific time period. It serves as a comprehensive measure of a nation's overall economic activity and is commonly used to compare the economic performance of different countries or to assess economic growth over time.

(Mankiw, 2021). GDP is widely used to assess economic growth, reflecting a country's production and consumption capacity (Rachmawaty et al., 2024).

- **Inflation Rate Differentials**

Definition: Inflation rate differentials refer to the difference in inflation rates between two countries. In simpler terms, it's a way to compare how quickly prices are rising in one country versus another. This gap can affect exchange rates, trade competitiveness, and investment decisions, as investors and businesses often consider these differences when choosing where to operate or invest (Krugman et al., 2022). Persistent inflation differentials can lead to real exchange rate misalignments, affecting competitiveness within a monetary union (European Parliament, 2022).

- **Interest Rate Differentials**

Definition: Interest rate differentials refer to the difference in interest rates between two countries. Think of it as a comparison of how much return you could earn on investments, like bonds, in one country versus another. These differences play a big role in currency values and investment flows, as investors often move their money to where they can earn higher returns (Madura, 2021).

Interest rate differentials denote the difference in interest rates between two countries. These differentials can influence capital flows, exchange rates, and are central to strategies like the carry trade. Interest rate differentials play a significant role in exchange rate dynamics, with larger differentials potentially leading to currency appreciation but also increased risk of depreciation (Antolin-Diaz et al., 2023).

1.8 Structure of the Study

This study is organised into five chapters, each serving a distinct purpose in the research process:

Chapter One: Introduction

This chapter provides the background to the study, articulates the problem statement, outlines the research objectives and questions, and discusses the significance of the research.

Chapter Two: Literature Review

This section presents a comprehensive review of both theoretical frameworks and empirical studies related to exchange rate volatility, establishing the context and identifying the gap that the current study aims to address.

Chapter Three: Research Methodology

This chapter details the methodological approach employed to achieve the research objectives, including the research design, data sources, and analytical techniques used in the study.

Chapter Four: Results and Discussion

This section presents the findings derived from the data analysis and interprets the results concerning the research questions and existing literature.

Chapter Five: Conclusion and Policy Recommendations

The final chapter summarises the key findings, draws conclusions, and offers policy suggestions for further study and areas for future research, based on the study's limitations and findings.

1.9 Chapter Summary

Following the collapse of the Bretton Woods system in 1973, South Africa transitioned to a floating exchange rate regime in the mid-1990s and adopted an inflation-targeting framework in the early 2000s. This shift led to increased exchange rate volatility, influenced by both domestic and global factors. Significant events, such as the 2001 depreciation of the rand and the 2016 Brexit vote, exemplify the currency's susceptibility to external shocks. The study aims to analyze the determinants of exchange rate volatility in South Africa from 1990 to 2023, focusing on variables like trade openness, capital flows, economic growth rates, financial development, foreign reserves, external debt, and exchange rate regimes.

The study sought to empirically investigate the existence of long-run relationships and short-run dynamics between exchange rate volatility and its potential determinants. It also aimed to analyse causal relationships and their directions. Understanding these relationships is crucial, as exchange rate volatility poses significant risks to the financial industry and economic stability, particularly in emerging markets like South Africa.

Chapter Two: Literature Review

2.1 Introduction

This chapter provides an overview of theoretical and empirical literature related to the determinants of exchange rate volatility. The chapter is structured as follows: Section 2.2 presents a theoretical literature review, where exchange rate theories such as the purchasing power parity and the monetary models are discussed. In terms of empirical literature, studies conducted by researchers examining determinants of exchange rate volatility are examined in Section 2.3. An assessment of the empirical literature reviewed is presented in Section 2.4. Section 2.5 presents the summary of the chapter.

2.2 Theoretical Literature Review

This section presents theoretical literature related to the topic of the determinants of exchange rate volatility. The literature does not provide a consensus on the macroeconomic determinants of exchange rate volatility. This is due to the employment of several methodologies based on various theoretical models of exchange rate determination. Some studies investigated the causes of exchange rate volatility using a specific exchange rate level model, while others used a synthesis of exchange rate level models.

Specific models include (1) studies based on monetary models of exchange rate level determination that focus on monetary variables as determinants of exchange rate volatility. (2) the Optimum Currency Areas model, which focuses on trade links, asymmetry or similarity of economic shocks to production, country size, and geographic factors as causes of exchange rate volatility and, (3) New Open Economy Macroeconomics which emphasises the role of monetary and non-monetary variables in explaining exchange rate volatility.

Studies that synthesise exchange rates employ factors from different specific models deemed significant in understanding exchange rate fluctuations in the countries of their studies. Other studies, however, find no correlation between macroeconomic fundamentals and exchange rate volatility. They provide credence to the importance of non-macroeconomic causes of exchange rate volatility.

The next section, therefore, presents the three specific models relating to the topic on the determinants of exchange rate volatility. They are the monetary model of exchange rate level determination, the Optimum Currency Areas model, and the New Open Economy Macroeconomics model.

2.2.1 Theoretical models

Theoretical Foundations of Exchange Rate Determination

The study of exchange rate volatility draws on a rich theoretical tradition, evolving through successive frameworks that offer different perspectives on the forces driving currency movements. The earliest and most enduring is the *Purchasing Power Parity* (PPP) theory, which rests on the *law of one price*: identical goods should sell for the same price in different countries when expressed in a common currency, assuming no transaction costs or trade barriers.

In practice, however, PPP often holds only in the long run due to frictions such as price stickiness, transportation costs, and the presence of non-tradable goods. While PPP explains long-run parity conditions, it does not fully account for the short-run dynamics of exchange rates. This limitation led to the development of *Monetary Models*, which embed PPP within a broader money market equilibrium framework.

While monetary models incorporate key macroeconomic fundamentals, they are often static or partial equilibrium in nature, limiting their ability to explain persistent deviations from PPP or the role of expectations. The emergence of *New Open Economy Macroeconomics* (NOEM) addressed these gaps by embedding open-economy macroeconomics within microeconomic foundations (Obstfeld & Rogoff, 1995).

In NOEM, households maximize lifetime utility subject to intertemporal budget constraints, and firms set prices according to staggered adjustment rules (e.g., Calvo pricing). When taken together, the evolution from PPP to monetary models and finally to NOEM reflects a shift from static, purely price-based theories to dynamic, micro founded frameworks that better capture real-world exchange rate behaviour. This progression is especially relevant for analysing volatility in emerging markets like South Africa, where macroeconomic shocks, nominal rigidities, and structural factors often interact in complex, asymmetric ways.

The different theoretical models are explained in detail:

- **The Purchasing Power Parity**

The Purchasing Power Parity (PPP) is one of the strands of monetary models of exchange rate level determination. The exchange rate of any pair of currencies is the point where their respective purchasing powers are equal. The purchasing power of a currency is what a unit of the currency can buy which is determined by the price. In the long term, the average exchange rates of any pair of currencies depend on their relative purchasing powers (Aravind, 2023).

This theory takes its root from the "law of one price", which expresses that identical products ought to be sold at identical prices. The PPP theory, in this way, expresses that over the long run, identical products and services in various nations should cost the equivalent in those nations. This depends on the assumption that the exchange rate will change in accordance with and wipe out arbitrage opportunity (Madura, 2011). However, in the process of wiping out any arbitrage opportunity exchange rate fluctuate excessively, or exchange rate becomes more volatility (Odoom, 2019).

This theory has two variations: the absolute and the relative forms.

- (i) **Absolute Purchasing Power Parity Theory**

The absolute form of PPP expresses that the exchange rate between the currencies of two nations is equivalent to the ratio of the price levels in the two nations (Lafrance & Schembri, 2002; Odoom, 2019). The theory goes on to stipulate that "the exchange rate should be equal to the ratio of the average price levels in the two economies" (Solnik & McLeavey, 2004).

The theory is demonstrated in the following equation:

$$E = P/P^* \dots\dots\dots (2.1)$$

Where:

E is the equilibrium exchange rate,

P is the price level in country A, and

P^* is the price level in country B

(Van der Merwe & Mollentze, 2010).

It must also be realised that absolute PPP considers a weighted average of a number of goods and services, rather than focusing on the price associated with a particular good or service (Solnik & McLeavey, 2004). Thus, a 'basket' containing similar homogenous goods and services between two countries should have the same price when denominated in a common currency. This alleviates the problem of goods in different countries not being completely identical, so that the theory still appears relevant despite products being slightly different among countries.

Certain issues or weaknesses that has arisen with this particular theory cannot, however, be ignored. One shortcoming that affects the relevance of the absolute model is the presence for factors such as tariffs and transportation expenses, of which this model makes no consideration (Pilbeam, 1998). One cannot deny that such factors will be present, particularly with international dealings. Another fault lies in the fact that "there are many non-traded goods included in the price index of countries that cannot be equated with international trade" (Van der Merwe & Mollentze, 2010). For example, non-traded goods could include the cost of visiting a dental practitioner. If such a service is slightly cheaper in South Africa as compared to China, it is unrealistic to assume that one would make the journey all the way to China due to the cheaper price.

(ii) Relative PPP Theory

This version of PPP explains how “the appreciation or depreciation of a currency is given by the difference between the two nations inflation rates” (Daniels & Van Hoose, 2002). The relative PPP theory is of the view that the exchange rate between two countries can be explained by inflation differentials, and the equilibrium exchange rate should adjust to offset these inflation differences. The relative form of PPP theory also states that the percentage change in the exchange rate between two currencies over any period of time is equivalent to the difference between the percentages of change in the price levels of goods over that same time period. The relative PPP form therefore translates an absolute PPP form from a statement about price and exchange rate levels into one about price and exchange rate changes (Lafrance & Schembri, 2002).

This theory can be demonstrated by considering relative price changes:

$$E = \theta P/P^* \dots\dots\dots (2.2)$$

Where, θ represents a constant reflecting the obstacles to trade (Dornbusch, 1985).

With θ being held constant, the following then holds true as a reflection of the relative purchasing power parity theory after utilising logs of the absolute version and differentiating:

$$\Delta E = \pi - \pi^* \dots\dots\dots (2.3)$$

Where, ΔE is a proportionate change in the exchange rate,

π is the inflation rate in country A, and

π^* is the inflation rate in country B

(Van der Merwe & Mollentze, 2010).

The relative model is thus a weaker variety of the absolute one, as it highlights the relevance of changes in prices as compared to absolute prices (Daniels & VanHoose, 2002). By loosening the definition of PPP, this latter model overcomes some of the weaknesses associated with the absolute model by not focusing on absolute flows but rather highlighting the importance of the changes in these flows.

Despite this advantage, the relative PPP theory still presents some major limitations. Both the absolute and relative models are unable to address financial flows or money stock changes (Daniels & VanHoose, 2002). These theories thus examine only the changes in exchange rates that occur as a result of international dealings of goods and services. It seems inadequate to make no reference to financial flows and money stock changes considering the overall relative importance of these items in recent years.

A second issue that must be noted is statistical problems, in that countries may associate different weightings towards different product categories in computing price indexes (Pilbeam, 1998). This makes it difficult to compare baskets of goods and services that are similar. This statistical problem becomes a greater issue in comparing first and third-world countries. Consumers in first-world countries are likely to attach greater importance to higher, more durable quality goods and services, whilst consumers in third-world countries find greater significance in basic staple items.

The exchange rate between two nations is equivalent to the ratio of the price levels within the two nations. Hence, PPP predicts that the level of exchange rates is dictated by relative prices, and adjustments in relative prices will result in exchange rate volatility. A nation with high inflation would encounter a high exchange rate volatility and subsequently a currency depreciation, whilst a nation with low inflation will experience a stable exchange rate and subsequently a currency appreciation (Hill, 2008). From the foregoing discussion, it can be deduced that changes in the price levels in a country leads to exchange rate volatility.

2.2.2 The Monetary Models

Three main monetary models that often appear in traditional literature, are all common in that “the supply and demand for money are the key determinants of exchange rate determination” and “they assume that domestic and foreign bonds are equally risky so that their expected rates of return are equalised” (Pilbeam, 1998). However, this is as far as the similarities between these models extend. Differences arise that distinguish each from the next, as shall now be discussed.

- **The Flexible Price Monetary Model**

This model was first developed by Frenkel (1976), Mussa (1976) and Bilson (1978). According to Bilson, the approach reflects the quantity theory of money and strict PPP. The Flexible Price Monetary Model (FPMM) incorporates the effect of inflationary expectation, and its major argument is that within an economy, all prices (wages, exchange rates, prices, etc.) are in both the long run and short run flexible (upwards and downwards). The FPMM assumes that goods prices are perfectly flexible, implying that the PPP always holds instantaneously.

The assumption about PPP implies that the real exchange rate is constant over time (Diamandis et al, 1996) In contrast to the Mundell-Fleming model, the FPMM proposed by Frenkel (1976), as suggested by the name, works with the assumption that all prices are flexible. This model for computing a floating exchange rate assumes not only that prices are flexible, and that domestic and foreign bonds are perfect substitutes, but that the concept of purchasing power parity holds in the long term (Södersten & Reed, 1994). The concept of PPP holding in the long term refers to the law of one price and homogeneous items costing the same amount after a common currency conversion.

The FPMM builds on the Cambridge equations and equilibrium conditions for money supply and money demand:

$$Ms = m (D + F) \dots\dots\dots (2.4)$$

$$Md = kPy \dots\dots\dots (2.5)$$

$$\text{Equilibrium condition occurring where } Ms = Md \dots\dots\dots (2.6)$$

Where,

Ms is the money supply,

m is the money multiplier,

D is the domestic component of the monetary base,

F shows the foreign reserve component of the monetary base,

Md is money demand,

k is the desired ratio of nominal money balances to nominal national income,

P is the price level, and

y is real national income

(Salvatore, 2007).

Equations 2.4 and 2.5 illustrate the various components that constitute nations demand for and supply of money. As shown by equation 2.6, equilibrium occurs when a nation's demand for money equals a nation's supply of money. Based on the above, the following equations hold true for a two-country model, consisting of country A and country B:

$$M_{SA} = K_A P_A Y_A \dots \dots \dots (2.7)$$

$$M_{SB} = K_B P_B Y_B \dots \dots \dots (2.8)$$

Now the absolute purchasing power parity condition $E = P/P^*$ can be substituted into the equilibrium condition for country A, such that

$$M_{SA} = K_A S P_A Y_A \dots \dots \dots (2.9)$$

$$M_{SB} = K_B P_B Y_B \dots \dots \dots (2.10)$$

By incorporating the equilibrium condition, one can now solve for the exchange rate S :

$$\frac{M_{SA}}{M_{SB}} = S \times \frac{K_A S P_B Y_A}{K_A P_A Y_A}$$

$$\text{So that } S = \frac{M_{SA}}{M_{SB}} \times \frac{K_B Y_B}{K_A Y_A} \dots \dots \dots (2.11)$$

This implies that the exchange rate is proportional to the ratio of money supplies and output levels in the two economies, weighted by their respective velocity and demand for money.

