

**VOLATILITY SPILLOVER EFFECTS OF MACROECONOMIC VARIABLES
AND COMMODITIES ON FINANCIAL MARKETS IN SOUTH AFRICA.**

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DECLARATION

I, the undersigned, Harton Taunganirwa Nhidza, student number G19N2681, hereby declare that except for references specifically indicated in the text, and such help as has been acknowledged, this thesis is wholly my own work and has not been submitted to any other University, Technikon or College for degree purposes.



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12 February 2025

ABSTRACT

South Africa boasts one of the fast-developing stock market coupled with a well-established currency making both markets attractive for investors. However, the increased globalisation and integration of financial markets, commodities markets and macroeconomic uncertainty make it important to continuously uncover the nature of the interactions. The current research examines the time-varying volatility spillover nexus of macroeconomic variables and commodities on financial markets by using monthly data from January 2005 to January 2024. For this purpose, we employ the Diebold and Yilmaz (2009,2012) spillover index under the generalised VAR framework.

Firstly, regarding the stock market, the empirical findings point to more significant time-varying directional volatility spillovers from the stock market, particularly the JSE stocks returns, to both the commodities and the macroeconomic variables although bi-directional spillovers exist. Between the macroeconomic variables and commodities, inflation has the highest spillover to the JSE stocks returns at 16.1%. Secondly, the foreign exchange market is both a directional and net directional spillover recipient from both macroeconomic variables and commodities with inflation having the highest directional spillover at 13.3 %. Bi-directional spillovers also exist in this regard.

The time-varying pairwise spillover analysis for both markets shows that their spillover connectedness with the real economy is significantly affected during and post global economic shocks such as the GFC and the COVID-19 pandemic. Our conclusion was that there exist bi-directional volatility spillovers between the two financial markets and the real economy. The stock market has been a dominant spillover giver to the real economy except for oil prices whilst the foreign exchange market has remained a net receiver of volatility spillover effects. These findings provide investors with opportunities and threats for investment strategies and offer much needed information on the financial markets and real economy volatility spillover nexus for policymakers.

Keywords:

Volatility, Spillovers, Cross-market, Macro-financial.

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DEDICATION

I dedicate this work to my parents.

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LIST OF ACRONYMS

ADF	Augmented Dickey-Fuller
AIC	Akaike's information criterion
APARCH	Asymmetric Power Autoregressive Conditional Heteroskedasticity
APT	Arbitrage Pricing Theory
ARCH	Autoregressive Conditional Heteroskedasticity
ARCH-LM	Autoregressive Conditional Heteroskedasticity-Lagrange multiplier
AR-GARCH	Augmented autoregressive Generalised Autoregressive Conditional Heteroscedastic
ARMA-GARCH	Autoregressive Moving Average-Generalised Autoregressive Conditional Heteroscedastic
BEKK-GARCH	Baba, Engle, Kraft, and Kroner Generalised Autoregressive Conditional Heteroscedastic
BIST	Borsa Istanbul
BRIC	Brazil, Russia, India and China
BRICS	Brazil, Russia, India, China and South Africa
CAPM	Capital Asset Pricing Model
CBDC	Central Bank Digital Currency
COVID-19	Coronavirus disease
CPI	Consumer price index
DCC-GARCH	Dynamic Conditional Correlation-Generalised Autoregressive Conditional Heteroscedastic
DJ	Dow Jones
DY	Diebold and Yilmaz
EGARCH	Exponential Generalised Autoregressive Conditional Heteroscedastic
EMH	Efficiency Market Hypothesis
EXR	Exchange Rate
FIG	Figure
FIN	Financials
FEVD	Forecast Error Variance Decomposition
FTSE	Financial Times Stock Exchange
GARCH	Generalised Autoregressive Conditional Heteroscedastic
GDP	Gross Domestic Product
GFC	Global Financial Crisis
GIRF	Generalised Impulse Response Functions
GJR-GARCH	Glosten–Jagannathan–Runkle-Generalized Autoregressive Conditional Heteroskedasticity
GVAR	Generalised Vector autoregressive
HQ	Hannan-Quinn information criteria
IND	Industrials
IPI	Industrial Production Index

JSE	Johannesburg Stock Exchange
LSEG	London Stock Exchange Group
MGARCH	Multivariate Generalised Autoregressive Conditional Heteroscedastic
MIN	Mining
OPEC	Organisation of the Petroleum Exporting Countries
RALSH	Returns for All Share Index
RES	Resources
RET	Retails
RFIN	Returns for Financials 15
RMIN	Returns for Mining
RRET	Returns for Retailers
SARB	South African Reserve Bank
SC	Schwarz information criteria
TARCH	Threshold Autoregressive Conditional Heteroskedasticity
TBEKK	Threshold Baba, Engle, Kraft, and Kroner
TVP-SV-VAR	Time-Varying Parameter stochastic volatility vector autoregression
VAR	Vector autoregression
VAR-GARCH	Vector autoregression Generalised Autoregressive Conditional Heteroscedastic
UAE	United Arab Emirates
US	United States
USD	United States Dollar
WTI	West Texas Intermediate
ZAR	Rand

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND AND CONTEXT

The increased financial markets integration through globalisation and liberalisation of capital markets has led to them being more exposed to volatility between markets resulting in the influence that macroeconomic variables and commodities have on financial markets returns (Chipeta, 2012). This has had significant implications on investment strategies and portfolio diversity and management to shield portfolio risk exposure and for hedging purposes.

The first moment effects of macroeconomic variables and commodities on both the stock market and the foreign exchange market rate has been uncovered in both the developed and emerging markets as the first stream of literature to study the interaction between macroeconomic variables, commodities and financial markets. Studies on the US economy and the BRICS countries by Nisha (2015) and Gay (2016) all concluded that macroeconomic variables such as gross domestic product (GDP), interest rate and money supply and commodity prices such as oil prices had a significant impact on both markets. It is therefore important from an investment perspective to not only understand the impact but to uncover the second-moment linkages of volatility spillover effects of these macroeconomic variables and commodities on the financial markets given the increased exposure these markets face due to global economic integration (Diebold and Yilmaz, 2012).

The second stream of literature that came after establishing the relationship between macroeconomic variables and financial markets employed different volatility models to examine volatility spillover effects between macroeconomic variables and stock market returns. Earlier work in this regard made use of the Engle (1982) autoregressive conditional heteroscedasticity (ARCH) model under the VAR framework to capture conditional volatility clustering and measure the direction and magnitude of volatility spillovers. In this regard, a notable amount of empirical work has been done both for the developed and developing economies. Diebold and Yilmaz's (2009, 2012) spillover index framework added more dimensions to the volatility spillover studies

enabling researchers to uncover time-varying spillovers within the financial markets providing more insights into second-moment linkages.

Regarding macroeconomic variables, South African inflation has been levelling off between 3.2% and 6.9% stabilising around 4.5% (Miyajima, 2024). Given the inflation target is between 3% and 6%, periods where inflation is volatile and hovering closer to the upper bound tend to bring with them high macroeconomic uncertainty which may induce spillovers to the financial markets. Price stability in South Africa helps to alleviate the problems of price uncertainty making it easier for investors to formulate a well-thought investment strategy and for policymakers to construct sound monetary policy. South African broad money supply, M3, has witnessed a great deal of volatility from 1965 to 2024 with an increase of 7.7% year-on-year being recorded from October 2023 to November 2023 only (Vermeulen, 2024). This level of volatility is bound to spill over to economic and trading activity as the literature section will review.¹

Our focus on gold and oil is not arbitrary but rather derived from the nature in which these two commodities contribute to the economy of South Africa. South Africa is still regarded as one of the top ten gold exporters in the world meaning gold's strong prices would be beneficial for the economy of South Africa and its mining sector returns (Boakye *et al*, 2024). International oil price increases directly and immediately affect South Africa in terms of fuel prices and could also drive up imported inflation. In 2022 alone, South Africa spent USD 4.34 billion on crude petroleum imports pushing it to the 34th largest importer of the commodity (Tambari *et al*, 2024). It is also worth noting it was the 3rd most imported product for South African imports. Such a heavy reliance on the commodity means that negative shocks in its price could lower economic growth, drive up inflation and affect returns on investments. Meng and Chen (2023) define cross-market spillovers as volatility shocks that can spill over from one market to another market. This could be between financial markets such as the stocks market and the foreign exchange market or the commodities market and the stock market. Including gold prices and oil prices in this study will allow us to capture the dynamics of commodity markets and financial markets' volatility spillovers.

¹ See [Erdem *et al* \(2005\)](#) and [Chinzara \(2010\)](#).

1.2 PROBLEM STATEMENT

A thorough understanding of time-varying volatility spillover linkages of macroeconomic variables and commodities with the financial markets of South Africa has critical implications and provides important information for investors and policymakers. Firstly, investors have the paramount goal of maximising returns for their assets whilst minimising both their systematic and unsystematic risk exposure. Financial markets tend to undergo significant changes due to structural changes in the economy, global integration and technology (Diebold and Yilmaz, 2012). This means that investors need up-to-date information on the nexus between financial markets and the real economy to be able to make good returns on their investments.

Secondly, financial stability is of paramount importance to policymakers since it fosters financial system soundness, economic stability and growth and employment creation. If a financial market of an economy is well integrated with the real activity of the economy, then a collapse of the former or any negative shocks would significantly impact the economy threatening financial system stability. In particular, the South African Johannesburg Stock Exchange-(JSE) accounts for 99% of the capital markets value in South Africa making it a more representative measure of full market capital value (Russell, 2023). If this stock market were to crash, it would crumble the capital markets and the extent to which it is integrated with the economy will determine the extent to which the economic shock will be felt. Understanding the volatility spillover nexus between the two would aid in proper policy and regulations construction.

1.3 RESEARCH GOALS

The main goal of this research is to uncover the dynamics of volatility spillover effects of macroeconomic variables and commodities on financial markets for the South African economy.

The sub-goals of this study are thus:

1. To uncover the directional and total spillover effects of macroeconomic variables and commodities on financial markets

2. To determine the net directional spillover effects of macroeconomic variables and commodities on financial markets and determine the significance of pairwise volatility spillover between them.

1.4 JUSTIFICATION FOR THE STUDY

Since increased second-moment linkages between macroeconomic variables, commodities and financial markets have risen due to global trends, it has become more important to understand the nature and extent of volatility spillovers in this context. The direction of volatility spillover effects on financial markets influences investors on the choice of investment strategy and hedging purposes. Policymakers in advanced and emerging economies are always weary of the impact of policy on stock markets given that most of the stock markets in these economies are well established and integrated with the real economy and financial system. It is thus important to understand the connectedness of financial markets and the real economy over time given the linkages are bound to change over time with structural changes and globalisation. For a country like South Africa, the JSE is at the centre of the stock market hence a question needs to be asked on whether it is as integrated with the economy as in other developed and emerging economies or whether most of its returns are determined through its own shocks meaning minimal interdependency.

This study seeks to add to the scant literature that exists on the volatility spillover nexus between macroeconomic determinants, commodities and financial markets for South Africa. Jebran *et al* (2017) attribute the importance of studying volatility spillover effects in financial markets to technological developments, financial deregulation and integration of financial markets and the real economy. These aspects change the dynamics in which both interact with each other as the literature will review. The need to shield assets from risk exposure and continue to make investment gains makes it important for investors to have access to the volatility spillover linkages in financial markets. For policymakers, maintaining a sound financial system is vital especially if the financial markets are well integrated with the economy.