(Daniels & VanHoose, 2002).

A given increase in domestic money supply, due to extended domestic credit, will result in prices increasing and the domestic currency depreciating (Daniels & VanHoose, 2002). In essence, when domestic money supply increases and begins to exceed domestic money demand, consumers are likely to induce greater expenditure, particularly on foreign products. As this occurs, so will the local currency begin to depreciate in value until the point that domestic money supply once again equilibrates to domestic money demand.

To state this occurrence in a general perspective, one could say that a country experiencing higher inflationary pressures compared to other countries, will find the exchange rate increasing (and local currency depreciates) (Salvatore, 2007). And thus, it can also be said for the reverse that a country experiencing lower inflationary pressures compared to other countries may find the exchange rate to be decreasing (and local currency appreciating).

With respect to real domestic income, a growth in income will lead to domestic prices falling and an appreciation of the domestic currency to maintain purchasing power parity (Du Plessis, 1998). At the same time therefore a given decrease in real domestic income will lead to domestic prices rising and a depreciation of domestic currency.

And lastly, a rise in domestic interest rates will cause domestic money demand to drop, and the domestic currency to depreciate (Pilbeam, 1998). A fall in domestic interest rates will thus result in domestic money demand rising and the domestic currency appreciating.

This model has shortcomings with respect to the belief that purchasing power parity holds in the long term. The reason for this is because the theories surrounding PP have not performed all that well empirically, thus resulting in the FPMM also showing poor results in historical testing (Pilbeam, 1998). However, this model is important in that it first introduced the concept of the necessity for including money stock within exchange rate determination.

- **The Dornbusch Sticky Price Monetary Model**

The sticky-price monetary model (associated with Dornbusch, 1976) assumes that prices of goods are sticky in the short run, and that PPP holds only in the long run but does not hold in the short run because goods prices adjust slowly relative to asset prices. This model “allows substantial overshooting for both the nominal and the real price-adjusted exchange rates beyond their long-run equilibrium (PPP) levels, since the exchange rates and the interest rates compensate for sluggishness in the goods prices” (Diamandis et al, 1996). According to the Dornbusch model, after money supply rise, the exchange rate fluctuates or changes more in the short-run than its long-run changes, therefore the exchange rate is said to be overshooting when its immediate response to a disturbance is greater than its long-run response (Dornbusch, 1976).

Exchange rate overshooting is an important phenomenon because it helps explain why exchange rates change so sharply or excessively from day to day. Overshooting in exchange due to price stickiness contributes to explaining the high volatility displayed by exchange rate (Al Samara, 2009). Therefore, the Dornbusch exchange rate overshooting model postulates that an increase in money supply increases exchange rate volatility whilst a decrease in money supply decreases exchange rate volatility.

Exchange rate overshooting can now be explained as how “prices in markets that adjust relatively quickly to some disturbance may have to overreact (overshoot) in the short term to compensate for the lack of (or too limited) reaction of prices in markets that adjust more slowly” (Du Plessis, 1998). In this instance, exchange rate overshooting occurs because exchange rates overreact in the short term to make up for slow adjustments in the goods market and labour market. It must be stated here that purchasing power parity thus only holds in the long term and does not necessarily hold in the short term. Deviations in purchasing power parity in the short term can be experienced due to this phenomenon of exchange rate overshooting occurring (Dewing, 2017).

Due to Dornbusch (1976), the sticky price model provides an explanation why the exchange rate under the floating system is volatile, overshooting above the long run equilibrium. This is a spill off from the monetarist model in which employment is full and goods prices become sticky rather than flexible. That is to say the price of 'non-traded' goods changes s their new equilibrium after a disturbance, while 'traded' goods prices increase in proportion to the money supply (Dornbusch (1995, 1988), Dornbusch, Fischer & Samuelson (1977)).

Hence, the overall price level increases less than the money supply, leaving the demand for money lower than the supply. In these circumstances, the exchange would go beyond its new equilibrium before returning to it. Eventually, the excess supply of money is eliminated via rising nontraded goods prices. The basic tenet of the sticky price model is that when currency is devalued and the price of goods remains fixed for short run, the currency value may 'overshoot'.

The overshooting in the exchange rate refers to a temporary overreaction of the nominal exchange rate before moving back toward the equilibrium value in the long run. According to Frenkel (1976), the exchange rate may temporarily overshoot its long run equilibrium value for at least three reasons. First, the exchange rate overshoots due to imperfect information on the shock of money supply levels. The currency may overshoot after it has been floated as a result of the 'sticky price' effect of the goods markets combined with instantaneous adjustment in asset market. Third, the lack of credibility, sustainability and confidence in government after periods of high inflation causes the political support to inevitably fall off. Thus, the currency chaos can be resulted in self-fulfilling perpetual currency depreciation belief resulting in hyperinflation period.

Nevertheless, Dornbusch (1995) posits that currency speculation attack by itself is not the cause of the currency crisis. It is the economic fundamental underlining the currency that causes the currency to depreciate or appreciate. Speculation is just an accelerator to the currency realignment at the faster rate to reach its fundamental equilibrium value. The problem is thus that of vulnerability. This leads to full scale financial crisis and forced 'de facto' devaluation by changing currency regime from fixed to float. One lesson from this episode is to avoid vulnerability in the first place.

This can only be done by having good macroeconomics management including financial deregulation and supervision, avoiding overvalue real exchange rate to achieve disinflation, lengthening the foreign capital maturity and plenty of transparency.

The Dornbusch model has been credited with several benefits, in that it explicitly refers to returns on portfolios influencing exchange rates and it assists in explaining as to why exchange rates can be more volatile than actual determinants (Pilbeam, 1998). In terms of returns on portfolios, this model discusses as to how exchange rates are impacted by investors seeking to equate their expected yields or returns on worldwide investments. With respect to volatility, the earlier example in explaining this model referred as to how a determinant such as money supply when increased resulted in an even greater depreciation in the exchange rate.

However, despite these accreditations, there is one major fault of the Dornbusch sticky price monetary model. This theory makes no reference to specifically incorporate inflation expectations, despite empirical evidence supporting the importance of such inflation changes in the past having significantly contributed to exchange rate determination (Pilbeam, 1998). As a result, further expansion into monetary theories has been conducted.

- **New Open-Economy Macroeconomics Models**

The New Open-Economy Macroeconomics (NOEM) framework emerged in the 1990s as a response to the limitations of traditional open-economy models, such as the Mundell-Fleming model, which lacked microeconomic foundations. NOEM integrates dynamic stochastic general equilibrium (DSGE) modeling techniques and explicitly incorporates optimizing behavior by households and firms, nominal rigidities, and imperfect competition into open-economy macroeconomic analysis (Obstfeld & Rogoff, 1995). Meese and Rogoff (1983) argue that monetary models are unable to replicate and forecast exchange rate swings, implying that monetary variables are only one of several factors driving exchange rate volatility. Thus, the literature that uses the NOEM model argues that non-monetary factors have gained importance in explaining exchange rate volatility (Mpofu, 2016).

In the context of exchange rate regimes, NOEM models provide a powerful analytical framework to evaluate the short-run and long-run implications of fixed versus flexible exchange rate systems. One of the key contributions of NOEM is its ability to assess how monetary and fiscal policies interact with international price stickiness and incomplete markets. This has direct implications for the optimal choice of exchange rate regime.

Under a flexible exchange rate regime, the NOEM framework shows that monetary policy can play a stabilizing role, especially when prices are sticky and there is limited international risk-sharing. The nominal exchange rate can adjust to external shocks, helping to smooth output and consumption volatility (Corsetti & Pesenti, 2005). This flexibility allows countries to maintain independent monetary policies, which is particularly beneficial when domestic and foreign economic cycles diverge.

Conversely, in a fixed exchange rate regime, or within a currency union, the absence of exchange rate adjustment places greater importance on fiscal transfers, wage flexibility, and financial integration to absorb shocks. NOEM models suggest that in the presence of nominal rigidities and asymmetric shocks, fixed regimes can lead to welfare losses unless supported by mechanisms such as supranational fiscal policies or strong automatic stabilizers (Devereux & Engel, 2003). Moreover, NOEM models highlight that the welfare implications of exchange rate regimes depend on deeper structural characteristics such as the degree of openness, the extent of nominal price rigidity, and the type of external shocks. For example, economies highly exposed to terms-of-trade shocks may benefit more from flexible exchange rates, which can adjust quickly to changing international prices (Obstfeld & Rogoff, 2000).

Compared to most of the more traditional models of exchange rate determination, particularly the Mundell-Fleming model, the sticky-price and FPMM, and the portfolio balance model, the NOEM seek to provide a more rigorous analytical foundation built on fully specified micro-foundations. In contrast, the fundamental advantage of more traditional models is their simpler analytical framework, which makes them easier to discuss and utilise in applied policy analysis. Furthermore, because the predictions of NOEM model are frequently highly sensitive to the exact specification of the micro-foundations, policy evaluation and welfare analysis are typically dependent on the

specific specification of preferences and nominal rigidities. The counterargument is that traditional models achieve analytical simplicity by making various implicit assumptions (Taylor & Frankel, 2012).

In summary, NOEM models have advanced our understanding of the macroeconomic trade-offs associated with different exchange rate regimes by embedding them in a rigorous micro-founded framework. They emphasize the role of nominal rigidities, intertemporal optimization, and international financial frictions, offering nuanced insights into the optimal design of monetary and exchange rate policies in an open economy setting.

- **Theory of Optimum Currency Areas**

The theory of the Optimum Currency Area (OCA), developed by Robert Mundell (1961), provides a framework for determining the most efficient geographical regions for adopting a common currency or fixed exchange rate system. According to the theory, a group of countries can benefit from sharing a currency or fixing their exchange rates if they meet certain criteria that minimize the costs of losing independent monetary policy and exchange rate flexibility.

The key criteria identified in the OCA theory include labor mobility, capital mobility, price and wage flexibility, fiscal integration, and similarity in business cycles (Mundell, 1961; McKinnon, 1963; Kenen, 1969). If these conditions are satisfied, countries can respond to asymmetric shocks through mechanisms other than exchange rate adjustments, making a fixed exchange rate or a currency union more optimal.

In the context of exchange rate regimes, the OCA theory suggests that economies closely linked through trade and economic activity are better candidates for fixed exchange rate arrangements. Conversely, countries that do not meet the OCA criteria are more likely to benefit from flexible exchange rates, as these allow for independent monetary policy to address country-specific economic disturbances (Frankel & Rose, 1998).

One of the key insights from OCA theory is that countries that are highly economically integrated through trade, investment, labour mobility, and similar business cycles are more likely to benefit from a shared currency. If these conditions are met, then the costs of giving up independent monetary policy and a flexible exchange rate are relatively small (De Grauwe, 2018).

On the other hand, if countries are very different economically and experience asymmetric shocks where one economy might boom while another slump then having a common currency could be problematic. In such cases, a flexible exchange rate would usually act as a stabilizer, helping to absorb economic shocks by adjusting the relative prices of goods and services across countries (Krugman & Obstfeld, 2009). When a common currency is adopted, this mechanism disappears, potentially worsening the impact of such shocks.

The adoption of a common currency, such as the euro, has been a practical application of the OCA theory. However, the European debt crisis revealed the limitations of the OCA framework when some member states lacked sufficient economic convergence, highlighting the challenges of rigid exchange rates without full fiscal and political union (De Grauwe, 2018). A real-world example of this is the Eurozone, which adopted the euro as a single currency. Some member states, like Germany, have strong economies, while others, such as Greece or Italy, have faced severe economic downturns. Because they share a currency, they can't devalue to regain competitiveness or adjust interest rates independently. Critics argue that the Eurozone lacks some key OCA characteristics, such as full labour mobility and fiscal integration, making it vulnerable to these kinds of challenges (De Grauwe, 2018). Therefore, the OCA theory remains a foundational model for evaluating the trade-offs associated with different exchange rate regimes. It underscores the importance of economic integration and flexibility in determining the feasibility and desirability of fixed versus floating exchange rate systems.

2.3 Empirical Literature Review

Exchange rate volatility is influenced by a broad range of macroeconomic and financial factors, but the magnitude and direction of these influences vary depending on the country's economic context, the period analysed, and the methodological approach used. Trade openness, for instance, is frequently cited as a key determinant. Frankel and Rose (1996) argue that greater trade openness can reduce exchange rate volatility by anchoring currency values more closely to trade fundamentals, thereby stabilizing exchange rates. However, Baillie and Osterberg (1997) present contrasting findings, noting that in some emerging economies, increased openness heightens exposure to external shocks, leading to greater volatility. Mpofu (2016), focusing on South Africa, similarly found that trade openness reduces rand volatility only under certain exchange rate measurements, highlighting the complexity of its effects in specific country contexts. These contrasting findings highlight that trade openness has complex and varied effects on exchange rate volatility depending on the specific economic context and measurement approach.

Capital flows also play a significant role in exchange rate dynamics. Flood and Rose (1995) observe that volatile capital movements often exacerbate currency fluctuations in emerging markets, whereas Goldberg (1998) notes that in advanced economies with developed financial markets, capital mobility can actually mitigate volatility by enabling smoother adjustments. Aigheyisi (2021) supports this view by showing that increased net capital flows and deeper financial integration help reduce exchange rate volatility in Nigeria, while external debt and monetary expansion contribute to greater instability. Ghauri et al. (2024) further emphasize that debt levels and political stability are critical drivers of currency fluctuations, affecting economic sustainability. The differing impacts of capital flow underlines the importance of a country's financial market maturity and institutional environment in shaping exchange rate stability.