Firstly, it will become apparent in the empirical section of the literature review chapter that most studies focus on the spillover connectedness of the stock market with the real economy without

considering the other financial markets of South Africa. Some of the advanced studies were done in the BRICS context and did not give the volatility spillover dynamics of financial markets in South Africa a fully deserving analysis. This study goes further to include at least two financial markets inclusive of three sectors from the JSE, two crucial commodities for South Africa and two macroeconomic variables.

Secondly, of the studies that carried out similar research to this study, different macroeconomic variables, commodities and stock market sectors were used leaving a gap in the literature for spillover analysis such as that between the JSE mining sector and gold prices or the JSE retail sector and inflation to name a few. Methodologically, studies that employed the same technique as this study were mostly able to capture directional spillovers and their magnitude ignoring total spillovers, net spillovers and time-varying pairwise spillovers. This information is of fundamental importance to both investors and policymakers.

1.5 OUTLINE OF THE STUDY

The chapters are organised as follows: Chapter Two is an overview discussion of trends and linkages of the variables for this study while Chapter Three will review both the theoretical literature and the empirical literature. The empirical literature is divided into three sections for developed economies, developing economies and lastly the South African context with each of the three looking specifically at macro-financial spillovers and cross-market spillovers. Chapter Four gives a formal description of the data for the study and outlines the methodology to meet the goals of this research. Chapter Five presents, interprets and analyses the empirical findings while Chapter Six summarises the key findings and concludes before discussing the implications of the findings and identifying areas of future research.

CHAPTER TWO

SOUTH AFRICAN MACROECONOMIC VARIABLES, COMMODITIES AND FINANCIAL MARKETS TRENDS AND LINKAGES: AN OVERVIEW

2.1 INTRODUCTION

This chapter provides an overview of the trends of macroeconomic variables, commodities and the financial markets of South Africa under study in this research. In this regard, this chapter is divided into three sections. Section 2.2 presents an overview of trends and linkages of the financial markets with gold prices and oil prices. Section 2.3 analyses the trends and linkages of financial markets with inflation and money supply before concluding with Section 2.4.

2.2 FINANCIAL MARKETS AND COMMODITIES TRENDS AND LINKAGES

The South African Stock Market

At the heart of the South African stock market is the Johannesburg Stock Exchange which accounts for 99% of all the stock trading and capital formulation in South Africa (Russell, 2023). The JSE boasts of being the biggest stock exchange on the African Continent and is well considered amongst the world's best for its size, complexity, standardisation and regulation. The exchange caters to both large caps firms and the small to medium caps through its main board and AltX parallel market for inclusivity (Russell, 2023). Trading on the exchange is standardised making the stock market a more reliable platform for raising capital for both individuals and organisations. Returns for the JSE are captured through the JSE All Share index which encompasses all the sectors of the economy such as the mining sector and the retailer sectors which individually have their own indices. Since the JSE includes all sectors of the economy, its returns are dependent on the performance of these sectors and the dynamics of which sector contributes the most towards stock market returns differ per structure of the economy. The JSE returns have shown resilience post the pandemic witnessing a 12.2% year-on-year increase in cents per share in 2023 from 2022

despite investors' global uncertainty and asset allocation shifts (Bloomberg, 2024). Trends of how the JSE All Share index paired with the other sectors of this study are in [Appendix A.1](#).

The South African Foreign Exchange Market

Since South Africa plays a crucial role in global gold supplies and oil imports, it comes as no surprise that 80% of the trading in the Rand is done outside of the country (Phume, 2023). Turnover for the Rand trading has continued to decline significantly post the pandemic as noticed in other pair-levelled countries such as Mexico and Turkey (Chen *et al*, 2022). This turnover is mostly driven by swaps derivatives for which obstacles such as the successive sovereign debt and credit ratings downgrade since 2014 do not favour. Dealings with the currency in over-the-counter foreign exchange markets have also witnessed significant declines due to unfavourable economic conditions. However, all is not gloomy as the pairwise currencies of the US dollar and the Rand remain the most traded currency pair reaching levels of 75% in 2022 (Phume, 2023). The US dollar has continued to dominate trading in the world and act as a benchmark for currency value. For investors, the strength of the local currency impacts their choice of investment when trading in forex or even stocks as South Africa is an active trader of goods and services on the global platform. Policymakers are often weary of what the value of the currency could do to investor confidence, inflation and the import bill.

Gold prices

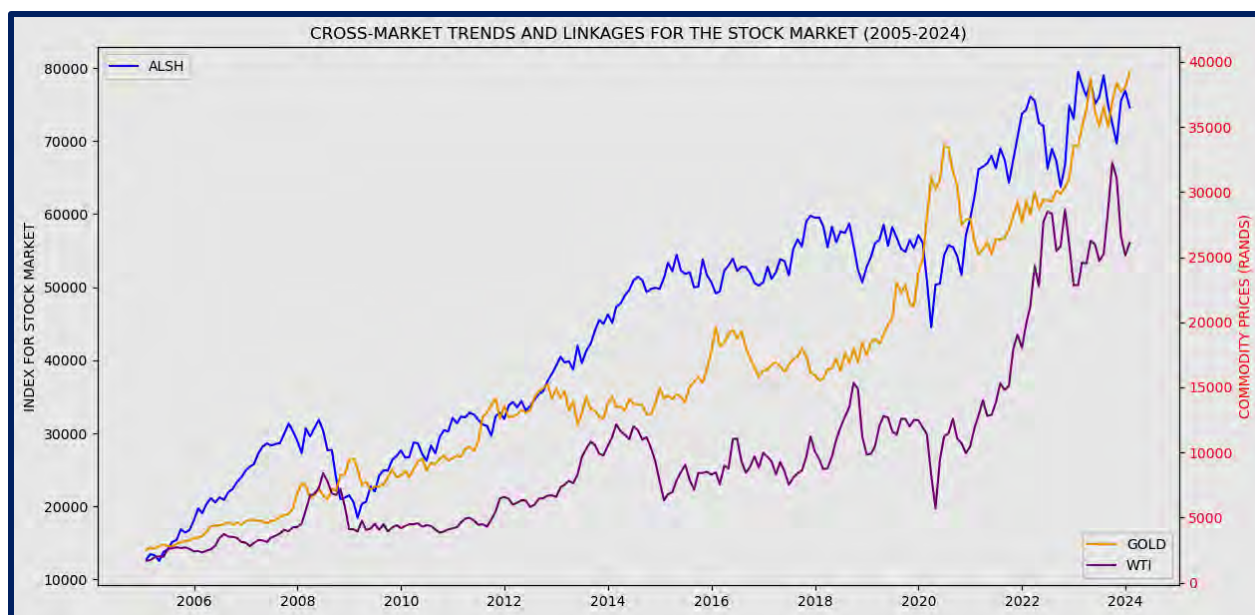
In 2022 alone, South Africa made USD 22.7 billion worth of gold exports alone moving it to the 5th largest exporter of the commodity globally (World Bank, 2024). It comes as no surprise that it was the most exported product from South Africa during that year and has continued to dominate exports over time. It is worth noting that South Africa also imports the commodity ranking 22nd largest importer of the product in 2022 (World Bank, 2024). This makes the commodity a crucial part of economic growth and foreign currency generation through exports. Gold has long been used by investors as a hedge for inflationary economic conditions and to store wealth parallel to the domestic currency. International gold prices have thus been good indicators of global economic outlook and growth.

Oil prices

South Africa derives its energy products mainly from fossil fuels such as natural gas, coal and oil. The country however has limited resources of oil and hence resorts to importing the product. The country imports both Brent crude oil and WTI crude oil although dominantly BRENT crude oil given most of the imports come from Nigeria and Saudi Arabia (OEC², 2023). As discussed earlier, the country is 34th in global oil imports in 2022 alone with oil imports amounting to USD 4.34 billion (Tambari *et al*, 2024). The commodity ranked 3rd among the largest imports of South Africa making it a crucial commodity for the economy and worthy for investors and policymakers to keep track of (Tambari *et al*, 2024). Since crude petroleum drives most of the automotive and other industrial production industries in South Africa, price changes of the commodity are bound to impact operational costs for these industries and at end revenues. Investors would be weary of their returns from these industries whilst policymakers are concerned about the impact on economic output. Trends of how WTI crude oil prices are paired with Brent crude oil prices are in [Appendix A.1](#).

FIG 2.1

Stock Market and Commodities Trends



Source: Author's computation based on data obtained from the London Stock Exchange Group and World Bank

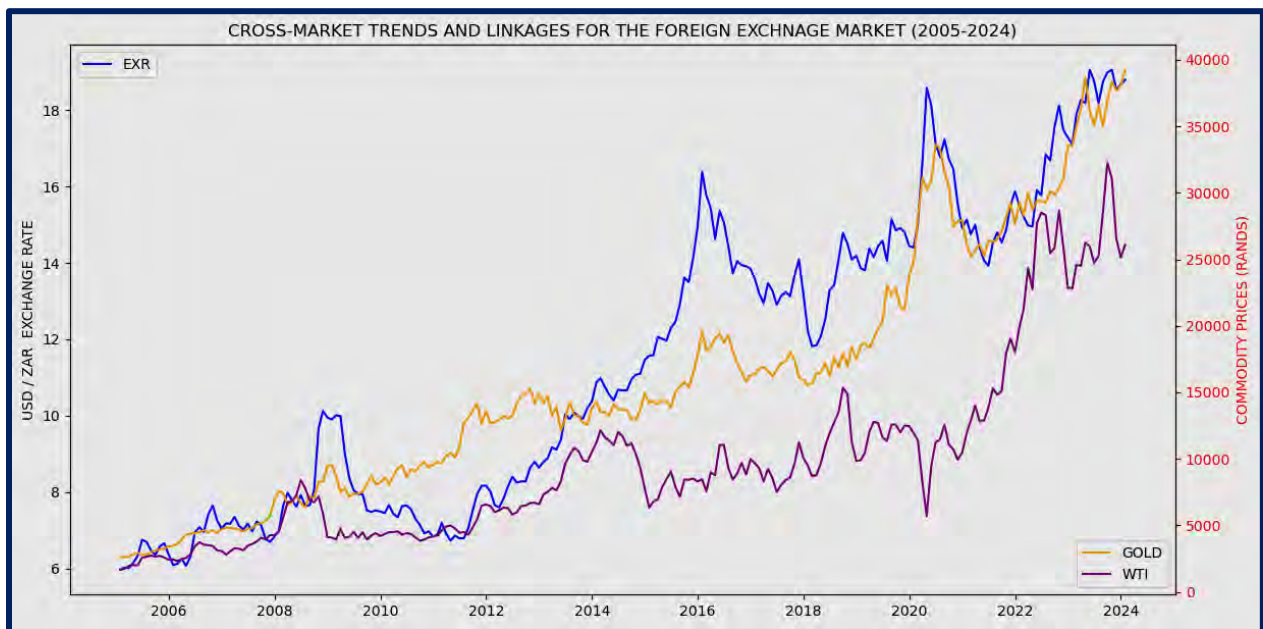
Notes: ALSH is the JSE All Share Index, WTI is the Western Taxes Intermediate crude oil price per barrel and GOLD represents international gold prices per troy ounce.

² Observatory of Economic Complexity.