Economic growth rates influence exchange rate stability as well. Rodrik (2000) documents that unstable or rapid growth can increase volatility due to shifting investor expectations and macroeconomic imbalances, while Edwards (1989) finds stable growth associated with steadier exchange rates. Studies such as Hussaini et al. (2018) confirm these patterns in West African countries, revealing a negative relationship between real exchange rate volatility and GDP growth. Naderi et al. (2020) also highlight GDP per capita as a major factor affecting exchange rate volatility in Iran,

while Dewing (2017) identifies economic growth as a relatively minor but significant contributor to rand volatility in South Africa. Together, these studies demonstrate that while economic growth influences exchange rate volatility, its effects depend on the stability and pace of growth within the country.

Financial development tends to mitigate exchange rate volatility by improving market depth and risk-sharing mechanisms. Chinn and Ito (2006) find that countries with sophisticated financial markets generally experience lower exchange rate fluctuations. However, Reinhart and Rogoff (2004) caution that the benefits depend heavily on institutional quality and regulatory frameworks. Ahmed and Suliman (2018) and Rashid and Basit (2021) also show that financial market volatility, such as that in foreign reserves or government spending, can differently impact exchange rate volatility across countries, underscoring the importance of local institutional environments. The evidence shows that financial development's role in reducing volatility is contingent on the quality of institutions and regulatory frameworks.

Foreign reserves serve as a crucial buffer against exchange rate volatility. Ben-Bassat and Gottlieb (1992) demonstrate that abundant reserves empower central banks to intervene effectively and stabilize currency movements. Ramli (2020) confirms this negative relationship between reserve assets and exchange rate volatility in Indonesia. Conversely, Broner et al. (2013) and Aigheyisi (2021) find that high external debt levels increase currency risk and volatility, a dynamic also emphasized by Ghauri et al. (2024) who identify debt as a key driver of exchange rate fluctuations. The stabilizing influence of foreign reserves contrasts with the destabilizing effect of high external debt, emphasizing the need for prudent fiscal management.

Exchange rate regimes significantly influence volatility patterns. Obstfeld and Rogoff (1995) show that fixed regimes typically experience less short-term volatility but are vulnerable to sudden crises, while floating regimes allow more flexible but often more volatile exchange rates. Mpofu's (2016) research indicates that South Africa's switch to a floating regime led to increased rand volatility, aligning with this global observation. The trade-offs inherent in different exchange rate regimes reflect global trends and suggest that regime choice must therefore, be supported by sound macroeconomic policies.

Beyond these factors, several studies have contributed country-specific insights. Bodiwala and Trivedi (2016) identify government debt and unemployment as significant predictors of the Indian Rupee–US Dollar exchange rate, while Kilicarslan (2018) finds that domestic investment, money supply, and trade openness positively affect Turkey’s real exchange rate volatility. Odoo (2019) demonstrates that inflation positively influences Ghana’s exchange rate volatility, while interest rates and money supply reduce it. Nyandoro (2020) shows that inflation and interest rates explain volatility differently across Southern African countries, highlighting regional heterogeneity. Country-specific studies reveal that determinants of exchange rate volatility are highly context-dependent, necessitating tailored approaches to analysis and policy.

Anjelo et al. (2022) note that terms of trade, export concentration, and export prices significantly impact exchange rate volatility, while financial factors like interest rate differentials influence sudden large movements. Umoru et al. (2023) analyze seven African countries and find that inflation, income differentials, productivity growth, money supply, and oil price shocks variably explain volatility, depending on each country’s specific conditions. Aysun (2024) adds a macro-financial perspective, emphasizing the dominant role of external financial shocks in driving exchange rate fluctuations in small open economies. The range of factors influencing volatility in various African economies underscores the interplay of internal fundamentals and external shocks in shaping exchange rate behavior.

Despite the rich array of findings globally, the literature specifically addressing the origins and causes of exchange rate volatility in South Africa remains relatively sparse. Mpofu (2016) and Dewing (2017) provide valuable insights but also illustrate the complexity and context-specific nature of the drivers involved, shaped by South Africa’s status as an emerging, commodity-dependent economy with structural vulnerabilities and evolving institutional frameworks (Ncube & Ndou, 2023; Mensah & Ofori, 2021; Okoro & Adebayo, 2022). This underscores the need for further empirical research tailored to South Africa’s unique economic environment. Overall, these insights affirm that exchange rate volatility results from a complex mix of factors whose relative importance varies across contexts, making customized policy responses essential for South Africa’s economic stability.

2.4 Assessment of Literature Reviewed

Empirical research has identified several variables relevant to understanding exchange rate volatility, many of which may need to be incorporated into the present investigation. For instance, Ramli (2020) established a link between exchange rate volatility and productivity, while Rashid and Basit (2021) found that factors such as foreign reserves, government spending, industrial production, gold prices, and terms of trade influence real exchange rate volatility in several Asian economies, including Bangladesh, China, India, Indonesia, Malaysia, and Pakistan.

In the South African context, empirical studies on the causes of exchange rate volatility are limited, with notable contributions from Dewing (2017) and Mpofu (2016), though their findings diverge. Mpofu's research suggests that trade openness, output volatility, commodity prices, money supply, and foreign reserves significantly affect exchange rate volatility. By contrast, Dewing (2017) identified interest rate differentials, inflation rate differentials, economic growth, trade openness, money supply, and government spending as key determinants. While Rauff (2022) highlights inflation and interest rates as the primary drivers of exchange rates in Nigeria, Mpofu (2016) presents mixed evidence for South Africa, showing that trade openness reduces ZAR volatility when bilateral exchange rates are considered but increases volatility when using multilateral exchange rates. Mpofu also found significant effects from output volatility, commodity prices, money supply, and foreign reserves. Despite some overlap in identified determinants, discrepancies remain, particularly regarding the role of trade openness, Mpofu (2022) finds it highly significant, while Dewing (2017) considers it insignificant. This lack of consensus underscores the need for further investigation in the South African context, with the present study aiming to contribute to and deepen the existing body of literature.

2.5 Chapter Summary

The literature on exchange rate volatility demonstrates a lack of consensus regarding its macroeconomic determinants, reflecting the complexity and multifaceted nature of currency fluctuations. This divergence is largely attributable to the various theoretical frameworks employed to explain exchange rate dynamics. Some studies rely on specific exchange rate level models, such as purchasing power parity or monetary

models, to identify the sources of volatility, whereas others adopt a more integrative approach, synthesizing multiple exchange rate models to capture broader determinants. Consequently, the findings on the effects of macroeconomic variables, including interest rates, inflation, GDP, oil prices, and trade openness, often differ depending on the theoretical assumptions and analytical techniques used.

From the theoretical perspective, the relationship between exchange rate volatility and its determinants is not unidirectional. Certain variables may exert a positive effect, amplifying volatility, while others may have a stabilizing or negative impact, depending on the structural characteristics of the economy under consideration. For instance, trade openness can either reduce volatility by promoting liquidity and risk-sharing, or increase it if the economy is heavily exposed to external shocks. Similarly, oil price fluctuations may lead to pronounced volatility in economies reliant on energy imports or exports, while inflation and interest rate differentials can have varying effects depending on monetary policy credibility and market expectations.

Empirical evidence further highlights the context-specific nature of these relationships. Studies in emerging markets, including South Africa, show that the impact of macroeconomic determinants on exchange rate volatility may vary not only across countries but also across time periods, reflecting the influence of economic crises, structural breaks, and policy interventions. Therefore, it is difficult to draw definitive conclusions a priori regarding the direction or magnitude of these effects. Instead, the relationship between exchange rate volatility and its determinants is essentially an empirical question, dependent on the choice of methodology, the frequency and period of data, and the specific institutional and economic characteristics of the country studied.

In summary, literature underscores the need for rigorous, context-sensitive empirical analysis to clarify the determinants of exchange rate volatility. This chapter highlights the gaps and inconsistencies in prior research, demonstrating the relevance of the current study, which employs a nonlinear approach to capture asymmetric effects and address the limitations of existing studies in the South African context. By doing so, the study seeks to provide more robust evidence on the dynamics of exchange rate volatility and offer insights that are directly applicable to policy design and economic stability.

Chapter Three: Research Methodology

3.1. Introduction

This chapter provides a discussion on research methodology. The chapter is structured as follows: Section 3.2 presents the theoretical framework, outlining the theoretical model that underpins the study. In Section 3.3, the empirical model is presented. Sections 3.4 and 3.5 discuss estimation techniques (the econometric tools employed to estimate the model) and data issues. Finally, Section 3.6 presents a summary of the chapter.

3.2. Theoretical Framework

The NOEM model forms the basis of the study. The model is appropriate for analysing South Africa's economic openness and the volatility of exchange rate fundamentals because the country serves as a good case study following the 1995 capital account liberalisation, which resulted in trade openness. Furthermore, unlike models that rely barely on monetary or optimal currency areas to determine exchange rates, this model stresses the importance of both monetary and non-monetary variables in explaining exchange rate volatility.

Monetary models cannot reproduce or forecast exchange rate swings, showing that monetary variables are only one of multiple factors influencing exchange rate volatility. Thus, the literature based on the NOEM model contends that non-monetary factors have acquired importance in explaining exchange rate volatility (Mpofu, 2016).

3.3 The Empirical Model

The study follows Ilu's (2020) model in using the nonlinear autoregressive distributed lag (NARDL) model. Given the tendency of the presence of asymmetries and other stylised effects in the series, Shin et al (2011) proposed the NARDL as an extension of the conventional ARDL model to capture the long-run impact of positive and negative effects of the independent variables on the dependent variable in a relationship.

Therefore, this facilitates the examination of the positive and negative effects of the explanatory variable, where the short-run and long-run nonlinearities are introduced through positive and negative partial sum decomposition of the explanatory variable. The NARDL approach helps solve the issue of non-normality arising due to outliers by capturing the asymmetries in the speed of adjustment.

The cointegration testing or the bounds test procedure, as well, is the same as that of a linear ARDL model, where the calculated F Statistic is contrasted against I (0) and I (1) critical values. F-test for joint significance of lagged variables, also known as a bound test. The criterion/rule of thumb for acceptance or rejection of H0 is that if the F-statistic is below the lower bound, the null hypothesis of no long-run relationship cannot be rejected while if, the F-statistic that is greater than the upper bound means that the null hypothesis can be rejected, signifying the existence of a long-run relationship. However, if the F-statistic falls between the lower and upper bounds, the result is said to be inconclusive (Ilu, 2020).

A NARDL $(p, q)^4$ model proposed by Shin et al. (2014) is written as:

$$y_t = \sum_{j=1}^p \phi_j y_{t-j} + \sum_{j=0}^q (\theta_j^{+'} x_{t-j}^{+} + \theta_j^{-'} x_{t-j}^{-} + \varepsilon_t \dots \dots \dots (3.1)$$

Where x_t is a $k \times 1$ vector of multiple regressors and $x_t = x_0 + x_t^{+} + x_t^{-}$, ϕ_j is the autoregressive parameter θ_j^{+} and θ_j^{-} are the asymmetrically distributed lag parameters, ε_t is the error term with zero mean and constant variance. The NARDL model can be estimated by the Ordinary Least Squares (OLS) estimation method since it is linear in all parameters.

The conditional nonlinear error correction form of the NARDL (p, q) model is as follows:

$$\Delta y_t = \rho \xi_{t-1} + \sum_{j=1}^{p-1} \gamma_j \Delta y_{t-j} + \sum_{j=0}^{q-1} \pi_j^{+} \Delta x_{t-j}^{+} + \pi_j^{-} \Delta x_{t-j}^{-} + \varepsilon_t \dots \dots \dots (3.2)$$

Where ξ_t is the nonlinear error correction term.

$$\xi_t = y_t - \beta^{+} x_t^{+} + \beta^{-} x_t^{-}$$

Where β^{+} and β^{-} are the asymmetric long-run parameters and $\beta^{+} = \theta^{+} / \rho$, $\beta^{-} = \theta^{-} / \rho$

The Wald test is used to test both the short- and long-run symmetries. The null hypothesis of the long-run symmetry is $\beta^{+} = \beta^{-}$ that of the short-run symmetry is:

$$\sum_{i=0}^{q-1} \pi_i^+ = \sum_{i=0}^{q-1} \pi_i^- \text{ or } \pi_i^+ = \pi_i^-, i = 1, \dots, q-1 \dots\dots\dots (3.3)$$

Shin et al. (2014) derived the cumulative asymmetric dynamic multiplier effects of a unit change in x_t^+ and x_t^- on y_t as follows:

$$m_h^+ = \sum_{j=0}^h \frac{\delta y_{t+j}}{\delta x_t^+} = \sum_{j=0}^h \frac{\delta y_{t+j}}{\delta x_t^-} \dots\dots\dots (3.4)$$

$h \rightarrow \infty, m_h^+ \rightarrow \beta^+$ and $m_h^- \rightarrow \beta^-$. β^+ and β^- are the asymmetric long-run coefficients.

The NARDL model has some significant advantages over existing methodological approaches. It allows the joint modelling of asymmetries and cointegration dynamics and can be estimated readily. It can also determine cointegrating relationships efficiently in small samples. The NARDL does not require that all the regressors with the same order of integration; in other words, it allows for the inclusion of $I(0)$ and $I(1)$ (but not $I(2)$) regressors (Rezitis, 2019; Karaoğlu & Demirel, 2021).

The empirical model of exchange rate volatility in time t is stated as follows:

$$ERV_t = f(TOPEN, OPRICE, INF_t, INT_t, GDP_t) \dots\dots\dots (3.5)$$

Where ERV_t represent exchange rate volatility, $TOPEN_t$ is a proxy for trade openness, $OPRICE_t$ represents oil price. INF_t is a proxy for the inflation rate, INT_t is a proxy for the interest rate, and GDP_t .

To test the asymmetric assumption, the NARDL model (which is, an asymmetric expansion of the linear ARDL model) is used. The model allows the decomposition of the independent variables into both positive and negative partial sums of processes to investigate the nonlinear characteristics.

$$\begin{aligned} \Delta EXR_t = & \alpha_0 + \partial_1 EXR_{t-1} + \partial_2 GDP_{t-1} + \partial_3 INFR_{t-1} + \partial_4 INTR_{t-1} + \partial_5 OP_{t-1} + \\ & \sum_{i=0}^n \beta_1 \Delta EXR_{t-1} + \sum_{i=0}^n \beta_2 \Delta GDP_{t-1} + \sum_{i=0}^n \beta_3 \Delta INFR_{t-1} + \sum_{i=0}^n \beta_4 \Delta INTR_{t-1} + \\ & \sum_{i=0}^n \beta_5 \Delta OP_{t-1} + \varepsilon_t - \dots\dots\dots \end{aligned} \quad (3.6)$$

If the impact of the explanatory variables on the dependent variable has the same magnitude of changes in the two cases (positive and negative), the relationship is symmetric. However, if the impact has a different magnitude of changes, the relationship is asymmetric. The NARDL model denotes the positive partial sum of changes in X by X^+ and the negative partial sum of changes in X by X^- .

The asymmetric error-correction form of our empirical model, as proposed by Pesaran et al. (2001) and Shin et al. (2014), is as follows:

$$\begin{aligned} \Delta ERV_t = & \alpha_0 + \sum_{i=1}^p \alpha_1 \Delta ERV_{t-i} + \sum_{i=0}^q \alpha_{21} \Delta TOPEN_{t-i}^+ + \sum_{i=0}^q \alpha_{22} \Delta TOPEN_{t-i}^- + \\ & \sum_{i=0}^q \alpha_{31} \Delta OPRICE_{t-i}^+ + \sum_{i=0}^q \alpha_{32} \Delta OPRICE_{t-i}^- + \sum_{i=0}^q \alpha_{41} \Delta INF_{t-i}^+ + \sum_{i=0}^q \alpha_{42} \Delta INF_{t-i}^- + \\ & \sum_{i=0}^q \alpha_{41} \Delta INT_{t-i}^+ + \sum_{i=0}^q \alpha_{42} \Delta INT_{t-i}^- + \sum_{i=0}^q \alpha_{41} \Delta GDP_{t-i}^+ + \sum_{i=0}^q \alpha_{42} \Delta GDP_{t-i}^- + \\ & (\varphi_{11}^+ \Delta ERV_{t-1}^+ + \varphi_{12}^- \Delta ERV_{t-1}^-) + (\varphi_{21}^+ \Delta TOPEN_{t-1}^+ + \varphi_{22}^- \Delta TOPEN_{t-1}^-) + \\ & (\varphi_{31}^+ \Delta OPRICE_{t-1}^+ + \varphi_{32}^- \Delta OPRICE_{t-1}^- + \sum_{i=0}^q \alpha_{41} \Delta INF_{t-i}^+ + \sum_{i=0}^q \alpha_{42} \Delta INF_{t-i}^- + \\ & \sum_{i=0}^q \alpha_{41} \Delta INT_{t-i}^+ + \sum_{i=0}^q \alpha_{42} \Delta INT_{t-i}^-) + \rho y_{t-1} + \mu_t \dots \dots \dots (3.7) \end{aligned}$$

The short and long-run asymmetry can be detected using the Wald test. A Wald F-statistic assumes the hypothesis test of joint significance where:

$$\left\{ \begin{array}{l} H_0: \rho = \varphi_{11}^- = \varphi_{12}^+ = \varphi_{21}^- = \varphi_{22}^+ = \varphi_{31}^+ = \varphi_{32}^- = 0 \Rightarrow \text{non cointegration} \\ H_\alpha: \rho = \varphi_{11}^- = \varphi_{12}^+ = \varphi_{21}^- = \varphi_{22}^+ = \varphi_{31}^+ = \varphi_{32}^- \neq 0 \end{array} \right\}$$

If the F-statistic is greater than the critical values (Pesaran et al., 2001), the decision is the rejection of the null hypothesis and this means that a long-run relationship can exist.

$$\left\{ \begin{array}{l} H_0 = \rho = 0 \\ H_\alpha \neq \rho < 0. \end{array} \right\}$$

According to Banerjee et al. (1998), if the null hypothesis is rejected the long-run relationship can exist in the presence of an asymmetric effect.

Wald proposed a hypothesis test for the symmetric or asymmetric effect as follows:

We calculate the coefficient of long-run asymmetry:

$$\left\{ \begin{array}{l} \frac{-\varphi_{12}^+ = L_{M_1}^+}{\rho} \\ \frac{-\varphi_{22}^- = L_{M_1}^-}{\rho} \end{array} \right\}$$

The hypothesis test for the long-run effect is:

$$\left\{ \begin{array}{l} H_0: \frac{-\varphi_{11}^+}{\rho} = \frac{-\varphi_{12}^-}{\rho} \Rightarrow \text{symmetric effect of } TOPEN_{t-1} \text{ on } ERV_t \text{ in long run} \\ H_\alpha: \frac{-\varphi_{11}^+}{\rho} \neq \frac{-\varphi_{12}^-}{\rho} \Rightarrow \text{asymmetric effect of } TOPEN_{t-1} \text{ on } ERV_t \text{ in long run} \end{array} \right\}$$

The hypothesis test for the short-run effect is:

$$\left\{ \begin{array}{l} H_0: \frac{-\alpha_{21}^+}{\alpha_1} = \frac{-\alpha_{22}^-}{\alpha_1} \Rightarrow \text{symmetric effect of } TOPEN_{t-1} \text{ on } ERV_t \text{ in short run} \\ H_a: \frac{-\alpha_{21}^+}{\alpha_1} \neq \frac{-\alpha_{22}^-}{\alpha_1} \Rightarrow \text{asymmetric effect of } TOPEN_{t-1} \text{ on } ERV_t \text{ in short run} \end{array} \right\}$$

The same hypothesis test goes for the short and long-run effects of oil price, inflation, interest rate, and GDP, on exchange rate volatility.

A Priori Assumption

- **Exchange rate volatility and trade openness**

There are several studies that suggest that there is an interlink between greater openness of economies and higher exchange rate stability; hence, there is a certain relationship between them. The empirical analysis finds that overall trade openness helps attenuate the effects of volatile fluctuations in RER fundamentals, whereas financial openness amplifies shocks to the RER, as our results show a robust negative (positive) relationship between trade openness (financial openness) and RER volatility. Our finding that greater international trade integration lowers RER volatility is consistent with theoretical models (Obstfeld & Rogoff, 1995; Hau, 2000; Calderon & Kubota, 2018).

- **Exchange rate volatility and oil price**

The exchange rate appreciates in response to rising oil prices and depreciates in response to falling oil prices in oil-exporting countries, while the opposite is expected to be the case in oil-importing countries (Krugman 1983; Ogundipe, Ojeaga & Ogundipe 2014).

An a priori assumption often made in the literature is that fluctuations in global oil prices can significantly influence the volatility of exchange rates, particularly in oil-exporting and oil-importing countries. In oil-exporting countries, increases in oil prices are expected to strengthen the domestic currency due to improved trade balances and increased foreign exchange inflows, potentially leading to reduced exchange rate volatility. Conversely, in oil-importing nations, rising oil prices can worsen trade balances, weaken the currency, and heighten exchange rate fluctuations. This

theoretical link is grounded in the notion that oil price shocks act as a major external macroeconomic disturbance affecting currency markets (Chen & Chen, 2007).

- **Exchange rate volatility and GDP**

Exchange rate volatility is one of the most noteworthy indicators of economic growth, and global trade and economic integration have been approved as important catalysts that accelerate a country's economic growth (Niyonsaba, 2023). According to Ozata (2020), the review of literature on the impact of exchange rate volatility on economic growth provides mixed results. The impact differs between developed and developing countries. To ensure sustainable economic growth, it is necessary to strengthen the fiscal and financial structure and reduce the volatility in exchange rates.

Exchange rate stability is the main source of economic growth, and it is important that monetary authorities and governments of the countries should pay attention to exchange rates by adopting an exchange rate policy that leads to stable exchange rates (Morina, Hysa, Ergün, Panait, & Voica, 2020). In a cross-section, ordinary least squares (OLS) study a negative relationship between real exchange rate volatility and countries' economic growth (Cottani, Cavallo & Khan, 1990). In the same paper quoted before, Dollar (1992) shows a negative relationship through a cross-section regression between rates of growth and exchange rate volatility in a large sample of countries.

Rapetti (2020) studied the rates of growth of the Organisation for Economic Co-operation and Development (OECD) countries and the developing countries and finds evidence of the negative effect of real exchange rate volatility on growth. This evidence is stronger for developing countries, and he also finds that real exchange rate volatility has been particularly detrimental for developing countries during the period of financial globalisation

Nevertheless, the impact of fiscal policy on growth can be influenced by exchange rate movements. For instance, a depreciation of the domestic currency may increase import prices and potentially dampen the positive effects of fiscal stimulus on growth (Obstfeld, 1985). In summary, according to the Mundell-Fleming model, exchange rate fluctuations can impact economic growth through their effects on trade balances, capital flows, and the interaction with fiscal policy (Mussa, 1986). The specific

outcomes depend on the nature and direction of exchange rate movements and the underlying economic conditions in the country (Krugman, 1986).

- **Exchange rate volatility and interest rate**

There has been growing interest in assessing the relationship between interest rates and exchange rates in both advanced and developing economies in recent years. This is attributable to the important role these variables play in determining developments in the nominal and real sides of the economy, including the behaviour of domestic inflation, real output, exports and imports (Sánchez, 2005). The subject of exchange rate volatility and interest rate is even more critical due to globalization; countries intermingle with each other through trade and investment (Suranovic, 2012). In the Mundell-Fleming model, a rise in domestic interest rates related to those in foreign countries resulting from the appreciation of the exchange rate can attract capital inflows (Dornbusch, 1976).

- **Exchange rate volatility and inflation rate**

The relatively high rand volatility may have an implication for inflation. While the passthrough of exchange rate appreciation and depreciation to inflation has declined due partly to increased central bank credibility, exchange rate volatility, often considered as an indicator of uncertainty could still increase risk premia and inflation. Across major emerging markets, higher exchange rate volatility increases risk premia and local currency sovereign bond yields (Gadanecz et al, 2018). In South Africa, global uncertainty shocks could depreciate the rand and increase inflation (Mumtaz and Theodoridis, 2015). Uncertainty shocks could also be inflationary due to precautionary increases in prices by firms (Redl, 2015).

Specification of Variables and Sources of Data

- **Exchange Rate Volatility**

Exchange rate volatility is a measure of the fluctuations in an exchange rate. It is also known as a measure of risk, whether in asset pricing, portfolio optimization, option pricing, or risk management and presents a careful example of risk measurement, which could be the input to various economic decisions. It can be measured hourly,

daily, weekly, monthly, or annually. Based on the assumption that changes in an exchange rate follow a normal distribution, volatility provides an idea of how much the exchange rate can change within a given period.

The volatility of an exchange rate, just like that of other financial assets, is usually calculated from the standard deviation of movements of exchange rates. It is an unobservable variable and, thus, its measure is a matter of serious contention. Consequently, the literature is not unanimous regarding the most appropriate measure. Recent literature, however, seems to be increasingly adopting the use of Bollerslev's (GARCH) models.

Volatility refers to the spread of all likely outcomes of an uncertain variable. Typically, in financial markets, we are often concerned with the spread of asset returns. Volatility is related to, but not the same as, risk. Risk is associated with an undesirable outcome, whereas volatility as a measure strictly for uncertainty could be due to a positive outcome (Poon, 2005).

- **Real Gross Domestic Product**

Real GDP is an inflation-adjusted measure that reflects the value of all goods and services produced by an economy in a given year, expressed in base-year prices, and is often referred to as "constant-price" or "inflation-corrected". The RGDP is also used as a proxy for economic growth which can be a positive or a negative number given the prevailing economic realities at any different time. Data for RGDP was sourced from the World Bank.

- **Inflation Rate**

Inflation is defined as the persistent and sustained rise in the general price level which leads to a fall in the value of money. During inflation, large amounts of money purchase fewer bundles of goods and services, which affects the purchasing power of money in an economy. The data on the inflation rate was also obtained from the World Bank.

- **Interest Rate**

Interest rates are also referred to as the monetary policy rate (MPR). The data on interest rates are also obtained from the World Bank database.

- **Oil Price**

Oil prices are determined by global oil trade deals mostly traded on a futures contract. Forces of demand and supply and market sentiments are the major determinants of oil prices, however, organizations and institutions like the OPEC and the American government can considerably influence oil prices.

- **Trade Openness**

Trade Openness is the sum of imports and exports normalized by GDP (Alotaibi & Mishra, 2014). Trade openness is defined as the ratio of exports plus imports over GDP (Global Imbalances, Financial Crises, and Central Bank Policies, 2016). With trade openness, researchers usually measure the degree to which countries are open to international trade with their imports and exports (Fatima, et al., 2020).

3.4 Estimation Techniques

3.4.1 Introduction

This study employed the nonlinear autoregressive distributed lag (NARDL) bounds cointegration technique to ascertain the long-run relationships and short-run dynamics between nonlinear and asymmetric exchange rate volatility determinants. Before discussing the different tests, a discussion on the descriptive statistics is given.

3.4.2 Descriptive Statistics

Descriptive statistics summarises the sample being studied without drawing any inferences based on probability theory. Even if the primary aim of a study involves inferential statistics, descriptive statistics are still used to give a general summary. When describing the population using tools such as frequency distribution tables, percentages, and other measures of central tendency, like the mean, we are talking about descriptive statistics.

Descriptive statistics can help in summarising data in the form of simple quantitative measures, such as percentages or means, or in the form of visual summaries such as histograms and box plots. They can be used to describe a single variable (univariate analysis) or more than one variable (bivariate/multivariate analysis). In the case of more than one variable, descriptive statistics can help summarize relationships between variables using tools such as scatter plots (Kaliyadan & Kulkarni, 2019).

3.4.3 Stationarity testing

The initial step in conducting a cointegration analysis entails evaluating each time series to determine its degree of integration through stationarity testing. The rationale behind autoregressive moving average (ARMA) estimation relies on time series that demonstrate stationarity. Stationarity is defined as a condition where the average and auto-covariance of the series remain constant over time (Kwiatkowski et al. 1992). An instance of a non-stationary series is exemplified by the random walk equation:

$$\beta_t = \beta_{t-1} + \mu_t \dots\dots\dots (3.8)$$

Where, μ_t is a stationary random disturbance term. The series β has a constant forecast value, conditional on t , and the variance increases over time. The random walk is a differenced stationary series since the first difference of y is stationary.

$$\beta_t - \beta_{t-1} = (1 - L)y_t = \mu_t \dots\dots\dots (3.9)$$

A series that remains the same over time is referred to as an integrated series and is represented by (d). The value indicates the level of integration. Integration level refers to the number of original elements present in the series, or the number of operations required to make the series stable. As an example, in the given random walk, there is one original element, making it a series $I(1)$. Similarly, a series that is stable is considered stationary $I(0)$.