The JSE ALSH index has had an upward trend from 2005 to 2024 with noticeable sharp rises during the Global Financial Crisis and after 2020. Both gold price and oil prices witnessed a sharp rise post 2020 which was in line with the JSE ALSH which could indicate the existence of a strong relationship. The general positive correlation growth trends between the gold price and the stock market index could point towards a heavy reliance of the stock market on the precious metal. There was however an inverse trend between gold prices and the stock market performance around 2020. This may be attributed to the pandemic-induced economic downturn where investors preferred to store their wealth in the precious metal as opposed to currency-based assets given that the Rand depreciated a lot around the same period as we will see below. The sharp drop in oil prices around 2020 can be attributed to the drop in demand for the commodity due to low economic activity. Both commodities in this case have remained highly volatile much like the stock market which could increase the dynamics of volatility spillovers.

FIG 2.2

Foreign Exchange Market and Commodities Trends



Source: Author’s computation based on data obtained from the London Stock Exchange Group and World Bank
Notes: EXR is the USD/ZAR exchange rate, WTI I is the Western Texas Intermediate crude oil price per barrel and GOLD represents the international gold price per troy ounce.

Both gold price and the exchange rate seem to have significantly correlated spikes during similar periods such as 2016 and the immediate period after 2020. The Rand is losing its value as gold

price increases. This points to the inverse relationship between currencies and gold prices as investors tend to use both as a store of value with gold being the preferential during times of economic turmoil. Both witnessed a significant increase post the COVID-19 pandemic in which case the Rand was depreciating against the Dollar whilst gold prices went up. Oil price has remained volatile also witnessing a sharp rise post 2020. The upward trend is noticed for all the above variables which for commodities could mean they may be feeding into the depreciation of the Rand. It comes as no surprise that gold prices have continued to rally post the pandemic given the global weakening of currencies as a store of value for investors. The Rand has remained volatile and exposed to global economic trends coupled with imported inflation and the sovereign debt hurting the country.

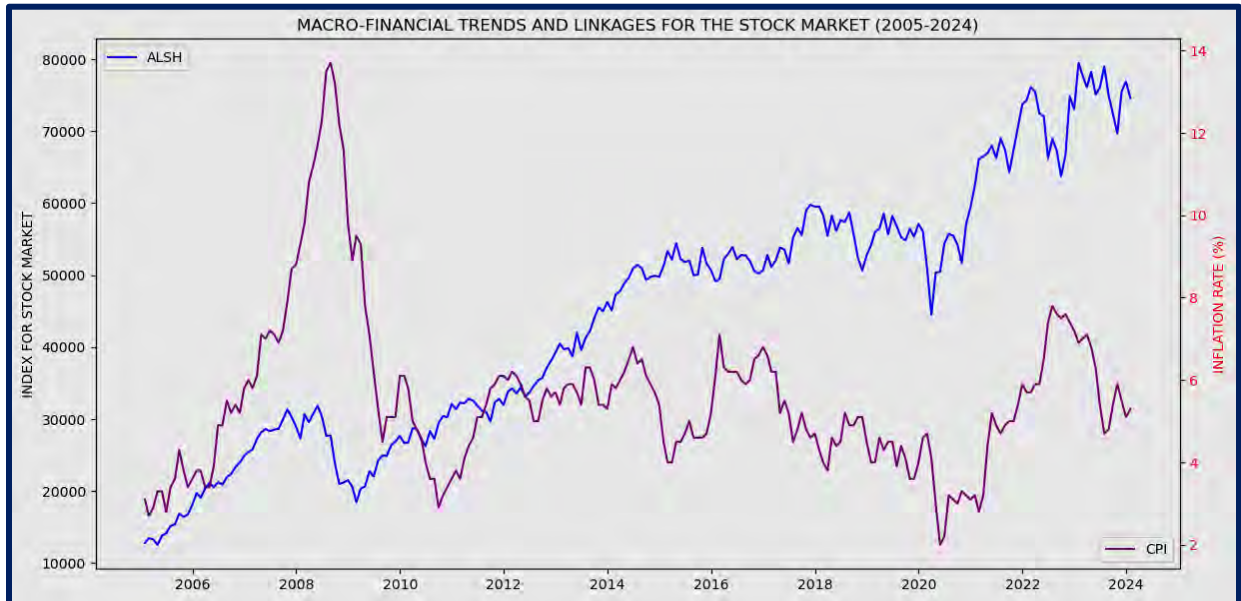
2.3 FINANCIAL MARKETS AND MACROECONOMIC VARIABLES TRENDS AND LINKAGES

South Africa Inflation Trend

It will become apparent in the literature review that one of the most studied macroeconomic variable and the nature of its impact on financial markets is inflation. Whilst inflation is simply the general rise in the price of both goods and services overtime, it has the capability to erode both savings and investments by weakening the value of a currency. To this end, investors often make use of hedging tactics which may include the use of derivatives to limit the exposure to general price rise. On the other hand, policymakers in South Africa made a crucial move to introduce an inflation target which would enable the Monetary Policy Committee to try and maintain inflation levels between 3% and 6% (Ndou and Gumata, 2024). The policy move came with accountability and transparency in policy implementation which fostered a degree of certainty for investors. This would cushion more effective investment strategy construction and portfolio management with some knowledge of how monetary policy would react to any unfavourable inflation changes.

FIG 2.3

Stock Market-Inflation Trend and Linkages



Source: Author's computation based on data obtained from the London Stock Exchange Group.

Notes: ALSH is the JSE All Share Index and CPI is the Consumer Price Index representing the inflation rate for South Africa.

The JSE ALSH and CPI both witnessed a sharp rise during the GFC of 2008 reaching levels of 30 000 and 14% respectively. Post the GFC, inflation has remained between 2% and 8% despite the inflation target which is between 3% and 6%. It is worth noting that despite the movements in inflation before the GFC of 2008, the stock market was not as responsive to these movements in comparison to the period after the GFC where it became more volatile. This may indicate a heavy reliance on minerals such as gold in the stock market as the mineral prices are not significantly exposed to inflation unlike financial assets. This could point towards the JSE becoming a more integral part of South Africa's economic activity. The sharp rise in inflation post-2020 meant that the returns for the JSE ALSH experienced inflationary growth which would erode investor's holdings and savings in real terms.

FIG 2.4

Foreign Exchange Market-Inflation Trend and Linkages



Source: Author’s computation based on data obtained from the London Stock Exchange Group.

Notes: EXR is the USD/ZAR exchange rate and CPI is the Consumer Price Index which represents the inflation rate for South Africa.

There appears to be a positive correlation between the two trends except for the immediate period before 2016 and the immediate period after 2020 where there was a significant diversion. This general positive correlation between the exchange rate and inflation means that if inflation goes up, the Rand will depreciate. The significant diversion between the two trends means that other factors and not inflation can be attributed to the fall in value of the Rand and other factors besides the exchange rate can be attributed to the rise in inflation in certain times. Notably, there was a sharp fall in inflation due to low economic activity during 2020 accompanied by a sharp decline of the Rand value. A different scenario however played out during the 2008 GFC where both the Rand and inflation had an upward trend due to a rapid decline in the Rand value accompanied by the sharp rise of prices as economic activity persisted.

Broad Money Supply Trend

World Bank (2024) defines broad money supply (M3) as the sum of currency outside banks, demand deposits other than those belonging to the government, time savings, foreign currency deposits other than those of the government, traveller’s and bank checks and other securities such

as certificates of deposits (COD). In the case of South Africa, the SARB defines broad money supply (M3) as the total amount of money circulating within the country, including cash, long-term deposits, certificates of deposit, and other less liquid assets. Since these definitions includes securities such as CODs and commercial paper, the introduction and growth in financial instruments and technology mean that more of these products would be contributing to the growth of money supply in an economy. Policymakers often have preferred trends in money supply depending on macroeconomic outlooks on whether to adopt a contractionary monetary policy or expansionary monetary policy. Inflationary conditions in the economy may undermine the true value of money supply in the economy although the two have a reciprocal causal relationship (Gharehgozli and Suhyung, 2022). A growth of money supply under low inflation conditions would avail more liquidity to investors for trading in the stock market although it may negatively impact the foreign exchange market because of the negative relationship between the two.

FIG 2.5

Stock Market-Money Supply Trend and Linkages



Source: Author’s computation based on data obtained from the London Stock Exchange Group.

Notes: ALSH is the JSE All Share Index and M3 is the broad money supply for South Africa.

Money supply trend has consistently remained upward from 2005 to 2024 breaching the ZAR 5 trillion mark in the latter year. This continuous upward trend is a similar trend witnessed by the JSE ALSH index which could imply a significant positive correlation between the two although

not in real inflation terms. The relationship could also be reciprocal where more money in the economy enables more investment into the stock market whilst more investment in capital markets results in the creation of more money coupled with the creation of new financial instruments that fall under the broad definition of money supply.

FIG 2.6

Foreign Exchange Market-Money Supply Trend and Linkages



Source: Author’s computation based on data obtained from the London Stock Exchange Group.
Notes: EXR is the USD/ZAR exchange rate and M3 is the broad money supply for South Africa.

Both trends seem to have a positive correlation for the rest of the period. Money supply can thus be attributed to the loss of value of the Rand to a certain extent although the impact might be less significant in real terms when accounting for inflation. Since this correlation persisted until the USD/ZAR 18 levels for the exchange rate, one can assume that this relationship dynamics is consistent during times of economic boom and turmoil.

2.4 CONCLUSION

This chapter has examined the nine variables that constitute the focus of this study under the categories of macroeconomic variables, commodity prices and financial markets. What has emerged from the presentations above is that all variables have continued to show trends that are

either a result of the other or other factors outside the scope of this study. Variables such as inflation and gold prices seem to have a directional volatile impact on the financial markets, the dynamics of which will be revealed by this study. Since these linkages seem to exist at a par level, it would be justified to study the effects of their volatility especially on the financial markets as is the focus of this study and determine how well these variables are connected to each other.

CHAPTER THREE

THEORETICAL AND EMPIRICAL LITERATURE REVIEW

3.1 INTRODUCTION

This chapter reviews both the theoretical and empirical literature on the volatility spillover effects to the financial markets, primarily focusing on the shocks transmitted from the macroeconomic variables and commodities being used for this study. The first section discusses the theoretical disposition of the relationship between financial markets, macroeconomic variables and commodities. Secondly, we discuss the empirical findings of the dynamics of volatility spillovers on financial markets for both developed and developing economies before looking at South Africa in isolation.

3.2 THEORETICAL LITERATURE

The increased globalisation and convergence of economies have raised the need to monitor the risk associated with financial markets closely (Asis *et al*, 2020). The vulnerability of emerging markets like South Africa to external shocks raises more concern for investors seeking to minimise both foreign and domestic risk exposure for their assets (Asis *et al*, 2020).

Building on Markowitz's (1952,1959) work, Sharpe (1964), Lintner (1965) and Mossin (1966) independently proposed the Capital Asset Pricing Model (CAPM) further approved by Fama and MacBeth (1973). The model argues that a risk-free asset means an investor has a certain guaranteed level of return without taking any risk and hence would need to take up some unsystematic market risk to earn more returns. The theory assumes that individual investors choose portfolios that they perceive to be mean-variance efficient hence they will always try and minimise risk whilst ensuring good returns. It is thus important to understand how macroeconomic variables that present risk to financial markets interact together during normal economic activities and times of structural breaks. The international single-factor CAPM is given as follows:

$$\bar{R}_i = R_F + \left(\frac{\bar{R}_M - R_F}{\sigma_M^2} \right) \sigma_{iM} \quad (1)$$

\bar{R}_i are the returns for a portfolio determined by the risk-free asset, R_F , market returns, \bar{R}_M and risk σ with the single-systematic risk for the asset i classified as σ_{iM} . The underlying assumption of the CAPM is that in an efficient market where most information is available, all unsystematic risk such as that of exposure to commodity price movements or macroeconomic uncertainty risk can be diversified away so that the only risk that would remain in the portfolio is the systematic risk σ_{iM} (Engle *et al*, 1988). Both macroeconomic uncertainty and commodity price movements often cause systematic risk for most assets meaning that investment strategies are heavily reliant on both hence considering only one source of systematic risk for an investment strategy is not ideal. The relevance of using the CAPM model in South Africa to determine returns was found in the study of Peerbhai and Strydom (2018). The study found that using the CAPM, more specifically the International CAPM as opposed to the domestic index for the CAPM was more appropriate in estimating returns for the firms in South Africa which had practical implications for investors and analysts. This was because the international CAPM accounted for more diversifiable risk than the domestic index meaning a better investment strategy could be adopted in constructing a portfolio with superior returns since foreign risk had been accounted for.

While the CAPM, was able to capture the linear relationship between portfolio betas and returns, some authors such as Black (1972) argued that the model was too simplistic in its approach to assessing the risk-return relationship between asset returns and risk. Ross (1976a) proposed a completely different model from the CAPM, the Arbitrage Pricing Theory (APT). The APT theory assumes that an unspecified number of variables can cause systematic asset return deviations from expectations. As opposed to the CAPM which argues for only one type of systematic risk that cannot be diversified away in a portfolio Ross (1976a), the APT theory proposes more than one source of systematic risk that an asset may have hence the greater need to diversify a portfolio. The theory also suggested that investors could engage in arbitrage in different markets that do not have the same systematic risk and earn abnormal profits. The specification of the APT is as follows:

$$R_i = a_i + b_{i1}I_1 + b_{i2}I_2 \dots b_{ij}I_j + e_i \quad (2)$$

a_i is the expected level of returns for an asset i in the absence of all systematic risk³. I_j represents the systematic risk index coming from either macroeconomic uncertainty or commodity price movements and unlike in the CAPM, there is more than one source of systematic risk in this model. b_{ij} is the sensitivity of the stock to each source of systematic risk whilst e_i is the random error term.

Since equation (2) holds in determining the returns of a single asset when considering more than one source of systematic risk, it is rational that this model would be a better predictor of asset returns. While it is enough to determine the exposure from these systematic risks, economic trends and globalisation raise questions such as the time-varying effect of macroeconomic variables and commodity price movements on financial markets in terms of second-moment volatility spillover linkages, which this study will empirically address for South Africa.

The APT theory's applicability relies on how well information is easily accessible to investors as categorised by the Efficiency Market Hypothesis (EMH) of Fama (1970). One of the assumptions of the APT is that there is no long-run arbitrage in the market as any asset mispricing is immediately exploited such that abnormal returns are eroded. Fama (1970) distinguished market efficiency into three levels through considering different types of information. The first one was the weak form of the EMH which asserts that asset prices fully reflected all historical sequences that may affect their value. This would mean the current information on macroeconomic fundamentals, commodity price movements and firm-specific risk is not priced into the assets, presenting arbitrage opportunities and also more risk on assets. The second category is the semi-strong form of EMH which posits that current asset prices are reflective of both historical information and current publicly available information presenting less prospects for arbitrage than the weak form. The last form of market efficiency is the strong form of EMH which postulates that asset prices are reflective not only of the historical and current publicly available information but also of private information that can give investors an edge for superior gains (Malkiel, 1989:127). This would dampen the prospects of arbitration as supported by the APT theory as all the information is priced into an asset and investors can only make short-run abnormal returns on asset

³ Similar to the risk-free returns in the CAPM model.

mispricing. It thus makes it important to understand volatility spillover linkages of the sources of systematic risk for assets to be able to make these short-run gains and most importantly shield assets returns from real economic sources of risk.

The debate as to which model has better prediction ability for firm returns has been ongoing in several directions. Most of the criticism rendered against the CAPM is for its assumptions that are too simplistic such as ignoring taxes and transaction costs (Watson and Head, 1998). It is for this reason the APT has been considered a better model for predicting returns although literature deems it a subjective case depending on the industry in which the firm is in or the economy (Jugu and Amodu, 2014). Wahyuni and Gunarsih (2020) found that the CAPM model was more precise in modelling returns than the APT model for the construction companies listed on the Indonesia Stock Exchange. This may be expected as these companies are likely to face similar systematic risks from being in the same industry.

3.3 EMPIRICAL LITERATURE

The literature review section will be threefold starting with the focus on the relationship between macroeconomic variables, commodities and financial markets before discussing the empirical studies on the volatility spillover effects on financial markets for both developed and developing economies. The last segment will be on previous studies on the volatility spillover effects of macroeconomic variables and commodities on the financial markets in South Africa with a focus on the equity market and the foreign exchange market.

3.4 RELATIONSHIP BETWEEN MACROECONOMIC VARIABLES, COMMODITIES AND THE STOCK MARKET

The first wave of literature concerning the interaction between macroeconomic variables, commodities and financial markets was to uncover the relationship that existed between them. Most of the studies employed common techniques to uncover causality such as the Granger (1969) Causality test and the Johansen (1991) Cointegration test framework. Adequate work has been done for both the developed and developing economies with regard to investigating the relationship between the macroeconomic variables and the concerned financial markets. Early

work was done in developed economies such as the study in US and Japan conducted by Humpe and Macmillan (2009) using monthly data under the Johansen (1991) Cointegration approach which showed that industrial production, the consumer price index, money supply, long-term interest rates and stock prices in these countries had a positive significant impact on each other although money supply did not have a significant impact. Out of these variables, consumer price index and long-term interest rates had a negative impact on stock prices. These first-moment linkages build a foundation on how the second-moment linkages of volatility spillovers are determined. In terms of developing economies, studies such as those by Nisha (2015) and Gay (2016) all concluded that macroeconomic variables such as gross domestic product (GDP), interest rate and money supply had a significant impact on both the equities market and the foreign exchange market on a monthly basis when employing the Johansen (1991) Cointegration approach. The study of Gay (2016) however did not find a significant impact of oil price on the stock market index returns for any of the BRICS countries which may have been due to other domestic factors such as the dependency on oil for energy and or other international macroeconomic factors.

3.5 RELATIONSHIP BETWEEN MACROECONOMIC VARIABLES, COMMODITIES AND THE FOREIGN EXCHANGE MARKET

Regarding the foreign exchange market, Ramasamy and Abar (2015) did a study for Australia, the United States and Germany using the Johansen (1991) approach to uncover the relationship between interest rate, inflation, employment levels and the USD-based exchange rate. Interest rates and inflation had a long-run significant negative impact on the exchange rate whilst the other variables had a positive relationship. Ouedraogo (2018) also did a study for Brazil, South Africa, Germany and the United Kingdom to assess the relationship between macroeconomic variables and the foreign exchange rate. Using the Johansen (1991) test for cointegration framework, the Granger (1969) causality test and the variance decomposition, the study found that macroeconomic variables such as interest rates, inflation, money supply, and trade balances have a significant impact on the exchange rate of these economies when using the US dollar as the base currency. It is therefore important from an investment perspective to understand the impact and uncover the volatility spillover effects between these macroeconomic variables and the financial markets given the increased exposure these markets face due to global economic integration.

3.6 MACROECONOMIC VARIABLES, COMMODITIES AND THE STOCK MARKETS FOR DEVELOPED ECONOMIES

3.6.1 Cross-market volatility spillovers:

Arouri, Jouini and Nguyen (2011), investigated the volatility spillover effects between oil prices and stock returns from selected sectors. The study employed the VAR-GARCH using monthly data for the automobile and parts, financials, industrials, basic materials, technology, telecommunications, utilities sectors, the S&P 500 index and Dow Jones (DJ) Stoxx Europe 600 index for the United States and Europe consecutively. Their research found significant unidirectional volatility spillover effects from oil prices to the stock market and the selected sectors in Europe whilst it is bidirectional in the United States. These findings proposed that investors in these sectors had different exposures in terms of risk in both markets. Summer, Johnson and Soenen (2011) investigated the volatility spillover effects amongst gold prices, the stock market and the bond market using the Diebold and Yilmaz (2012) spillover index. Using weekly data for the U.S bond market, stock market and gold price, their research found that there existed significant spillover effects between the bond market and the stock market of the United States. The non-existence of significant spillover effects from gold prices to the stock market however raised questions as to whether gold price volatility can be used as a predictor to determine stock prices. Different conclusions have however been reached in other countries as discussed below. Ewinga and Malik (2015), investigated the volatility spillovers between oil prices and the stock market under structural breaks in the United States. Using monthly data for both the univariate and bivariate GARCH models, their research found that volatility spillover effects were present when they accounted for the structural breaks in the model and no volatility spillover effects existed when structural breaks were ignored in the variance.

Khalifaoui *et al* (2015), investigated the volatility spillover effects between oil prices and the stock markets for the G-7 countries. Warranted by the increasing importance of oil prices, the research employed daily data for both the oil prices and the stock prices using both the multivariate GARCH models and wavelet analysis: wavelet-based MGARCH approach. The research found that there were significant volatility spillovers between the oil price and the stock markets for the countries coupled with time-varying correlations for various market pairs. The extent to which the stock market of an economy responds to the volatility in oil prices however depends on whether the

country imports or exports oil. Oil-importing countries have their stock markets severely affected by the volatility in oil prices as proven in the study by Khalfaoui *et al* (2019). Husaina *et al* (2019), using the Diebold and Yilmaz (2012) spillover index, found that gold price was one of the strongest contributors to the volatility experienced in the stock market although the spillovers from the stock market to the gold prices were marginal for the monthly US data.

Liao *et al* (2021) investigated the volatility nexus between gold prices, oil prices and the stock market returns of developed economies such as the United States, Germany and Britain. The research used daily data for the period January 2000 to July 2020 allowing them to capture the disturbance of the pandemic. Employing the Diebold and Yilmaz (2012) spillover index, the results of the research found that there still existed a significant bidirectional volatility spillover effect amongst the stock markets of these countries and the gold prices and oil prices. Similar findings were found when Elgammal *et al* (2021) did a study on both the global equity markets and the gold markets in the US using the bi-variate GARCH approach. A significant bidirectional volatility spillover effect persisted between the global equity markets and the gold markets raising expectations that a likely picture might be seen looking into the individual countries.

Chen and Zhang (2023) investigate the effect of crude oil price shocks given the global price rise the commodity has been witnessing and the volatility spillovers to the stock markets for countries such as Canada and the United States. The research employed the DCC-GARCH model and the asymmetric BEKK-GARCH model to capture the increasing volatility of global oil prices. The results indicated a significant volatility spillover effect from oil price movements to the stock markets. Demand shocks proved to produce more volatility spillover effects as compared to the supply shock. Crude oil importers continued to be at higher risk of price fluctuations in comparison to the oil-exporting economies. However, the extent to which an oil-exporting economy is shielded from volatility spillovers from oil price fluctuations depends on the size of contributions that oil exports have on the economy's balance sheet.