When conducting regressions with a dependent variable or regressors that are integrated, standard inference procedures cannot be applied. Therefore, it is crucial to determine the stationarity of a series before using it in a regression. The unit root test is a formal method used to test the stationarity of a series.

Various tests are employed to assess the presence of a unit root. These examinations include the Augmented Dickey-Fuller (1979) and Phillips-Perron (1988) tests, the GLS-detrended Dickey-Fuller (Elliot, Rothenberg, & Stock, 1996) test, Kwiatkowski, Phillips, Schmidt, and Shin (KPSS, 1992) test, Elliott, Rothenberg, and Stock Point Optimal (1996) test, and Ng and Perron (NP, 2001) test for unit root. In this research, the Augmented Dickey-Fuller (ADF) and Phillips-Perron tests are utilised. The ADF test is widely employed for evaluating the null hypothesis of a unit root (Guney & Komba, 2016).

3.4.3.1 The Augmented Dickey-Fuller Test

The Augmented Dickey-Fuller (ADF) technique was formulated by David Dickey and Wayne Fuller in 1979. This technique entails a regression analysis that involves examining the first difference of a variable on its lagged level, along with additional lags of the first difference (Gujarati & Porter, 2009). When employing the ADF technique, the null hypothesis suggests that the time series possesses a unit root, thus requiring further differentiation to attain stationarity. Conversely, the alternative hypothesis suggests that the series is stationary. Thus, eliminating the necessity for additional differentiation.

According to Gujarati & Porter (2009), the ADF unit root test is used to check the stationarity of the variables. Suppose one determines that Y and X are not stationary in level forms following the random walks but become stationary at first difference ΔY_t and ΔX_t respectively.

$$\beta_t = \beta_t - 1 + t + ut \dots\dots\dots (3.10)$$

Serial correlation presents a problem. To account for this, the augmented Dickey-Fuller tests of the model include lags of the first differences of β_t . The present research employs the ADF model to conduct the unit root test, wherein the equation utilized is as follows:

$$\Delta Y_{t=\mu+\beta t+eY_{t-1}+\sum_{t-1}^N p_t \Delta Y_{t-1}+e_t} \dots\dots\dots (3.11)$$

Where:

Y_t = time-series tested

t = time trend variable

Δ = the first difference operator

N = Number of lags which are added to the model to ensure that there are residuals

e_t = white noise disturbance

Therefore, the ADF test focuses on estimating the parameter in equation (3.1). To ascertain the degree of integration in non-stationary time series data, the unit root test is employed. The hypotheses for the unit root test are presented as follows:

H_0 = All variables are not stationary

H_1 = All variables are stationary

Hence, if the t-statistic exceeds the critical value, the null hypothesis (H_0) is rejected, indicating that the time series is stationary, and there is no presence of a unit root. Conversely, if the t-statistic is below the critical value, the null hypothesis (H_0) is not rejected, signifying that the time series is non-stationary, and a unit root is present.

3.4.3.2 Phillip- Perron Test

As per Gujarati & Porter (2009), the Phillips–Perron (PP) test (1988) assesses whether a variable possesses a unit root. The null hypothesis suggests that the variable contains a unit root, while the alternative hypothesis suggests that the variable is stationary. PP employs Newey–West (1987) standard errors to adjust for serial correlation. PP's test statistics can be considered as Dickey–Fuller statistics made robust to serial correlation by utilising the Newey–West (1987) heteroscedasticity- and autocorrelation-consistent covariance matrix estimator.

3.4.3.3 Zivot-Andrews Structural Breaks test

Zivot and Andrews's 1992 endogenous structural break test is a sequential procedure that utilises the entire sample and employs distinct dummy variables for each potential break date. The break date is determined where the t-statistic (for α) from the ADF test of unit root attains a minimum (most negative or significant). This break date indicates strong evidence against the null hypothesis of a unit root (Nilsson, 2009). The critical values of Zivot and Andrews (1992) differ from those of Perron (1989) due

to the selection of the break time being treated as the outcome of an estimation procedure, rather than predetermined exogenously (Glynn et al., 2007).

In the Zivot and Andrews test, if the null hypothesis of the unit root cannot be rejected, the results may not be entirely reliable. Testing the unit root hypothesis while allowing for structural breaks offers the advantage of preventing the test outcomes from being biased towards the unit root and identifies the occurrence of any potential breaks (Nilsson, 2009).

The Zivot-Andrews's approach offers a higher level of generality as it permits shifts in the level of the series (Fahmi et al., 2019). Within this framework, the choice of the breakpoint (TB) is selected to minimise the one-tailed t-statistic. The Zivot-Andrews model can detect and accommodate one endogenous structural break within a series, as detailed below. Model A allows a one-time change in the intercept of the series:

$$y_t = \mu + \epsilon y_{t-1} + \beta_t + \theta DU_t + \sum_{p-1}^n c - p + y_{t-p} + e_t \dots \dots \dots (3.12)$$

where: DU_t represents the intercept dummy $DU_t = 1$, if $(t > TB)$ breakpoint and zero otherwise.

Model B allows a one-time change in the slope of the series:

$$y_t = \mu + \epsilon y_{t-1} + \beta_t + \gamma DT_t + \sum_{p-1}^n c - p + y_{t-p} + e_t \dots \dots \dots (3.13)$$

DT represents the slope dummy $DT_t = t - TB$, when $t > TB$ (breakpoint) and zero otherwise.

Model C allows a one-time change in both the slope and intercept of the trend function of the series:

$$y_t = \mu + \epsilon y_{t-1} + \beta_t + \theta DU_t y + DT_t + \sum_{p-1}^n c - p + y_{t-p} + e_t \dots \dots \dots (3.14)$$

Therefore, the present study employs the Zivot & Andrews (1992) test to check for unit roots, allowing for one endogenously determined structural break.

3.4.4 Co-Integration Testing

The Johansen test approaches the testing for cointegration by examining the number of independent linear combinations (k) for an m time series variable set that yields a stationary process. In principle, testing for Cointegration is like testing the linear regression residuals (ϵ_t) for stationarity. Moreover, the Johansen test statistical

method is used to assess the presence of cointegration in a group of time series variables. It determines the number of independent linear combinations (k) that result in a stationary process among a set of variables. The process of testing for cointegration might be compared to the process of verifying the stationarity of linear regression residuals should first be conducted.

So, to establish a cointegration relationship, an OLS regression model for the variables is used and the residuals are tested for stationarity. Cointegration means that, while many developments can cause permanent changes in the individual variable ($X_{i,t}$), there is a long-run equilibrium relation tying the individual variables together, represented by some linear combination of them for your variables, and testing the residuals for stationarity (Gujarati & Porter, 2009).

3.4.5 The Wald Test

The Wald test is a useful statistical instrument for analysing short-run asymmetries in exchange rate pass-through (ERPT), which can aid in gaining a better understanding of how exchange rate changes influence prices and inform policy decisions (Tang & Lean, 2007).

The Wald test is a statistical test used to determine the significance of individual regression model coefficients. It can also be used to test hypotheses regarding the relevant parameters. In the context of short-run asymmetry in a regression model, the Wald test can be used to determine if certain coefficients are substantially different from zero, thereby indicating the presence of short-run asymmetry.

3.4.6 Diagnostic Tests

For this study, the diagnostic tests that will be employed are:

3.4.6.1 Breusch-Pagan Tests

In a linear regression model, a test of the null hypothesis of homoscedasticity is tested against the alternative hypothesis. The test statistic is $\eta = NR^2$, where N is the sample size and R^2 is the coefficient of determination from the second regression. Under the null hypothesis H_0 , η is asymptotically $\chi^2(s-1)$; this result does not depend on the function of h . (Black, Hashimzade, & Myles, 2009).

3.4.6.2 ARCH Test

The model is used to describe volatility clustering, that is, a pattern observed in many financial data where large and small tests errors appear to occur in clusters. It is a test of the hypothesis of homoscedasticity against an alternative of homoscedasticity, since under heteroscedasticity the ordinary least squares estimator of the covariance matrix is inconsistent. The test is performed by regressing squared OLS residuals from the main regression on all explanatory variables, their squares and cross-products, and a constant. The test statistic is given by NR^2 , where N is the sample size, and R^2 is the coefficient of determination from the test regression. Under the null hypothesis, there is an asymptotic Chi-square distribution with the degrees of freedom equal to the number of regressors in the regression, excluding the constant (Black et al,2009).

3.4.6.3. Autocorrelation Test

Autocorrelation can be defined as the relation between series of observations ordered in time Gujarati (2003). Autocorrelation is said to occur when there is an accumulation of error terms that are perfectly correlated over different periods of time. An event like this transpires when the error term that is related to the observations over a given period, in time series, is carried over into periods that are yet to be experienced (Maepa, 2015). The concerns that may arise in autocorrelation are that the OLS remains unbiased. Nevertheless, it becomes inefficient, and its standardised errors are estimated in the wrong way (Chicheke, 2009).

3.4.6.4. Heteroscedasticity Test

According to Gujarati (2003), heteroskedasticity arises if different error terms do not have identical variances, so that the diagonal elements of the covariance matrix are not identical. Thus, heteroskedasticity can be referred to as an econometric test that assumes that the variance of an error term is not constant, a condition termed homoscedasticity. If there is no constant variance in the error terms, then these error terms are said to be heteroscedastic (Sibanda, 2012). According to Gujarati (2003), if the normal testing process is taken without the heteroskedasticity test, any results or interpretations that are made from that result would be misinforming.

3.5. Data

The data for the study was obtained from secondary sources, which are the South African Reserve Bank (SARB), World Bank website and STATS SA (website), which publish official statistics; hence, the validity and reliability of the data are assumed from the data collection processes and also for their consistent purposes. This study utilises a quarterly data series covering the period from January 2015 to July 2023 to estimate the non-linear and asymmetric exchange rate pass-through to consumer prices in South Africa. The analysis of the data was conducted using STATA 17 and Eviews 12 softwares.

3.6 Chapter Summary

This chapter has discussed the methodological framework of the study, such as the model specifications and data sources. The chapter also looks at the analytical framework in which the determinants of exchange rate volatility will be investigated. The study utilised the NARDL model to determine the long-run relationships and short-run dynamics between exchange rate volatility and its determinants.

The sub-section also included the definitions of the unit root test, co-integration test, the Vector Error Correction Model (VECM), diagnostic tests, impulse response analysis and the variance decomposition of forecast errors, and finally, Granger causality was employed for the analysis of exchange rate volatility determinants in South Africa. The subsequent chapter runs the model specified in this chapter using the econometric package Eviews 12. The results of the techniques discussed above are presented in the following chapter.

Chapter Four: Presentation of Results and Discussions

4.1 Introduction

The chapter is structured as follows: sections 4.2 and 4.3 present the descriptive analysis and stationarity test results. In Sections 4.4 and 4.5, the NARDL and diagnostic test results. Section 4.6 summarises the chapter.

4.2 Descriptive statistics

A number of descriptive statistics were performed on the data. Descriptive statistics were done to assess the nature of the data. Results are shown in Table 4.1.

Table 4.1: Descriptive statistics

	OP	GDP	EXCH	TO	INF	INTER
Mean	519.09	.3264	-4.926	49.872	6.640	5.098
Maximum	1637.24	4.4	39.2	65.974	15.33	12.691
Minimum	54.9	-7.4	-18.8	34.321	-.6920	.4721
Std Dev	439.21	2.4698	11.981	8.8105	3.33658	2.705591
Skewness	.76491	-.8091	1.7561	-.06508	.7988	1.210
Kurtosis	2.8374	4.4072	6.6766	2.2146	4.043	4.114
Jarque Bera	3.353	6.515	36.63	.8977	5.158	10.07
Probability	.187	.0385	1.1108	.6384	.0758	.0065
Observations	34	34	34	34	34	34

The descriptive statistics indicate that the variables GDP (gross domestic product) and INTER (interest rate) deviate from normal distribution, as evidenced by significant Jarque-Bera (JB) statistics (p-values < 0.05). This non-normality suggests potential implications for subsequent econometric analyses. The remaining variables exhibit JB statistics with p-values exceeding 0.05, indicating conformity to normal distribution assumptions.

4.3 Stationary tests

Table 4.2: Zivot-Andrews unit root tests

Variable	Levels	First Difference
TO	-4.091	-5.323 **
INF	-4.788	-5.997**
INTER	-4.348	-5.604 **
OP	-0.450	-6.840 **
GDP	-4.810	-
EXCH	-5.953	-

Critical tests: ***1%: -3.430 **5%: -2.860 *10%: -2.570

The Zivot-Andrew's test, accommodating structural breaks within the series, reveals that gross domestic product (GDP) and exchange rate (EXCH) are stationary at levels. Conversely, trade openness (TO), inflation rate (INFL), interest rate (INTER), and oil price (OP) attain stationarity after first differencing. This test's consideration of structural breaks enhances the reliability of stationarity assessments in macroeconomic time series data.

Table 4.3 Augmented Dickey-Fuller Test Results

Variable	Levels	First Difference	
TO	-1.284176	-6.206306	I(1)
INF	-3.816292	-5.446228	I(0)
INTER	-2.638238	-5.097091	I(1)
OP	-0.214021	-6.133113	I(1)
GDP	-4.092104	-6.204719	I(0)
EXCH	-4.420443	-6.011213	I(0)

Critical value at 5% significance level: -2.954021

The ADF test results show that exchange rate, GDP, and inflation become stationary at levels, while trade openness, interest rate, and oil price only become stationary after first differencing.

Table 4.4 Phillips-Perron Test Results

Variable	Levels	First Difference	
TO	-0.648354	-12.59793	I (1)
INF	-3.259288	-5.563393	I (0)
INTER	-2.517797	-10.68974	I (0)
OP	-0.824989	-6.480767	I (1)
GDP	-4.092104	-11.84003	I (0)
EXCH	-4.260023	-18.43925	I (0)

Critical value at 5% significance level: -2.954021

The PP test results show that exchange rate, GDP, and inflation become stationary at levels, while trade openness, interest rate and oil price only become stationary after first differencing.

4.4 The Results

The results of the NARDL model are presented in Table 4.5, below.