3.6.2 Macro-financial volatility spillovers:

Bekaer *et al* (2013) describe macro-financial volatility spillovers as the influence that both macroeconomic uncertainty and financial markets have on each other. This can be between the Consumer Price Index and the stock market or forex market. Cotter *et al* (2023) attribute it to the

spillovers that occur between the real side of the economy and the economy of a country. Regarding money supply and inflation, Abbas *et al* (2019) did a robust study by analysing the volatility spillover effects between stock markets and macroeconomic factors in the G-7 countries. The research used monthly data for macroeconomic variables such as money supply, Consumer Price Index (CPI) and Industrial Production Index (IPI) and also for the stock market indices. Using the Diebold and Yilmaz (2012) volatility spillover index, bidirectional volatility spillover effects were found between all the macroeconomic variables and the stock markets of the separate countries. The research also found time-varying changes in the dynamics of the volatility spillover connectedness of the macroeconomic variables and the stock market.

Jiang *et al* (2024) investigated whether higher inflation generates more volatility in the stock market in Greece. Employing the quantile VAR approach, their research showed that during periods of high persistent inflation, there was more volatility spillover to the Greek stock market. What is however clear is that the volatility spillover effects between microeconomic variables and financial markets have remained significant in both ways over time.

3.7 MACROECONOMIC VARIABLES, COMMODITIES AND THE FOREIGN EXCHANGE MARKETS FOR DEVELOPED ECONOMIES

3.7.1 Cross-market volatility spillovers:

Most of the studies do not focus on the foreign exchange markets as a dependent variable but rather the independent variables in comparison with the stock market. This is rightly so as most of the time the exchange rate is used as a macroeconomic variable influencing a certain financial market. However, a few studies have been carried out for both the developed and developing economies with a focus on the foreign exchange market as a dependent variable. Zhang *et al* (2008) study concluded that there were strong volatility linkages between oil prices and the currency markets for the United States when they employed the ARCH model and the test for Granger causality. Antonakakis and Kizys (2015) investigate the volatility spillover effects between commodities such as gold and crude oil and the U.S. dollar-based exchange rate for the Euro currency, Japanese Yen, Swiss Franc and the British pound. Using weekly data, the study employs the Diebold and Yilmaz (2012) spillover index to measure the returns volatility spillover amongst the variables. The research found a significant bidirectional volatility spillover between the commodities and the

currency exchange rates under study. Mensia, (2017) investigated the volatility spillover effects between oil prices and the foreign exchange market in the United States. Using daily datasets for both variables, the study employed the Diebold and Yilmaz (2012) spillover index and the findings concluding that there existed strong evidence of time-varying volatility spillover between oil price and foreign exchange markets in the United States.

Lee and Kim (2023) investigated how oil price uncertainty generates volatility spillovers to financial markets like the foreign exchange market for the United States. The research extended on the Diebold and Yilmaz (2012) spillover index to be able to capture volatility in periods of high oil price volatility by employing the Markov switching model. The research found that oil prices spill the highest degree of volatility to the financial markets during periods of economic turmoil such as the GFC and the COVID-19 pandemic. The research into how oil price fluctuations affect both the oil-importing economies and the oil-exporting economies has witnessed increased attention since the cut in the commodity supply by OPEC and the recent Russia-Ukraine conflict. Zhu *et al* (2023) undertook to investigate spillover connectedness between oil prices and the exchange rate for oil-importing countries such as Japan and oil-exporting economies such as Canada. A quantile VAR approach to determine the spillover effects of oil price movements during periods of high economic uncertainty was adopted for the study. The research found that oil price movements have a higher spillover to the exchange rates in oil-exporting economies in comparison to the oil importers. The researcher also found that currencies for the oil-importing economies act as more of risk exposure receivers in comparison to the oil exporting economies.

3.8 MACROECONOMIC VARIABLES, COMMODITIES AND THE STOCK MARKETS FOR DEVELOPING ECONOMIES.

3.8.1 Cross-market volatility spillovers:

A fair number of studies have been conducted concerning emerging economies in comparison to developed economies. Developing economies are usually on the receiving end of the volatility spillovers from the developed economies both for the economies and the financial markets as stipulated in (Grosvenor and Greenidge, 2012; Li and Giles, 2015). Gencer and Musoglu (2015) investigated the volatility spillover effects amongst gold prices, bond prices and stock prices movements in Turkey. Daily data was used for the 10-year bond prices, the composite stock market

index of Borsa Istanbul (BIST100) and gold prices. Employing the BEKK-GARCH model, the research found a unidirectional volatility transmission from gold prices to bond prices whilst a bidirectional volatility transmission was found to be significant between gold prices and the stock market prices. These findings differ from what was found in the United States economy signifying better prospects for portfolio diversification in the United States. Arouri, Lahiani and Nguyen (2015), confirmed a bidirectional volatility spillover effect between gold prices and stock prices in China when they employed the multivariate GARCH models using daily stock prices and gold prices. When employing the generalized autoregressive conditional heteroskedasticity GARCH (1,1), Afsal and Haque (2016) found that there was no volatility spillover effects between the gold price and the stock market of Saudi Arabia. These findings may however differ if the extended models of the GARCH models are used.

Bagchi (2017) investigated the volatility spillover effects between oil prices and the stock markets of the BRIC (Brazil, Russia, India and China) economies. The author adopted the Asymmetric Power ARCH (APARCH) model to capture the long memory of the interaction between the variables and capture any leverage effects. The research found a strong and long-term memory in the volatility spillover effects between oil prices and the stock market returns for the BRIC countries. This was as expected as all these countries, besides Russia, are heavy oil importers. In the same year Boubaker and Raza (2017) adopted the multivariate ARMA-GARCH model and wavelet multiresolution analysis to investigate the volatility spillover effects between oil prices and the stock market returns for the BRIC countries. Using daily data, the research findings were well aligned with those of Bagchi (2017) with a bidirectional volatility spillover relationship found between the two variables. However, claims of only the large oil importers being the most vulnerable to oil price movements were refuted by authors such as Maghyereh *et al* (2017) who discovered that large oil exporters such as Saudi Arabia and the United Arab Emirates (UAE) experienced high volatility spillover effects from oil price movements to their stock markets.

Singhal *et al* (2019) investigated the volatility spillover effects between international gold prices and the stock market in Mexico. Using daily data, the research found significant volatility spillover effects from gold price to the stock market of Mexico. Diversification opportunities can exist in other economies if there exist no significant volatility spillover effects between gold price movements and the stock market hence the need for continuous research. Those economies that

largely export precious metals such as gold experience higher volatility spillover from gold prices to the stock market. Mensi *et al* (2021) concluded that precious metals such as gold contributed more to the forecasting variance for stock markets in those economies that are larger exporters of the minerals as compared to the importers of these metals as it offsets most a big portion of their balance sheets. The momentum of research for the interaction between macroeconomic variables and the financial markets has carried on beyond the COVID-19 pandemic.

Most of the econometric models to analyse volatility spillover effects have since been adopted for the emerging economies improving on the robustness and meaning of the results for studies done in developing economies. Kumar, Singh and Kumar (2021) investigated the volatility spillover effects amongst crude oil prices, gold prices and the stock market in India. The research employed the exponential generalized autoregressive conditional heteroscedastic (EGARCH) model to generate the volatility series for the data. The research found no volatility spillover from both gold prices and oil prices to the stock market of the country or vice versa. Mo, Meng and Wang (2023) investigated the volatility spillover effects between Crude oil prices and the Chinese stock market. Employing the time-varying Copula model and the conditional value-at-risk approach, the research found significant downside spillover effects from crude oil prices on the Chinese stock market are larger than the upside spillover effect. This has implications for investors as this means the Chinese stock market reacts differently in times of oil price increase decrease.

Sahadudheen and Kumar (2023) investigated the volatility spillover effects amongst oil prices, gold prices and the stock market in India. Based on the vector autoregression, the returns and volatility spillovers obtained from forecasted error variance decomposition indicated that volatility spillover between the commodities and the stock market remains low but was however high during the global financial crisis and the COVID-19 pandemic. India seems to have a unique case of having low volatility spillover between macroeconomic variables and the stock market during normal economic activity.

3.8.2 Macro-financial volatility spillovers:

Earlier work was done by Erdem *et al* (2005) in Turkey to investigate the volatility spillover effects of macroeconomic variables on the Istanbul stock exchange indexes. Using monthly data for the Exponential Generalized Autoregressive Conditional Heteroscedasticity (EGARCH) model, their research concluded that there existed a strong unidirectional volatility spillover from inflation and

interest rate to the stock market indexes. There was however no volatility spillover effects from industrial production to the stock market. Aliyu (2012) investigated whether inflation had volatility spillover effects on the stock markets of Nigeria and Ghana using monthly inflation data with the Consumer Price Index as the proxy. The research applied generalized autoregressive conditional heteroscedasticity (GARCH) to capture the volatility clustering and monthly data for the stock returns. The study found that volatility spillover effects were present from inflation to both the stock markets

Abbas *et al* (2019) investigated the volatility nexus between macroeconomic fundamentals and the stock market in China. Monthly data was used for macroeconomic variables such as industrial production index (IPI), money supply, consumer price index, gold price and oil price. Employing the Diebold and Yilmaz (2012) volatility spillover index, their research concluded that most of these macroeconomic variables were net receivers of the volatility spillover from the stock market rather than vice versa. This proves that money supply can be useful in forecasting the variance in stock markets. Significant volatility spillover effects between monetary policy and the stock market were also found when Balcilar *et al* (2020) employed Diebold and Yilmaz (2012) to study the United States stock market.

Aawaar *et al*, (2023) investigated the determinants of equity returns volatility in the African stock markets using monthly data. The research models went through iterations to find the best fit for each volatility series with models such as the ARCH, EGARCH and GJR-GARCH being tested. The research found that macroeconomic variables such as Treasury bill rates, money supply, inflation rates and movements in world crude oil prices had volatility spillover to the African equity markets. The research also found that African stock markets became more sensitive during the global financial crisis and have remained so. Exchange rates have remained a significant spillover to stock market returns although countries in North Africa are more shielded from this risk.

3.9 MACROECONOMIC VARIABLES, COMMODITIES AND THE FOREIGN EXCHANGE MARKETS FOR DEVELOPING ECONOMIES.

3.9.1 Cross-market volatility spillovers:

As discussed above, most of the studies about the exchange rate as a proxy for the foreign exchange market and macroeconomic variables focus on the exchange rate as an independent variable and

not a dependent variable. The interpretation and discussion of the results when the exchange rate is an independent variable however still provides helpful insights to our research. Mishra and Debasish (2017) analysed the volatility spillover effects between oil prices and the U.S. dollar exchange rate in India for the period June 2003 to March 2016. The research employed both the GARCH and the EGARCH models and the study found that there existed significant volatility spillover effects between oil prices and the exchange rate of the country.

Commodities such as gold form part of most African countries' exports and the changes in its price will likely affect the exchange rate as we saw in some oil-exporting economies. Mishra (2017) investigated the volatility spillover effects between gold and the U.S. dollar-based exchange rate for India with a set of other macroeconomic variables. Adopting the generalized autoregressive conditional heteroscedasticity dynamic conditional correlation (GARCH-DCC), the study found significant bidirectional volatility spillover effects between gold prices and the exchange rate of India despite India not being a major gold exporter. These findings align with what was found in most developed economies as well. Most commodities such as precious metals and crude oil tend to have bidirectional volatility linkages in both developed and developing economies⁴. Zankawah and Stewart (2020) investigated the volatility spillover effects of oil prices on the US dollar exchange rate for Ghana for the period January 1991 to December 2015. Employing the multivariate GARCH BEKK and TBEKK models, the research found that oil prices had significant volatility spillover effects on the U.S. dollar-based exchange rate of the country.