Table 4.5: NARDL - ECM

Variable	Coefficient	Std. Error	t-statistic	Prob
ECM (-1)	-.1608686	.01609	-9.99	0.000
OP_Pos	.0497431	.0298683	1.67	0.096
OP_Neg	.0614417	.0256186	2.40	0.017
GDP_Pos	-.041657	.018379	-2.27	0.024
GDP_Neg	-.0411243	.01864	-2.21	0.028
INTER_Pos	.032713	.020511	1.59	0.111
INTER_Neg	-.00542	.016572	-0.33	0.743
INF_Pos	-.006547	.013362	-0.49	0.624
INF_Neg	.0055046	.013732	0.40	0.689
TO_Pos	-.0352147	.0184264	-1.91	0.051
TO_Neg	-.031878	.0183023	-1.74	0.082

Error Correction Model

The error correction model known as ECM (-1), is negative and statistically significant, with a coefficient of -0.16. This indicates that approximately 16% of deviations from the long-run equilibrium are corrected annually, suggesting a gradual adjustment process towards equilibrium.

In the short run, positive changes in OP do not significantly impact EXCH, as indicated by an insignificant coefficient. However, negative changes in OP have a significant positive effect on EXCH, implying that decreases in OP lead to increased exchange rate volatility.

Both positive and negative changes in GDP significantly affect EXCH. Positive GDP changes are associated with a decrease in EXCH, while negative GDP changes also lead to a decrease in EXCH, suggesting a complex relationship between GDP fluctuations and exchange rate volatility.

INTER and INF are found to be statistically insignificant in influencing EXCH in the short run. TO exhibits a significant negative effect on EXCH when increasing, indicating that higher trade openness reduces exchange rate volatility. Negative changes in TO are insignificant, suggesting asymmetry in the impact of trade openness on exchange rate volatility.

4.6: NARDL (Long Run)

Variable	Coefficient	Std. Error	t-statistic	Prob
OP_Pos	.3819686	.197258	1.94	0.053
OP_Neg	-.0378188	.19295	-0.20	0.845
GDP_Pos	-.0364124	.047303	-0.77	0.442
GDP_Neg	-.0570276	.048049	-1.19	0.235
INTER_Pos	.0754758	.108053	0.70	0.485
INTER_Neg	-.0265249	.0822129	-0.32	0.747
INF_Pos	.065313	.033436	1.95	0.051
INF_Neg	-.011111	.033219	-0.33	0.738
TO_Pos	-.0546452	.0348934	-1.57	0.118
TO_Neg	-.119001	.036405	-3.27	0.001

Long-Run Coefficients

In the long run, positive changes in OP significantly increase EXCH, indicating that rising oil prices contribute to higher exchange rate volatility. Negative changes in OP are insignificant. This implies that there is an asymmetric long-run relationship between the two variables.

Positive changes in INF have a significant positive effect on EXCH, suggesting that higher inflation rates lead to increased exchange rate volatility. Negative changes in INF are insignificant. INTER and GDP are both statistically insignificant in the long run, indicating no substantial impact on EXCH over the extended period.

Positive changes in TO are insignificant, while negative changes significantly decrease EXCH, implying that reductions in trade openness exacerbate exchange rate volatility.

Asymmetric effect

The asymmetric effects results are shown in Table 4.7.

Table 4.7: NARDL

Variable	Coefficient	F-Stat	P>F
OP_Pos	0.309	2.86	0.091
OP_Neg	-0.382	6.156	0.013
GDP_Pos	-0.259	5.392	0.020
GDP_Neg	0.256	5.092	0.024
INTER_Pos	0.203	2.651	0.104
INTER_Neg	0.034	.1071	0.744
INF_Pos	-0.041	.2401	0.624
INF_Neg	-0.034	.1613	0.688
TO_Pos	-0.219	3.689	0.055
TO_Neg	0.198	3.056	0.081

The Wald test indicates significant long-run asymmetry for INF, while no significant asymmetry is detected for interest rate (INTER). This suggests that positive and negative changes in inflation rate (INF) have different long-run effects on exchange

rate (EXCH), whereas interest rate (INTER) does not exhibit asymmetric behaviour in influencing exchange rate volatility.

Cointegration test

The cointegration test was performed and the results are shown in Table 4.8.

Table 4.8: Cointegration test

Cointegration test statistics: t_BDM	-9.9935
F_PSS	9.1564

Both Student's (t_BDM) and Fisher's (F_PSS) statistics are in favour of the existence of a cointegrating relationship, where these two values are higher than the critical values of Pesaran et al. (2001).

4.5 Diagnostic Tests

After estimating the model, four diagnostic tests were reported, namely, normality. Ramsey RESET, autocorrelation, and heteroscedasticity tests.

Table 4.9: Normality Test

Jarque Bera	.8105
Prob	0.6668

Results show that the residuals are normally distributed. This is demonstrated by the p-value associated with the JB statistic, which is above 0.05.

Table 4.10: Ramsey RESET

Ramsey RESET test (F)	.1935
Prob	0.8933

Results from Table 4.10 above show that there was no misspecification in the model. The Probability of the F-statistic of 0.8933, which is above 0.05, implies the absence of misspecification.

Table 4.11: Breusch-Godfrey Serial Correlation LM Test

F-statistic	5.556139	Prob. F(2,4)	0.0701
Obs*R-squared	22.79475	Prob. Chi-Square (2)	0.0000

The null hypothesis of autocorrelation is that there is no autocorrelation in the residuals. Results show that there was no autocorrelation in the model. The probability of the F-statistic turned out to be 0.0701 is below 0.05. Hence, we fail to reject the null hypothesis of no autocorrelation.

Table 4.12: Breusch/Pagan heteroskedasticity test

Portmanteau test up to lag 40 (chi2)	0.3282
Prob	0.5667

The Breusch/Pagan heteroskedasticity test results show that there is no heteroskedasticity in the model. The Probability of the F-statistic turned out to be 0.5667, which is above 0.05. Hence, we fail to reject the null hypothesis of no heteroskedasticity.

4.6 Chapter Summary

This chapter presents the study's findings, structured to provide a comprehensive analysis of the data and results. It begins with descriptive statistics, offering an overview of the data's central tendencies and dispersion, followed by stationarity tests to assess the time-series properties of the variables. Subsequently, the Nonlinear Autoregressive Distributed Lag (NARDL) model results are discussed, highlighting both short-run and long-run dynamics. The key determinants of this study are trade openness, oil price, inflation, interest rate, exchange rate and GDP.

The results indicate that, in the long run, positive changes in oil prices (OP) significantly increase exchange rate volatility (EXCH), indicating that rising oil prices contribute to higher volatility, while negative changes in OP are insignificant. This suggests an asymmetric long-run relationship between the two variables. Positive changes in inflation (INF) also have a significant positive effect on EXCH, implying that higher inflation rates lead to increased exchange rate volatility, whereas negative

changes in INF are insignificant. Interest rates (INTER) and GDP show no significant impact on EXCH over the long term. Additionally, positive changes in trade openness (TO) are insignificant, while negative changes significantly increase EXCH, indicating that reductions in trade openness exacerbate exchange rate volatility.

Diagnostic tests, including assessments for serial correlation, heteroskedasticity, and model specification, are then presented to validate the robustness of the model. The chapter concludes with a summary of the key findings, setting the stage for the subsequent discussion and policy implications.

Chapter Five - Summary, Conclusions, Policy Recommendations

5.1 Introduction

This study analysed the determinants of exchange rate volatility in South Africa for the period spanning from 1990 to 2023. The chapter is divided into seven sections: Section 5.2 presents the problem statement, objectives, and contribution of the study. Theories and brief empirical studies are presented in Section 5.3. The gap in the literature is also highlighted in this section. Section 5.4 presents the estimation methods, and the data used in the study. In Sections 5.5 and 5.6 key findings and policy implications are provided, respectively. Finally, delimitations and areas of further research are presented in Sections 5.7 and 5.8, respectively.

5.2 Problem Statement, Objectives, and Contribution of the Study (Novelty)

Exchange rate volatility poses a major challenge to South Africa's financial sector, generating uncertainty that can undermine exporters' competitiveness, delay investment decisions, and negatively affect overall economic growth. This volatility is often shaped by multiple macroeconomic factors, including interest rates, inflation, and balance of payments dynamics. The complex interplay among these factors complicates the formulation of effective macroeconomic and monetary policies, making it difficult to achieve price stability and sustainable economic growth. While previous studies have identified determinants such as trade openness, capital flows, and exchange rate regimes, their impacts often vary depending on the analytical method, data frequency, and country-specific economic conditions.

Despite substantial research on the effects of exchange rate volatility on macroeconomic outcomes, there is limited empirical investigation into the underlying causes of exchange rate volatility in the South African context. Among the few studies, Mpofu (2016) identifies factors such as trade openness, commodity prices, money supply, and foreign reserves as key determinants. Dewing (2017), on the other hand, highlights interest rate differentials, inflation differentials, economic growth, and government spending, revealing inconsistencies and gaps in the existing literature. By addressing these gaps, this study contributes to a more nuanced understanding of the

drivers of exchange rate volatility in South Africa and informs policy strategies to stabilize currency fluctuations.

The novelty of this study lies in its exploration of the asymmetric effects of macroeconomic variables, particularly oil prices, inflation, and trade openness, on exchange rate volatility, employing the Nonlinear Autoregressive Distributed Lag (NARDL) model. Unlike prior studies that focus on linear relationships, this approach captures nonlinear and direction-dependent dynamics, providing insight into how positive and negative shocks in these variables differently influence exchange rate volatility.

Moreover, the study expands on existing South African research by highlighting the role of trade openness in mitigating currency fluctuations. The findings indicate that increases in trade openness reduce exchange rate volatility, while decreases exacerbate it, underscoring the importance of maintaining and promoting open trade policies. This result both complements and contrasts prior findings, such as those by Mpofu (2016) and Dewing (2017), offering a more refined understanding of trade openness within South Africa's unique economic context.

From a policy perspective, the study underscores the need for South African authorities to consider asymmetric responses of exchange rate volatility to macroeconomic shocks when designing interventions. Monitoring oil price fluctuations, maintaining stable inflation, and promoting trade openness emerge as critical strategies to manage currency risk and enhance economic stability. By integrating these insights, the study provides a comprehensive framework that strengthens the understanding of exchange rate dynamics in emerging markets, fills gaps in the South African literature, and informs evidence-based economic policymaking.

Exchange rate volatility presents a significant challenge to South Africa's financial sector, introducing uncertainty that can deter exporters, delay investment decisions, and negatively impact economic growth. This volatility is often driven by macroeconomic factors such as interest rates, balance of payments, and inflation. The complexity of these influences makes it difficult to set effective macroeconomic and monetary policies, complicating efforts to ensure price stability and sustainable

economic growth. While various factors like trade openness, capital flows, and exchange rate regimes have been suggested as determinants of exchange rate volatility, their influence varies depending on the analytical method, time frame, and specific economic conditions of a country.

Despite extensive literature on the impact of exchange rate volatility on macroeconomic aggregates, there is a relative paucity of research focusing on the origins and causes of exchange rate volatility in the South African context. Notably, the study by Mporu (2016) is among the few that delve into this subject within South Africa. This study aims to contribute to the existing literature by investigating the determinants of exchange rate volatility in South Africa, thereby providing insights that could inform appropriate economic policies to mitigate such fluctuations. By addressing this gap, the study seeks to enhance the understanding of exchange rate dynamics in emerging markets and support the development of strategies to promote economic stability.

The novelty of this study lies in its comprehensive examination of the asymmetric effects of macroeconomic variables particularly oil prices, inflation, and trade openness on exchange rate volatility in South Africa, utilizing the Nonlinear Autoregressive Distributed Lag (NARDL) model. While previous research has explored the relationship between oil prices and exchange rates, this study distinguishes itself by focusing on the asymmetric impacts of both positive and negative changes in these macroeconomic indicators on exchange rate volatility. By employing the NARDL approach, the study captures the nonlinear dynamics and provides a nuanced understanding of how different shocks affect the exchange rate differently depending on their direction.

Furthermore, the study contributes to the existing literature by highlighting the significance of trade openness in mitigating exchange rate volatility, an area that has received limited attention in the South African context. The findings suggest that increases in trade openness can reduce exchange rate volatility, while decreases may exacerbate it, underscoring the importance of maintaining open trade policies. This insight offers valuable policy implications for South African authorities aiming to stabilize the exchange rate and promote economic growth. By integrating these

aspects, the study provides a more comprehensive framework for understanding the complex interplay between macroeconomic variables and exchange rate volatility in South Africa.

5.3 Key Theories and Empirical Findings

The theory, as well as the empirics concerning the determinants of exchange rate volatility, were presented. Regarding the review of theoretical literature, three theories relating to the determinants of exchange rate volatility were discussed. Specific models include (1) studies based on monetary models of exchange rate level determination that focus on monetary variables as determinants of exchange rate volatility. (2) the Optimum Currency Areas model, which focuses on trade links, asymmetry or similarity of economic shocks to production, country size, and geographic factors as causes of exchange rate volatility and, (3) New Open Economy Macroeconomics which emphasizes the role of monetary and non-monetary variables in explaining exchange rate volatility. On the empirical side, literature on developed, developing, and, in particular, South Africa, was presented.

From the theoretical literature reviewed, the relationship between exchange rate volatility and its determinants can be either positive or negative. Furthermore, analysis from available empirical literature indicates that it may not be possible on a priori grounds to arrive at any definite conclusion on the relationship between exchange rate volatility and its determinants. The issue is basically empirical and critical, depending on the type of method used in the analysis, and the economy being considered.

In the case of South Africa, despite its relevance, few studies focus on determinants of exchange rate volatility, and the results are unclear on non-linearity. Though these two studies reveal almost common determinants of exchange rate volatility, according to Mpofu (2022), the level of significance regarding trade openness is high, whereas Dewing's (2017) results reveal that trade openness has an insignificant impact on exchange rate volatility. Thus, there is a need for a study on this topic for South Africa. The present study will help to deepen the literature on this topic.

5.4 The Key Methods and Data Used

This study employed the nonlinear autoregressive distributed lag (NARDL) and yearly data to investigate the relationship between exchange rate volatility and other variables in South Africa, and the complete data set consists of 103 observations. Secondary time series data were collected from the South African Reserve Bank. EViews 12 software package was employed to conduct stationarity (unit root) tests, tests for choosing the optimal lag length criterion, NARDL, Zivot- Andrews test, and diagnostic tests.