Chen, Xu and Hu (2022) investigated dynamic volatility spillover effects between crude oil, gold prices and the U.S. dollar in the BRICS countries using daily data from August 2005 to March 2020. Employing the VAR-BEKK(DCC)-GARCH model the research found that gold price movements were more on the receiving end of the volatility spillover from the oil market and the exchange rate market in Brazil and India. Significant bidirectional volatility spillover effects were however discovered between gold prices, oil prices and the exchange rate in Russia. Adi, Adda and Wobilor (2022) investigated the volatility spillover effects between oil prices and the U.S. dollar exchange rate for Nigeria. The research found a bidirectional volatility spillover effects between the USD/NAIRA exchange rate and the Brent crude oil price. There was however a unidirectional volatility spillover Brent oil price to the USD/NAIRA effective exchange rate when

⁴ See [Lee and Kim \(2023\)](#) and [Zhu et al \(2023\)](#)

adjusted for inflation in real terms. This means that the direction of spillover may change if the exchange rate is adjusted for inflation.

A similar study was done in China to investigate the volatility spillover effects of international crude oil prices on the Chinese real exchange rate from January 1995 to September 2021 by Huang and Li (2021). The research made use of monthly data for the variables employed the TVP-SV-VAR model to capture the volatility clustering. The research discovered a spot dynamic negative spillover effect on the exchange rate from oil prices suggesting that the exchange rate has a short-term memory from oil price movements shocks. However, results may differ as we have seen on the extent of spillover from commodities depending on whether the country is importing or exporting the commodity. Ding *et al* (2023) investigated whether the exchange rate in China acted as a pass-through channel for the volatility in oil prices and its spillover to domestic inflation. The research made use of monthly data from January 2010 to July 2022. Employing the DCC-GARCH-VAR model, their research concluded that there existed significant volatility spillover effects from oil price movements to the exchange rate which then acted as passage for the spillover to domestic inflation. These results had significant implications for the country in assessing whether the domestic or foreign forces were more responsible for the general price rise.

3.9.2 Macro-financial volatility spillovers:

Erdem *et al* (2005) investigated the volatility spillover effects between selected macroeconomic variables and the stock exchange indexes. Amongst the macroeconomic variables, he included the U.S. dollar exchange rate and money supply and studied how these variables spill over to each in Turkey. Employing the univariate Exponential Generalized Autoregressive Conditional Heteroscedasticity (EGARCH) model, the research found significant spillover effects between the U.S. dollar exchange rate and money supply. The research also concluded a bidirectional volatility spillover existed between inflation and the exchange rate. Atoi and Nwambeke (2021) investigated whether the exchange rate volatility spills over to monetary policy in the case of Nigeria. Employing the multivariate GARCH model, the research found a strong unidirectional volatility spillover from the exchange rate to the money market suggesting that, calming the volatility in the foreign exchange market does guarantee moderation of volatility in the money market, whereas the reverse is not the case (Atoi and Nwambeke, 2021).

3.10 SOUTH AFRICA

South Africa has had a decent amount of study done to understand more about the volatility spillover effects between financial markets and macroeconomic variables. Some studies focus on the spillover between financial markets, a by-product that this research will produce but not the main objective of the study. South Africa has robust financial markets considered to be the best on the African Continent and among the most resilient in the world (Odhiambo, 2014). Interest in the financial markets of emerging economies boomed after the high spillovers of credit bubbles from the U.S. markets during the Global Financial Crisis. The country has benefited from world investors who sought to diversify their portfolios by investing in emerging markets that promise higher returns whilst having institutions in place to protect their investments. The discussions below showcase the empirical work done in South Africa to be able to build a case for South Africa that necessitates this study.

3.11 MACROECONOMIC VARIABLES, COMMODITIES AND THE STOCK MARKET FOR SOUTH AFRICA

3.11.1 Cross-market volatility spillovers and macro-financial spillovers:

In comparison to the other African states on the African Continent, South Africa has arguably had the most studies undertaken for its economy specifically with regards to its financial markets due to the size of the economy and how developed the financial system in the country is. Earlier work was done by Chinzara (2010) when he analysed how macroeconomic variables volatility is transmitted into stock market volatility using the univariate augmented autoregressive Generalised Autoregressive Conditional Heteroscedastic (AR-GARCH) and vector autoregression (VAR) models. Monthly data was used for industrial production, consumer price index, broad money (M3), nominal exchange rate, oil price, treasury bill and gold prices whilst controlling for the four main sectors of South Africa namely, the financials (FIN), industrials (IND), general retails (RET) and mining (MIN). The study aimed to not only uncover the volatility spillover between macroeconomic variables and the stock market but also to see how the macroeconomic variables interact with each other. The findings show that the selected macroeconomic variables' volatility significantly influences stock market returns volatility. Most of the bidirectional volatility spillover

was positive with the macroeconomic variables except for inflation which was negative and possibly attributed to the uncertainty that comes with periods of high inflation.

Fowowe (2017) investigated the volatility spillover effects between oil prices and the stock market in South Africa. The research used weekly data whilst employing the Diebold and Yilmaz (2012) spillover index. The study found weak bidirectional volatility spillover effects between oil prices and stock market returns for South Africa. These findings proposed that there were prospects for diversification by investing in South African equity that was not well exposed to oil price movements. Boubaker and Raza (2017) investigated the volatility spillover effects between oil prices and the stock market for the BRICS countries. The research made use of daily data for the variables. Employing the multivariate ARMA-GARCH model and wavelet multiresolution analysis for the study, the research found significant bidirectional volatility spillover effects between oil price changes and stock market returns for all the BRICS nations. Differences between these findings in this paragraph may be due to differences in the econometric model used or the frequency of data used. Varda *et al* (2018) undertook a study to investigate the shock and volatility spillovers between stock and commodity markets in emerging markets. The research employed the VAR-BEKK GARCH model using daily data. The research found that South Africa had a significant bidirectional volatility spillover between gold prices and the stock market before the global financial crisis. The study further concludes that post the global financial crisis, the significance of the spillover has increased but not as that of developed economies and that oil prices and stock market volatilities started spilling over each other significantly post the crisis.

Morema and Bonga-Bonga (2020) investigated the impact of oil price and gold price fluctuations on the South African equity market together with three equity sectors accounted for separately namely the financial FTSE/JSE Financials (FIN), industrial FTSE/JSE Industrials Index (IND) and resources FTSE/JSE Resources (RES) sectors. The research made use of daily data. Using the multivariate ADCC-GARCH model, their study found significant volatility spillover between the gold and stock markets and the oil and stock markets including the sectors suggesting strong stock market commodity market linkage. Chen *et al* (2024) investigated the dynamic spillover and connectedness of the oil price-stock market nexus for South Africa under COVID-19. The research made use of daily data. Employing the asymmetric BEKK-Copula-GARCH and Wavelet

Coherence methods, the research found significant volatility from oil prices to the stock market of South Africa.

3.12 MACROECONOMIC VARIABLES, COMMODITIES AND THE FOREIGN EXCHANGE MARKET FOR SOUTH AFRICA

3.12.1 Cross-market volatility spillovers and macro-financial spillovers:

As previously stated, only a few studies were done on the foreign exchange market of South Africa in comparison to the stock market. Dlamini (2018) undertook to study whether there existed volatility spillovers between commodities such as oil and gold with the exchange rate of South Africa. The research employed the CCC-MGARCH and BEKK-MGARCH models using daily data. The study found significant volatility spillover effects between the selected commodities and the U.S. dollar-based exchange rate of the Rand. These findings are in support of the earlier study by Chinzara (2010) who found that the exchange rate of South Africa experienced volatility spillovers from gold prices and oil prices.

Hlongwane *et al* (2022) examined the volatility spillover effects between oil prices and the exchange rate in South Africa using monthly data. Employing the univariate threshold generalized autoregressive conditional heteroskedasticity (TARCH) model to analyse the volatilities, the study found that oil prices have a negative statistically significant volatility spillover effect on the exchange rates in South Africa. This is true for South Africa as the nation is a heavy oil importer and would be negatively impacted in terms of the exchange rate if oil prices were to increase. The expectations are that the exchange rate will also pass through some of this volatility spillover to domestic inflation as measured by the consumer price index.

Chen *et al* (2022) investigated the volatility spillover effects between crude oil prices, exchange rate and gold prices in the BRICS nations using daily data. Employing the VAR-BEKK(DCC)-GARCH model, the research found weak volatility spillover linkages between its exchange rate and gold markets with the crude oil market as opposed to Boakye *et al* (2023). Boakye *et al* (2023) investigated the volatility spillover effects amongst commodities, stocks, exchange rates and bonds markets in Africa including South Africa using closing daily data. Employing the Diebold and Yilmaz (2012) spillover index, the research found the existence of significant volatility spillover between the forex market and commodities such as gold and oil. This is to be expected as South

Africa is a heavy oil importer and gold exporter. The forex exchange market for South Africa was found to be at a higher systematic risk of volatility spillover from macroeconomic variables in comparison to the stock market.

3.13 CONCLUSION

The studies reviewed above bring to light the significant role that macroeconomic uncertainty plays in shaping volatility spillovers onto financial markets in both developed and developing economies. Studies for developed economies such as the United States, Germany and Japan⁵ have all shown that in most cases there exists a bi-directional volatility spillover relationship between macroeconomic variables, commodities and the two financial markets under study namely the foreign exchange market and the stocks or equities market. With regards to cross-market volatility spillovers between the commodities markets and financial markets in developed economies, these countries do not face similar volatility spillover effects onto their financial markets as this largely depends on whether the economy is a net importer or exporter of the commodity. A similar picture is painted for the developing economies. Macro-financial spillovers have continued to grow in importance given the rate of globalization for the developed economies. Abbas *et al* (2019) and Jiang *et al* (2024) have shown that the spillover effects of macroeconomic variables on financial markets are not static and continue to evolve in response to global economic and political outlooks. Emerging economies are more vulnerable to not only cross-market spillovers within the individual economies but also spillovers from the advanced economies. Both oil and gold commodities have continued to have significant spillover effects on the financial markets for both the net importers and exporters of these commodities. Such was the case for Saudi Arabia and the UAE as large oil exporters facing significant cross-market spillover effects between commodities such as gold and the financial markets in the studies of Bagchi (2017) and Raza (2017). Moreover, bi-directional macro-financial volatility spillovers continue to be significant across all emerging economies including the African markets. Much like the developed economies, macroeconomic variables such as interest rates and inflation have significant volatility spillover effects on the returns of the stock market and the exchange rate.

⁵ See [Ewinga and Malik \(2015\)](#); [Liao *et al* \(2021\)](#); [Antonakakis and Kizys \(2015\)](#) and [Lee and Kim \(2023\)](#).

The GARCH family of models under the VAR framework have proven to be the most dominant used technique to generate volatility series and capture spillover effects for both cross-market volatility spillovers and macro-financial spillovers in developed and developing economies⁶. The use of the Diebold and Yilmaz spillover index is more occurring in the developed economies and recently, more studies have started adopting it especially for African financial markets.

Regarding South Africa, the literature reviewed highlights South Africa's position in the global economy as a gold exporter and an oil importer which significantly shapes its cross-market spillovers between financial markets and commodities markets. The study of Morema and Bonga-Bonga (2020) confirmed significant bi-directional spillover effects between the stock markets and commodities such as gold posing a great influence on the stock returns of the JSE. Similar conclusions were reached by Boakye *et al* (2023) for the foreign exchange market.

With regards to macro-financial spillovers, bi-directional spillover effects were found between the two financial markets and macroeconomic variables such as inflation and money supply in the papers of Chinzara (2010) and Hlongwane *et al* (2022). The trend for South Africa seems to have followed the other fast-developing economies such as China and India signifying the extent to which the South African financial markets have developed. This then warrants continuous research between macroeconomic variables, commodities and financial markets, not only in first-moment linkages for studying the relationship but second-moment linkages as well in terms of volatility spillovers given the dynamics are different for each economy

Notably, a fair number of studies have been done to study volatility spillovers within South Africa using the GARCH family of models. A few have adopted the use of the Diebold and Yilmaz (2009, 2012) spillover index to measure the direction of spillovers as with other fast developing economies such as China although the same cannot be said for the other African economies. This research will expand on the existing literature and contribute to the ongoing research of understanding the spillover effects of macroeconomic variables and commodities on financial markets. Since the time-varying spillover connectedness in financial markets dynamics is likely to change as noticed in other countries post significant economic turmoil such as the Global Financial

⁶ See [Aliyu \(2012\)](#); [Mishra and Debasish \(2017\)](#) and [Ding *et al* \(2023\)](#).

Crisis and the COVID-19 pandemic, this research will also uncover whether that has been the case for South Africa.

CHAPTER FOUR

RESEARCH METHODOLOGY AND DATA

4.1 INTRODUCTION

To be able to analyse the volatility spillover effects of macroeconomic variables and commodities on the stock market and the foreign exchange market in South Africa, the following sections will uncover the data used for the research and the techniques employed. This will include the research paradigm, research design which consists of the model specification and theoretical framework, definition of variables, data description and sources, estimation techniques and diagnostic tests before moving to the conclusion.

4.2 RESEARCH PARADIGM

A research paradigm refers to the framework that guides a researcher in conducting research (Rehman and Alharthi, 2016). This framework is made up of philosophical assumptions, values and beliefs that underlie a study (Creswell and Tashakkori, 2007; Babbie, 2010). The choice of a research paradigm is influenced by the environment, perception and nature of the problem statement of the research (Trauth, 2009).

The three philosophical paradigms that exist are the critical theory paradigm, the interpretivism/constructivism paradigm and the positivism paradigm (Kivunja and Kuyini, 2017). The choice of paradigm for research depends on the nature of the study, the hypothesis, and the type of data or information being used for the study. This research will adopt a post-positivist paradigm. The paradigm is rooted in the ideas of Comte (1858). Comte (1858) asserted that scientific knowledge will always be the only way to uncover reality truth especially when dealing with a research problem. Pham (2018) argues that this paradigm puts more emphasis on evidence observation and empirical evidence, heavy logic reliance and measurable outcomes that can explain and predict a phenomenon. To ensure high validity and reliability of research work, the post-positivist paradigm involves formulating hypotheses, collecting accurate and quantifiable data, conducting statistical analysis and deriving findings and conclusions based on empirical work (Kivunja and Kuyini, 2017).

With regard to this research, the post-positivist paradigm will be adopted as the research seeks to uncover the volatility spillover effects of macroeconomic variables and commodities on financial markets. The study will formulate hypotheses that are based on empirical evidence, collect secondary data and use statistical models to analyse the data to arrive at a conclusion based on measurable outcomes.

4.3 RESEARCH DESIGN

The following segments will look at model specification and theoretical framework, definition of variables, data description and sources, estimation techniques and diagnostic tests for the data and research.

4.4 MODELS' SPECIFICATION AND THEORETICAL FRAMEWORK

4.4.1 Diebold-Yilmaz (DY) spillover index

The research will employ the Diebold and Yilmaz (2009, 2012) spillover index rooted in the recursive VAR model of Sims (1980) to analyse the volatility spillover effects of macroeconomic variables and commodities on financial markets. Unlike the VAR framework, the DY spillover index puts more emphasis on the invariance of the forecast-error variance decomposition to the variable ordering of a model allowing us to capture the connectedness of the variables in this study by capturing not only the directional spillovers but also total spillovers, net directional spillovers and rolling pairwise spillovers.

Variance Shares

Diebold and Yilmaz (2009) in their modelling defined own variance shares as the fractions of forecast error variances in forecasting x_i caused by shocks to x_i , for $i = 1, 2, \dots, N$, and the spillovers as fractions of the h-step-ahead forecast error variances in forecasting x_i because of shocks to another variable, x_j , for $i, j = 1, 2, \dots, N$, such that $i \neq j$. Based on the generalised VAR framework of Koop *et al* (1996) and Pesaran and Shin (1998), the h-step-ahead generalised forecast error variance decomposition is given by:

$$\theta_{ij}^g(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e'_{iA_h} \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e'_{iA_h} \Sigma e_j)^1} \quad (3)$$

Σ represent the sum of the matrix of the error vector ε . σ_{jj}^{-1} is the inverse of the standard deviation of the error term for the j th equation. e is the selection vector to isolate the response of both the i and the j variables. The squared impact of shocks from the j variable on the i variable at specified lag h is captured by $(e'_i A_h \Sigma e_j)^2$. $\theta(H)$ are the main diagonal elements of the matrix representing the contributions of own shocks whereas the contribution “from” other and “to” other variables is represented by the off-diagonal elements in the FEVD. A_h is the coefficient matrix from the moving average to show the propagation of past shocks. Since the sum of the variance contributions by own- and cross-variables is not equal to one under the GVAR due to statistical variable independence, the matrix is divided by the row sum as:

$$\tilde{\theta}_{ij}^g(H) = \frac{\theta_{ij}^g(H)}{\sum_{j=1}^N \theta_{ij}^g(H)} \quad (4)$$

with $\sum_{j=1}^N \tilde{\theta}_{ij}^g(H) = 1$ and $\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H) = N$ by construction.

$\theta_{ij}^g(H)$ is the generalised spillover effect from one variable to another. $\tilde{\theta}_{ij}^g(H)$ normalises this effect allowing us to later express each spillover effect as a percentage of the total spillovers received by the variable. $\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)$ is the sum of the normalised spillover effects received by the variable from all the other variables in the system. Equation (4) is the approximate fraction of the h -step-ahead forecast error variance of the variable i coming from j variable.

Total spillovers

The total spillover index is used to measure the contribution of the spillover effect of the variance decomposition of all the variables on average. The equation for total spillovers is as follows:

$$S^g(H) = \frac{\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)}{\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)} = \frac{\sum_{i \neq j} \tilde{\theta}_{ij}^g(H)}{N} \quad (5)$$

$\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)$ is the sum of all spillovers excluding own variance whilst $\sum_{i \neq j} \tilde{\theta}_{ij}^g(H)$ is the sum of all spillovers including own variance. Equation (5) measures the average contribution of spillovers to the forecast error variance hence it is flexible not only in terms of ordering of the variables but directional spillover determination.

Directional spillovers

While it is sufficient to study the volatility spillover index in total, the generalised VAR enables us to uncover the direction of volatility spillovers across the macroeconomic variables, commodities and financial markets. The generalised impulse response and variance decomposition in the GVAR are invariant to the ordering of variables enabling us to calculate the directional spillovers using the normalised elements of the generalised variance decomposition matrix (Diebold and Yilmaz, 2012). The directional spillovers transmitted from variable i to variable j can be given by⁷:

$$S_{i \rightarrow j}^g(H) = \frac{\sum_{i,j=1}^N \tilde{\theta}_{ji}^g(H)}{\sum_{i,j=1}^N \tilde{\theta}_{ji}^g(H)} \cdot 100 = \frac{\sum_{i,j=1}^N \tilde{\theta}_{ji}^g(H)}{N} \cdot 100 \quad (6)$$

$\sum_{i,j=1}^N \tilde{\theta}_{ji}^g(H)$ is the sum of spillovers received by j variable from the i variable whilst $j \neq i$

$\sum_{i,j=1}^N \tilde{\theta}_{ji}^g(H)$ is the sum of all spillovers in the model. The directional spillovers from variable j to variable i are thus given by:

$$S_{j \rightarrow i}^g(H) = \frac{\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)}{\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)} \cdot 100 = \frac{\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)}{N} \cdot 100 \quad (7)$$

$\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)$ is the sum of spillovers received by the i variable from the j variable whilst $j \neq i$

$\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)$ is the sum of all spillovers in the model. Multiplying by 100 converts the index into a percentage.

Net directional spillovers

The directional spillover gives a breakdown of the spillover index effect from one variable to another variable, that is between macroeconomic variables, commodities and financial markets where all are not equal to each other. The net directional spillover is simply the difference between

⁷ Both i and j can represent either macroeconomic variables, commodity prices or financial markets data depending on the pairwise directional spillover being considered.

gross volatility shocks transmitted to and those received from the other variables and can be obtained by netting the results of equations (6) and (7). The formula can thus be written as:

$$S_i^g(H) = S_{i \rightarrow j}^g(H) - S_{j \rightarrow i}^g(H) \quad (8)$$

Positive values from the net spillover index indicate that the macroeconomic variable, commodity or financial market is the net transmitter of directional spillover effects to the other variables while negative values indicate that the macroeconomic variable, commodity or financial market is a net receiver of the directional spillover effects from the others.

Pairwise spillovers

Pairwise spillover is further decomposed from the directional spillover to analyse the spillover connection in bivariate terms. The pairwise spillovers between the variables are determined through a rolling window of the GVAR forecast error variance decomposition. Pairwise spillover analysis will allow us to determine the time-varying intensity of the spillovers between two variables. The results on which variable dominates the spillovers to the other would have been deduced in the net spillover analysis above.

Rolling window: Time-varying volatility spillovers

Financial markets are guaranteed to go through turbulence and evolution making it unlikely that a single fixed-parameter model would apply for the entirety of the sample. Some of these changes may be attributed to but not limited to rise in hedging, increased integration among global financial markets, increased capital mobility and the rise of electronic trading (Diebold and Yilmaz, 2012: 61). To account for secular and cyclical movements in volatility spillovers, the research estimates the volatility spillovers using a 60-month rolling sample. This will allow us to determine the extent and nature of the spillover variation over time. Kavli and Kotze (2014) argue that using a large rolling window for the estimation gives a smoother dynamic index series and is more accurate while retaining the true index.

4.5 DEFINITION OF VARIABLES

4.5.1 Macroeconomic variables:

The following are the macroeconomic variables selected to conduct this research in accordance with relevant literature.

Inflation

Inflation refers to the general increase in price level in an economy. Inflation is included in this research as a macroeconomic variable as it is expected to have significant volatility spillover effects on financial markets as observed in the studies of Chinzara (2010) in South Africa and Aliyu (2012) for Ghana. Inflation erodes the purchasing power of both businesses and consumers whilst posing great liquidity threats to the financial markets. Concurrently, inflation can lead to tighter fiscal policies and monetary policies that can dampen the performance of financial markets to include those not in this study. This research hypothesises a negative relationship between inflation and the financial markets in line with what the literature has found⁸. Consumer Price Index (CPI) will be used as a proxy to measure inflation in South Africa as in the studies of Chinzara (2010) and Aliyu (2012).

Money Supply

Money Supply can be categorised into M0, M1, M2 and M3 with some economies going up to M4 with either M3 or M4 representing the broadest definition of money. This research will make use of the M3 definition of money which is made up of M2 plus all the currency in circulation in the economy (Nunes, 2010). M2 is simply the cash, savings accounts, money market funds and other deposits in the economy (Nunes, 2010; Aawaar *et al*, 2023). The use of M3 as a proxy for money supply is in line with other literature such as (Abbas *et al*, 2019; Aawaar *et al*, 2023). M3 has also been proven to be a better explainer of economic activity in South Africa than narrowly defined money due to its population outreach and financial inclusion prospects.