5.5 Key Findings

The study's findings reveal that exchange rate volatility in South Africa is significantly shaped by macroeconomic variables, with pronounced asymmetries in both short- and long-term dynamics. The Error Correction Model (ECM) indicates that approximately 16% of deviations from the long-run equilibrium are corrected annually, suggesting a relatively slow adjustment process towards stability. In the short run, negative shocks in oil prices significantly increase exchange rate volatility, while positive shocks are insignificant, implying that oil price declines exert a more destabilizing influence on the currency than equivalent increases. GDP fluctuations display a complex pattern, with both positive and negative changes linked to a reduction in volatility, hinting at possible measurement issues or underlying structural factors that dampen currency fluctuations during growth contractions as well as expansions. Interest rates and inflation are statistically insignificant in the short run, a result that contrasts with the theoretical expectation from monetary models, raising questions about possible lag effects, weak transmission mechanisms, or omitted variables. Trade openness exhibits a significant negative effect when increasing, suggesting that greater openness reduces volatility, though this finding is contingent on directionality and may mask underlying sectoral vulnerabilities.

In the long run, positive changes in oil prices and inflation significantly heighten exchange rate volatility, whereas negative changes are insignificant, reinforcing the asymmetric nature of these relationships. Trade openness again shows a directional asymmetry—positive changes are insignificant, but reductions significantly increase volatility, highlighting the vulnerability of the rand to trade restrictions or declines in

global integration. The Wald test confirms significant long-run asymmetry for inflation, suggesting that upward and downward movements in inflation have distinct long-run implications for exchange rate dynamics. Cointegration results confirm the existence of a long-run relationship between volatility and its macroeconomic determinants.

These findings both align and conflict with prior research. For example, they support Mporu (2016), who emphasized the stabilizing role of economic openness in reducing rand volatility. However, they contradict Calderón and Kubota (2018), who found that higher openness may amplify volatility, indicating that the openness–volatility relationship is context-dependent and possibly mediated by institutional strength, market depth, or trade composition. Dagume (2022) further complicates the picture by showing that volatility can positively influence GDP growth and trade openness, pointing to a more intricate feedback loop between macroeconomic performance and currency stability.

Methodologically, the study faces several constraints. The use of annual or quarterly aggregated data may smooth out high-frequency fluctuations, potentially underestimating short-term volatility responses to shocks, particularly relevant in a highly open and commodity-dependent economy like South Africa's. The absence of political risk indicators, such as measures of policy uncertainty or sovereign credit risk, limits the model's ability to capture volatility episodes linked to domestic governance or geopolitical shocks. Additionally, the chosen period may conceal structural breaks during global crises (e.g., the 2008 financial crisis or COVID-19), which could alter parameter stability and bias long-run coefficients. Potential endogeneity—where variables such as GDP or inflation are both determinants and outcomes of exchange rate volatility, also poses a concern, suggesting that instrumental variable approaches or structural VAR models could enhance causal inference.

By incorporating both symmetric and asymmetric effects, this research addresses a notable gap in South African literature, where most studies have either ignored asymmetry or focused on a narrower set of variables. The inclusion of inflation and interest rates is justified not only by their central role in monetary transmission mechanisms but also by mixed evidence in existing studies, which this paper helps to clarify. Likewise, integrating oil prices and trade openness reflects South Africa's

exposure to global commodity markets and trade shocks, while allowing the results to speak to both domestic policy debates and global macroeconomic linkages. The findings challenge the assumption of uniform macroeconomic effects on volatility, highlighting instead the importance of directional changes and asymmetries. This underscores the need for future work using high-frequency data, incorporating political and institutional variables, and testing for structural breaks to more fully understand the drivers of exchange rate volatility in South Africa.

The study rejects the following hypotheses:

- **Null Hypothesis (H_01):** There is no evidence of a long-run asymmetry relationship between exchange rate volatility and its determinants in South Africa.
- **Null Hypothesis (H_02):** There are no significant short-run asymmetry dynamics among exchange rate volatility and its explanatory variables in South Africa.

Thus, the following alternative hypotheses are accepted:

- **Alternative Hypothesis (H_{11}):** There is evidence of a long-run asymmetry relationship between exchange rate volatility and its determinants in South Africa.
- **Alternative Hypothesis (H_{12}):** There are significant short-run asymmetry dynamics among exchange rate volatility and its explanatory variables in South Africa.

5.6 Policy Recommendations

Based on the study's findings, several policy recommendations emerge to mitigate exchange rate volatility and its adverse effects on South Africa's economy:

Enhance Trade Openness: The study indicates that increased trade openness significantly reduces exchange rate volatility. Policymakers should continue to pursue trade liberalization policies, negotiate favorable trade agreements, and reduce trade barriers. Such measures can stabilize the exchange rate by diversifying export markets and reducing reliance on a narrow range of trading partners.

Monitor and Manage Oil Price Shocks: Given the asymmetric impact of oil price changes on exchange rate volatility, where negative shocks have a more pronounced

effect, it's crucial for South Africa to develop strategies to buffer against oil price fluctuations. This could include building strategic petroleum reserves, diversifying energy sources, and implementing hedging mechanisms to protect the economy from sudden oil price declines.

Strengthening Inflation Control Measures: The study finds that positive changes in inflation significantly increase exchange rate volatility. Therefore, maintaining a stable inflation rate within the target range is essential. The South African Reserve Bank should continue its inflation-targeting framework and employ monetary policy tools effectively to keep inflation expectations anchored.

Promote Economic Diversification: Diversifying the economy can reduce vulnerability to external shocks that cause exchange rate volatility. Encouraging growth in various sectors, such as manufacturing, agriculture, and services, can provide multiple streams of foreign exchange earnings and reduce dependence on a limited number of export commodities.

Implement Macprudential Policies: To address the financial stability risks associated with exchange rate volatility, authorities should consider macroprudential measures. These could include regulations to manage capital flows, requirements for foreign exchange risk management in financial institutions, and policies to prevent excessive credit growth during periods of currency appreciation.

Coordinate Fiscal and Monetary Policies: Effective coordination between fiscal and monetary policies can enhance the overall stability of the economy. For instance, prudent fiscal management can support monetary policy objectives by reducing the need for excessive borrowing, which can put pressure on the exchange rate.

By implementing these policy recommendations, South Africa can work towards reducing exchange rate volatility, thereby creating a more stable economic environment conducive to investment, trade, and sustainable growth.

5.7 Delimitations of the Study

This investigation also focuses on identifying quantitative factors or determinants that can affect exchange rate volatility in South Africa. Non-quantifiable factors such as political and social changes are not included in the model. For example, developments such as union strikes that affect investor confidence and the exchange rate are not included within the specified model equation. Any lack of reliable information and data

availability could affect measurement results. The data obtained from various sources may need to be manipulated and not used in the original format in which it was found. This could be because there is a lack of data in the form required for the investigation, and therefore data that is available will need to be altered.

5.8 Areas for Future Research

Based on the study's findings and the current literature, several avenues for future research can be identified to deepen the understanding of exchange rate volatility in South Africa and similar emerging markets:

- **Incorporation of Political and Social Factors:** The current study focuses on quantifiable economic determinants of exchange rate volatility. Future research could explore the impact of political events, governance quality, and social unrest on currency fluctuations. For instance, the role of political stability and policy uncertainty in influencing exchange rates could provide valuable insights, as suggested by studies examining economic policy uncertainty in South Africa
- **Sectoral Analysis of Exchange Rate Impacts:** Investigating how exchange rate volatility affects specific sectors, such as agriculture, manufacturing, or services, could offer a more granular understanding. For example, research has shown that real exchange rate volatility significantly impacts South Africa's agricultural trade, affecting both imports and exports
- **Comparative Studies Across Emerging Markets:** Conducting comparative analyses between South Africa and other emerging economies could help identify common determinants and unique factors influencing exchange rate volatility. Such studies could consider the effects of global financial cycles and commodity terms of trade on financial spreads in emerging markets

By pursuing these research avenues, researchers can contribute to a more comprehensive understanding of the multifaceted factors influencing exchange rate volatility, thereby informing more effective economic policies and financial strategies in South Africa and other emerging economies.

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APENDICCES

Appendix A: Data

YEAR	TRADE OPENNESS	INFLATION RATE	INTEREST RATE	OIL PRICE	GDP	EXCHANGE RATE
1990	38,2118	14,32096	4,811415	60.39	-2.4	1.2
1991	34,88161	15,3348	4,027493	54.90	-3.1	-6.1
1992	34,32135	13,87468	3,654137	55.22	-4.2	-3.3
1993	35,69812	9,717467	2,464688	56.26	-0.9	-12.7
1994	37,11461	8,938525	5,25547	56.21	1.1	-8.0
1995	39,47803	8,680444	6,367395	61.31	1.0	-2.2
1996	42,19925	7,354113	10,64481	87.52	2.1	-15.0
1997	42,30133	8,597783	10,9699	89.32	0.5	-7.3
1998	44,03575	6,880546	12,69103	74.12	-1.6	-16.1
1999	42,2583	5,181493	10,39507	109.90	0.3	-10.3
2000	46,22072	5,338951	4,870582	198.31	2.1	-11.4
2001	49,17095	5,7019	5,538341	207.90	0.4	-18.8
2002	53,4655	9,494711	2,854186	261.04	0.2	-18.8
2003	45,72386	5,679418	8,047848	219.28	1.5	39.2
2004	45,64358	-0,69203	4,950384	245.17	3.4	16.8
2005	47,42778	2,062846	4,761489	364.20	4.1	1.3
2006	53,76814	3,243908	4,810302	439.34	4.4	-5.6
2007	57,12514	6,177807	4,546046	512.91	4.0	-4.6
2008	65,97452	10,07458	6,745152	784.20	1.8	-13.4
2009	49,58754	7,215314	2,802509	508.46	-2.9	-2.3
2010	50,40609	4,08973	3,49096	580.92	1.5	14.0
2011	54,63635	4,999267	3,279301	806.07	1.6	1.3
2012	55,58262	5,724658	3,882873	916.47	0.8	-11.9

2013	58,87503	5,784469	2,509245	1050.17	0.9	-14.8
2014	59,49957	6,129838	3,567028	1073.20	-0.1	-11.2
2015	56,72668	4,540642	3,667743	663.05	-0.2	-14.5
2016	55,86126	6,571396	3,278252	637.20	-0.8	-13.6
2017	53,53593	5,184247	4,647315	723.37	-0.3	10.2
2018	54,48555	4,517165	5,856184	941.70	0.0	1.2
2019	53,898	4,120246	5,268416	930.10	-1.2	-8.9
2020	50,68684	3,210036	2,198414	674.68	-7.4	-11.8
2021	56,08462	4,611672	0,472107	1044.82	3.9	10.9
2022	65,06074	7,039727	3,618541	1637.24	0.9	-9.4
2023	65,72246	6,073909	6,388794	1524.40	-0.3	-11.6

Appendix B: Raw results

```
. jb TO
Jarque-Bera normality test: .8977 Chi(2) .6384
Jarque-Bera test for Ho: normality:

. jb OP
Jarque-Bera normality test: 3.353 Chi(2) .187
Jarque-Bera test for Ho: normality:

. jb GDP
Jarque-Bera normality test: 6.515 Chi(2) .0385
Jarque-Bera test for Ho: normality:

. jb EXCH
Jarque-Bera normality test: 36.63 Chi(2) 1.1e-08
Jarque-Bera test for Ho: normality:

. jb INF
Jarque-Bera normality test: 5.158 Chi(2) .0758
Jarque-Bera test for Ho: normality:
```

```
. summarize TO INF INT OP GDP EXCH
```

Variable	Obs	Mean	Std. dev.	Min	Max
TO	34	49.87264	8.810573	34.32135	65.97452
INF	34	6.640448	3.336586	-.69203	15.3348
INT	34	5.098042	2.705591	.472107	12.69103
OP	34	519.0985	439.2184	54.9	1637.24
GDP	34	.3264706	2.469856	-7.4	4.4
EXCH	34	-4.926471	11.98169	-18.8	39.2

TO				
	Percentiles	Smallest		
1%	34.32135	34.32135		
5%	34.88161	34.88161		
10%	37.11461	35.69812	Obs	34
25%	42.30133	37.11461	Sum of wgt.	34
50%	50.54646		Mean	49.87264
			Std. dev.	8.810573
75%	55.86126	Largest		
		59.49957		
90%	59.49957	65.06074	Variance	77.62619
95%	65.72246	65.72246	Skewness	-.0650853
99%	65.97452	65.97452	Kurtosis	2.214683
INF				
	Percentiles	Smallest		
1%	-.69203	-.69203		
5%	2.062846	2.062846		
10%	3.243908	3.210036	Obs	34
25%	4.611672	3.243908	Sum of wgt.	34
50%	5.929189		Mean	6.640448
			Std. dev.	3.336586
75%	8.597783	Largest		
		10.07458		
90%	10.07458	13.87468	Variance	11.13281
95%	14.32096	14.32096	Skewness	.7988328
99%	15.3348	15.3348	Kurtosis	4.043417
INT				
	Percentiles	Smallest		
1%	.472107	.472107		
5%	2.198414	2.198414		
10%	2.509245	2.464688	Obs	34
25%	3.49096	2.509245	Sum of wgt.	34
50%	4.704402		Mean	5.098042
			Std. dev.	2.705591
75%	5.856184	Largest		
		10.39507		
90%	10.39507	10.64481	Variance	7.320222
95%	10.9699	10.9699	Skewness	1.21082
99%	12.69103	12.69103	Kurtosis	4.114147
OP				
	Percentiles	Smallest		
1%	54.9	54.9		
5%	55.22	55.22		
10%	56.26	56.21	Obs	34
25%	89.32	56.26	Sum of wgt.	34
50%	473.9		Mean	519.0985
			Std. dev.	439.2184
75%	806.07	Largest		
		1050.17		
90%	1050.17	1073.2	Variance	192912.8
95%	1524.4	1524.4	Skewness	.7649185
99%	1637.24	1637.24	Kurtosis	2.837481
GDP				
	Percentiles	Smallest		
1%	-7.4	-7.4		
5%	-4.2	-4.2		
10%	-2.9	-3.1	Obs	34
25%	-.8	-2.9	Sum of wgt.	34
50%	.45		Mean	.3264706
			Std. dev.	2.469856
75%	1.6	Largest		
		3.9		
90%	3.9	4	Variance	6.100187
95%	4.1	4.1	Skewness	-.8091276
99%	4.4	4.4	Kurtosis	4.407263
EXCH				
	Percentiles	Smallest		
1%	-18.8	-18.8		
5%	-18.8	-18.8		
10%	-15	-16.1	Obs	34
25%	-12.7	-15	Sum of wgt.	34
50%	-8.45		Mean	-4.926471
			Std. dev.	11.98169
75%	1.2	Largest		
		10.9		
90%	10.9	14	Variance	143.5608
95%	16.8	16.8	Skewness	1.756137
99%	39.2	39.2	Kurtosis	6.676666
H				

Zivot-Andrews unit root test

Trade openness

Zivot-Andrews unit root test for TO

Allowing for break in intercept

Lag selection via TTest: lags of $D.TO$ included = 0

Minimum t-statistic -4.091 at 2015 (obs 26)

Critical values: 1%: -5.34 5%: -4.80 10%: -4.58

Zivot-Andrews unit root test for $D.TO$

Allowing for break in intercept

Lag selection via TTest: lags of $D.D.TO$ included = 2

Minimum t-statistic -5.323 at 2009 (obs 20)

Critical values: 1%: -5.34 5%: -4.80 10%: -4.58

Inflation rate

Zivot-Andrews unit root test for INF

Allowing for break in intercept

Lag selection via TTest: lags of $D.INF$ included = 1

Minimum t-statistic -4.788 at 1998 (obs 9)

Critical values: 1%: -5.34 5%: -4.80 10%: -4.58

Zivot-Andrews unit root test for $D.INF$

Allowing for break in intercept

Lag selection via TTest: lags of $D.D.INF$ included = 1

Minimum t-statistic -5.997 at 2009 (obs 20)

Critical values: 1%: -5.34 5%: -4.80 10%: -4.58

Interest rate

Zivot-Andrews unit root test for $D.INT$

Allowing for break in intercept

Lag selection via TTest: lags of $D.D.INT$ included = 2

Minimum t-statistic -5.604 at 2000 (obs 11)

Critical values: 1%: -5.34 5%: -4.80 10%: -4.58

Oil price

Zivot-Andrews unit root test for OP

Allowing for break in intercept

Lag selection via TTest: lags of $D.OP$ included = 1

Minimum t-statistic -4.350 at 2010 (obs 21)

Critical values: 1%: -5.34 5%: -4.80 10%: -4.58

Zivot-Andrews unit root test for $D.OP$

Allowing for break in intercept

Lag selection via TTest: lags of $D.D.OP$ included = 1

Minimum t-statistic -6.840 at 2014 (obs 25)

Critical values: 1%: -5.34 5%: -4.80 10%: -4.58

GDP

Zivot-Andrews unit root test for GDP

Allowing for break in intercept

Lag selection via TTest: lags of $D.GDP$ included = 0

Minimum t-statistic -4.810 at 2009 (obs 20)

Critical values: 1%: -5.34 5%: -4.80 10%: -4.58

ADF Test

Exchange rate (EXCH)

Null Hypothesis: EXCH has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-4.420443	0.0013
Test critical values: 1% level	-3.646342	
5% level	-2.954021	
10% level	-2.615817	

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

Null Hypothesis: EXCH has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-4.363831	0.0078
Test critical values: 1% level	-4.262735	
5% level	-3.552973	
10% level	-3.209642	

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

1st Difference

Null Hypothesis: D(EXCH) has a unit root

Exogenous: Constant

Lag Length: 1 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-6.011213	0.0000
Test critical values: 1% level	-3.661661	
5% level	-2.960411	
10% level	-2.619160	

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

Null Hypothesis: D(EXCH) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-5.896964	0.0002
Test critical values: 1% level	-4.284580	
5% level	-3.562882	
10% level	-3.215267	

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

GDP

Null Hypothesis: GDP has a unit root

Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-4.092104	0.0032
Test critical values: 1% level	-3.646342	
5% level	-2.954021	
10% level	-2.615817	

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

Null Hypothesis: GDP has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-4.008187	0.0182
Test critical values: 1% level	-4.262735	
5% level	-3.552973	
10% level	-3.209642	

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

1st Difference

Null Hypothesis: D(GDP) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-6.204719	0.0000
Test critical values: 1% level	-3.661661	
5% level	-2.960411	
10% level	-2.619160	

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

Null Hypothesis: D(GDP) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-6.193861	0.0001
Test critical values: 1% level	-4.284580	
5% level	-3.562882	
10% level	-3.215267	

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

Trade Openness (TO)

Null Hypothesis: TO has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.284176	0.6251
Test critical values:		
1% level	-3.646342	
5% level	-2.954021	
10% level	-2.615817	

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

Null Hypothesis: TO has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-3.149763	0.1120
Test critical values:		
1% level	-4.262735	
5% level	-3.552973	
10% level	-3.209642	

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

1st Difference

Null Hypothesis: D(TO) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-6.206306	0.0000
Test critical values:		
1% level	-3.653730	
5% level	-2.957110	
10% level	-2.617434	

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

Null Hypothesis: D(TO) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-6.095539	0.0001
Test critical values:		
1% level	-4.273277	
5% level	-3.557759	
10% level	-3.212361	

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

Inflation rate (INF)

Null Hypothesis: INFL has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-3.816292	0.0067
Test critical values: 1% level	-3.653730	
5% level	-2.957110	
10% level	-2.617434	

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

Null Hypothesis: INFL has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-3.859559	0.0260
Test critical values: 1% level	-4.273277	
5% level	-3.557759	
10% level	-3.212361	

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

1st Difference

Null Hypothesis: D(INFL) has a unit root
Exogenous: Constant
Lag Length: 3 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-5.446228	0.0001
Test critical values: 1% level	-3.679322	
5% level	-2.967767	
10% level	-2.622989	

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

Null Hypothesis: D(INFL) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 3 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-6.049392	0.0001
Test critical values: 1% level	-4.309824	
5% level	-3.574244	
10% level	-3.221728	

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

Oil price (OP)

Null Hypothesis: OP has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-0.214021	0.9270
Test critical values:		
1% level	-3.646342	
5% level	-2.954021	
10% level	-2.615817	

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

Null Hypothesis: OP has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-3.746383	0.0334
Test critical values:		
1% level	-4.273277	
5% level	-3.557759	
10% level	-3.212361	

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

1st Difference

Null Hypothesis: D(OP) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-6.133113	0.0000
Test critical values:		
1% level	-3.661661	
5% level	-2.960411	
10% level	-2.619160	

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

Null Hypothesis: D(OP) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-6.260850	0.0001
Test critical values:		
1% level	-4.284580	
5% level	-3.562882	
10% level	-3.215267	

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

Interest rate (IR)

Null Hypothesis: IR has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.638238	0.0957
Test critical values: 1% level	-3.646342	
5% level	-2.954021	
10% level	-2.615817	

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

Null Hypothesis: IR has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.758577	0.2216
Test critical values: 1% level	-4.262735	
5% level	-3.552973	
10% level	-3.209642	

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

1st Difference

Null Hypothesis: D(IR) has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-5.097091	0.0003
Test critical values: 1% level	-3.670170	
5% level	-2.963972	
10% level	-2.621007	

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

Null Hypothesis: D(IR) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 2 (Automatic - based on SIC, maxlag=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-5.299580	0.0009
Test critical values: 1% level	-4.296729	
5% level	-3.568379	
10% level	-3.218382	

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

PP-Test

EXCH

Null Hypothesis: EXCH has a unit root
Exogenous: Constant
Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-4.260023	0.0021
Test critical values:		
1% level	-3.646342	
5% level	-2.954021	
10% level	-2.615817	

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

Residual variance (no correction)	135.1290
HAC corrected variance (Bartlett kernel)	78.06207

Null Hypothesis: EXCH has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 7 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-4.183294	0.0121
Test critical values:		
1% level	-4.262735	
5% level	-3.552973	
10% level	-3.209642	

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

Residual variance (no correction)	134.7619
HAC corrected variance (Bartlett kernel)	75.59852

1st Difference

Null Hypothesis: D(EXCH) has a unit root

Exogenous: Constant

Bandwidth: 31 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-18.43925	0.0001
Test critical values:		
1% level	-3.653730	
5% level	-2.957110	
10% level	-2.617434	

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

Residual variance (no correction)	213.0194
HAC corrected variance (Bartlett kernel)	12.16158

Null Hypothesis: D(EXCH) has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 31 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-18.75829	0.0000
Test critical values:		
1% level	-4.273277	
5% level	-3.557759	
10% level	-3.212361	

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

Residual variance (no correction)	212.8585
HAC corrected variance (Bartlett kernel)	11.06678

GDP

Null Hypothesis: GDP has a unit root

Exogenous: Constant

Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-4.092104	0.0032
Test critical values:		
1% level	-3.646342	
5% level	-2.954021	
10% level	-2.615817	

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

Residual variance (no correction)	5.255935
HAC corrected variance (Bartlett kernel)	5.255935

Null Hypothesis: GDP has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-4.008187	0.0182
Test critical values:		
1% level	-4.262735	
5% level	-3.552973	
10% level	-3.209642	

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

Residual variance (no correction)	5.250431
HAC corrected variance (Bartlett kernel)	5.250431

1st Difference

Null Hypothesis: D(GDP) has a unit root

Exogenous: Constant

Bandwidth: 15 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-11.84003	0.0000
Test critical values:		
1% level	-3.653730	
5% level	-2.957110	
10% level	-2.617434	

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

Residual variance (no correction)	7.210984
HAC corrected variance (Bartlett kernel)	1.909943

Null Hypothesis: D(GDP) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 29 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-20.87645	0.0000
Test critical values:		
1% level	-4.273277	
5% level	-3.557759	
10% level	-3.212361	

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

Residual variance (no correction)	7.132170
HAC corrected variance (Bartlett kernel)	0.497874

Trade Openness (TO)

Null Hypothesis: TO has a unit root
Exogenous: Constant
Bandwidth: 15 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-0.648354	0.8460
Test critical values:		
1% level	-3.646342	
5% level	-2.954021	
10% level	-2.615817	

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

Residual variance (no correction)	19.62463
HAC corrected variance (Bartlett kernel)	8.613551

Null Hypothesis: TO has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
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Phillips-Perron test statistic	-2.977866	0.1532
Test critical values:	1% level	-4.262735
	5% level	-3.552973
	10% level	-3.209642

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

Residual variance (no correction)	15.49353
HAC corrected variance (Bartlett kernel)	12.72893

1st Difference

Null Hypothesis: D(TO) has a unit root

Exogenous: Constant

Bandwidth: 31 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-12.59793	0.0000
Test critical values:	1% level	-3.653730
	5% level	-2.957110
	10% level	-2.617434

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

Residual variance (no correction)	20.49278
HAC corrected variance (Bartlett kernel)	1.737230

Null Hypothesis: D(TO) has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 31 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-12.07806	0.0000
Test critical values:	1% level	-4.273277
	5% level	-3.557759
	10% level	-3.212361

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

Residual variance (no correction)	20.49146
HAC corrected variance (Bartlett kernel)	1.779540

Inflation rate (INF)

Null Hypothesis: INFL has a unit root

Exogenous: Constant

Bandwidth: 23 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-3.259288	0.0253

Test critical values:	1% level	-3.646342
	5% level	-2.954021
	10% level	-2.615817

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

Residual variance (no correction)	4.032236
HAC corrected variance (Bartlett kernel)	0.913276

Null Hypothesis: INFL has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 16 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-2.374568	0.3851
Test critical values:		
	1% level	-4.262735
	5% level	-3.552973
	10% level	-3.209642

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

Residual variance (no correction)	3.941284
HAC corrected variance (Bartlett kernel)	1.175198

1st Difference

Null Hypothesis: D(INFL) has a unit root
Exogenous: Constant
Bandwidth: 14 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-5.563393	0.0001
Test critical values:		
	1% level	-3.653730
	5% level	-2.957110
	10% level	-2.617434

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

Residual variance (no correction)	5.215986
HAC corrected variance (Bartlett kernel)	2.261740

Null Hypothesis: D(INFL) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 31 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-9.886780	0.0000
Test critical values:		
	1% level	-4.273277
	5% level	-3.557759

10% level -3.212361

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

Residual variance (no correction)	4.995845
HAC corrected variance (Bartlett kernel)	0.406428

Oil price (OP)

Null Hypothesis: OP has a unit root

Exogenous: Constant

Bandwidth: 12 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	0.824989	0.9930
Test critical values:		
1% level	-3.646342	
5% level	-2.954021	
10% level	-2.615817	

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

Residual variance (no correction)	30316.02
HAC corrected variance (Bartlett kernel)	12305.66

Null Hypothesis: OP has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 7 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-2.274723	0.4352
Test critical values:		
1% level	-4.262735	
5% level	-3.552973	
10% level	-3.209642	

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

Residual variance (no correction)	23472.27
HAC corrected variance (Bartlett kernel)	14244.81

1st Difference

Null Hypothesis: D(OP) has a unit root

Exogenous: Constant

Bandwidth: 16 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-6.480767	0.0000
Test critical values:		
1% level	-3.653730	
5% level	-2.957110	
10% level	-2.617434	

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

Residual variance (no correction)	31228.26
HAC corrected variance (Bartlett kernel)	7749.213

Null Hypothesis: D(OP) has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 23 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-8.603412	0.0000
Test critical values:		
1% level	-4.273277	
5% level	-3.557759	
10% level	-3.212361	

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

Residual variance (no correction)	30375.96
HAC corrected variance (Bartlett kernel)	3317.588

Interest rate (IR)

Null Hypothesis: IR has a unit root

Exogenous: Constant

Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-2.517797	0.1205
Test critical values:		
1% level	-3.646342	
5% level	-2.954021	
10% level	-2.615817	

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

Residual variance (no correction)	33.90929
HAC corrected variance (Bartlett kernel)	28.95731

Null Hypothesis: IR has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-2.664124	0.2568
Test critical values:		
1% level	-4.262735	
5% level	-3.552973	
10% level	-3.209642	

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

Residual variance (no correction)	32.99823
HAC corrected variance (Bartlett kernel)	29.85827

1st Difference

Null Hypothesis: D(IR) has a unit root

Exogenous: Constant

Bandwidth: 31 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-10.68974	0.0000
Test critical values:		
1% level	-3.653730	
5% level	-2.957110	
10% level	-2.617434	

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

Residual variance (no correction)	42.05572
HAC corrected variance (Bartlett kernel)	5.202865

Null Hypothesis: D(IR) has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 26 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-12.28274	0.0000
Test critical values:		
1% level	-4.273277	
5% level	-3.557759	
10% level	-3.212361	

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

Residual variance (no correction)	41.79443
HAC corrected variance (Bartlett kernel)	3.532960