This research hypothesises that there is a positive relationship between money supply and stock market returns as was found in Nisha (2015) and Gay (2016) supported by the trends in Chapter Two. The underlying argument is that as more money is available in the economy, investors have

⁸ See [Ramasamy and Abar \(2015\)](#) and [Ouedraogo \(2018\)](#)

more liquidity at their disposal to trade. With regards to the exchange rate, the expectation is that there is a negative relationship between money supply and the exchange rate as an increase in money supply will depreciate the currency leading to exchange rate erosion (Souza *et al* 2020).

4.5.2 Commodities:

The following commodities were selected for this study as guided by literature and the nature of the South African economy.

Gold prices

The research will make use of the Rand-denominated gold prices for consistency of data. Gold was included in the study as it is likely to largely influence the JSE Mining index which is one of the variables from the stock market. South Africa is a large gold exporter and the precious metal forms a significant part of the mining sector. Significant volatility spillover effects of gold prices have been discovered for both the stock market and the foreign exchange market (Dlamini, 2018; Morema and Bonga-Bonga, 2020).

Oil Prices

The research will made use of the West Texas Intermediate (WTI) oil prices as one of the commodities under study. WTI is a widely acceptable benchmark for measuring international oil prices as much as Brent crude although the former is much American based (Zhang and Yan, 2020). The strong correlation between the two prices is shown in [Appendix A.1](#). The dollar-denominated oil prices were changed in Rand value per barrel by multiplying the given oil price by the Rand value per Dollar at the given time to ensure consistency in the currency for the research. The conversion to Rand prices is thus given as follows:

$$P_R = E_U \cdot WTI_U \tag{9}$$

Where: P_R denotes the Rand oil price at a given time

E_U is the USD/ZAR exchange rate at a given time

WTI_U is the WTI USD price of oil at a given time

4.5.3 Financial Markets Indices and Foreign Exchange Rate:

The following financial markets indices and rate were selected for this study in accordance with the literature and relevance to the purpose of the study.

Nominal Exchange Rate

The nominal exchange rate refers to the unit amount of domestic currency needed to purchase foreign currency. This research will use the dollar-denominated Rand exchange rate (USD/ZAR). The US Dollar remains the most widely traded currency and is acceptable as a benchmark for international payments (Nyopa and Khumalo, 2022).

JSE All Share Index

The main exchange in South Africa is the Johannesburg Stock Exchange (JSE) represented by the FTSE/JSE All Share Index to measure returns. The index accounts for 99% of the full market capital value of capital markets in South Africa assisting in trading for financial markets such as the bond markets and equity markets meaning it is the primary indicator of stock performance in the country (De Beer, Keyser and van der Merwe, 2015). For this study, all the stock market indices will be transformed into logged returns to standardise the variance and reduce data skewness. The formula for calculating returns is given by:

$$R_t = \ln \frac{P_t}{P_{t-1}} \cdot 100 \quad (10)$$

Where: R_t denotes asset returns

p is the price index

t and $t-1$ indicate time

This proxy has been used in studies by Morema and Bonga-Bonga (2020) and Sadraoui *et al* (2021).

JSE Mining Index

The JSE Mining Index tracks the performance of large companies such as Anglo-American and mid-sized companies involved in mining in South Africa. The index is likely to be directly affected by gold price changes and provide more specific insights into gold price volatility effects on stock

markets hence it is included in the study. Since South Africa is a gold exporter, including this index will allow for better specific identification of how gold price movements affect the stock market. The formula for calculating returns for this index is the same one in equation (10). This proxy was used in the research of Chinzara (2010).

JSE Financials 15 Index

The JSE Financial 15 Index tracks the top 15 market-capitalised companies in the financial sector of South Africa. These companies include the major banks, asset management firms, brokerage firms and insurance companies to better track the performance of the sector. The formula for calculating returns for this index is the same one in equation (10). A similar proxy was used in the research of Chinzara (2010) and Morema and Bonga-Bonga (2020).

JSE Retailers Index

The JSE Retailers Index tracks the performance of publicly listed retail companies in South Africa. These include but are not limited to clothing stores like Woolworths, grocery stores like Pick n Pay and appliance stores such as Game. Most of the products bought from these stores form part of the general basket of goods that consumers consume monthly. Macroeconomic variables such as CPI will likely have a significant impact on the returns of this sector as it affects purchasing power. Spillover effects from oil prices as energy is a significant input for this sector are likely to be significant as well. The formula for calculating returns for this index is the same one in equation (10). This proxy was also used in the study of Chinzara (2010).

4.6 DATA DESCRIPTION

As indicated in Table 4.1 below, monthly data from January 2005 to January 2024 was used for this research. This period was chosen to allow us to capture the time-varying aspects of volatility spillover changes as it comes with significant events such as the Global Financial Crisis, oil price crisis and the COVID-19 pandemic. The study will use monthly data as macroeconomic variables such as money supply and inflation figures are published monthly.

Table 4.1

Summary of Data description and sources

<i>Code</i>	<i>Variable Type</i>	<i>Variable</i>	<i>Data Range</i>	<i>Frequency</i>	<i>Proxy</i>	<i>Data Source</i>
<i>M3</i>	Macroeconomic	Money Supply	01/2005-01/2024	Monthly	Y/Y Percentage Change	LSEG
<i>CPI</i>	Macroeconomic	Inflation	01/2005-01/2024	Monthly	Percentage	LSEG
<i>GOLD</i>	Commodity	Gold price	01/2005-01/2024	Monthly	Y/Y Percentage Change	LSEG
<i>WTI</i>	Commodity	Oil price	01/2005-01/2024	Monthly	Closing prices	Spot World Bank
<i>EXR</i>	Forex Rate	Exchange Rate	01/2005-01/2024	Monthly	USD/ZAR rate	spot LSEG
<i>RALSH</i>	Stocks Index	JSE All Share Index	01/2005-01/2024	Monthly	Closing prices	LSEG
<i>RMIN</i>	Stocks Index	JSE Mining Index	01/2005-01/2024	Monthly	Closing prices	LSEG
<i>RFIN</i>	Stocks Index	JSE Financials 15 Index	01/2005-01/2024	Monthly	Closing prices	LSEG
<i>RRET</i>	Stocks Index	JSE Retailers Index	01/2005-01/2024	Monthly	Closing prices	LSEG

Source: Author's compilation.

Notes: Inflation (CPI), USD/ZAR exchange rate (EXR), gold price (GOLD), broad money supply (M3), JSE All-Share index (RALSH), JSE financials 15 index (RFIN), JSE mining sector index (RMIN), JSE retail sector index (RRET), oil price (WTI) and London Stock Exchange Group (LSEG).

4.7 ESTIMATION TECHNIQUE

To generate the volatility series that will be used to determine the direction and magnitude of the spillover effects, the research will employ the univariate autoregressive conditional heteroskedasticity (GARCH) family of models of Engle (2001). This model will allow us to extract the conditional volatility clustering of the macroeconomic variables, commodities and the financial markets data. Use of the models such as the exponential GARCH (EGARCH) and threshold (TGARCH) will also allow us to account for the leverage and asymmetric effects of the conditional volatility series from the macroeconomic variables, commodities to the financial markets data.

To determine the direction and magnitude of the spillover effects from macroeconomic variables and commodities to the financial markets, the next step will be to employ the Diebold and Yilmaz spillover index approach DY index (2012). The DY index is based on variance decompositions

(VD) and impulse response functions that use a vector autoregressive (VAR) modelling framework allowing us to determine the direction and magnitude of the spillover effects.

To avoid the results from being spurious and maintain the integrity of the data analysis, a stationarity test for the data will be performed using the Augmented Dickey-Fuller (ADF). Additionally, other diagnostic tests will be carried out for the data.

4.7.1 Stationarity test

To test for the relationship between variables requires a test for stationarity and to also determine the order of integration of the variables. Crucially, the series should be integrated in the same order and not beyond I(2) as this will result in spurious regressions. The study will employ the Augmented Dickey-Fuller (ADF) due to its capability of relaxing the postulation of autocorrelation among residuals (Khalid and Khan, 2017). The test ensures that variables will return to their long-run means after a shock is applied. Banda (2017) specified the ADF as follows:

$$y_t = \alpha_0 + \delta y_{t-1} + \sum_{i=1}^p \beta_i + y_{t-1} + \varepsilon_t \quad (11)$$

Where:

y_t = the time series to be tested

α_0 = intercept

β_i = coefficient of interest in analysing the unit root

p = order of the autoregressive process and $\delta = p - 1$

ε_t = white noise error term

The null and alternative hypotheses are specified as:

$H_0: \rho = 1$ [Variable has a unit root (Variable is not stationary)]

$H_1: \rho = 0$ [No Unit root (Variable is stationary)]

A null hypothesis tests if the series is not stationary hence it contains a unit root. A preferable outcome is rejecting the null hypothesis meaning the series will not have a unit root and is thus stationary. Chinzara (2008) and MacFarlane (2011) argue that it is only possible to forecast and reduce spurious regressions if a series is stationary as a non-stationary series would produce a high R^2 despite there being no economic relation between the variables under study.

4.7.2 General autoregressive conditional heteroskedasticity (GARCH) group of models

The first step to constructing the volatility spillover indexes is to find an estimate of volatility for each of the macroeconomic variables, commodities and the stock market and forex market indices. Diebold and Yilmaz (2012) adopted the Garman Klass estimators for volatility estimates for the various assets under their study. The German Klass estimators however require high-frequency data to which studies such as those of Kavli and Kotze (2014) did not have access to and proceeded to use squared returns instead. This approach however does not account for the asymmetry of the return for the data and in this case the financial markets data and the macroeconomic data. To address this limitation, this study will employ the generalized autoregressive heteroskedasticity (GARCH) models to generate monthly conditional volatilities to capture the asymmetric effects in the data. To allow the effects of both positive shocks from good news and negative shocks from bad news to have different effects than shock below the threshold, the research will employ the Threshold GARCH model (TARCH) of Glosten, Jaganathan and Runkle (1993) and Zakoian (1994). The exponential GARCH (EGARCH) of Nelson (1991) will capture asymmetry and leverage effects as it does not require non-negativity from estimated coefficients. The mean equation which remains the same for all the univariate GARCH models is given as follows:

$$Y_t = \mu + e_t \quad (12)$$

Where μ denotes the mean around which the time series will exhibit random fluctuations with the error term e_t . The variance of the error in the current period is influenced by information disclosed in the preceding period. The simple ARCH q model with q being any specified lag length and σ_t^2 as the conditional variance is given as:

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \alpha_2 u_{t-2}^2 + \dots + \alpha_q u_{t-q}^2 \quad (13)$$

α_1 represents the impact of the past squared residual u_{t-q}^2 . Whilst the ARCH model can capture the conditional variance, it is likely to breach the non-negativity constraint. To minimise the occurrence of a negative variance, avoid overfitting data and allow the conditional variance to be dependent on previous own lags, we follow Bollerslev (1986) and propose the GARCH model as:

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-q}^2 + \beta \sigma_{t-q}^2 \quad (14)$$

Where $\beta\sigma_{t-q}^2$ captures the GARCH term of the conditional variance with β specifically measuring volatility persistence overtime. The equations to both the EGARCH and the TGARCH are defined as the following respectively:

$$\log(\sigma_t^2) = \omega + \beta \log(\sigma_{t-q}^2) + \gamma \frac{u_{t-1}}{\sqrt{\sigma_{t-q}^2}} + \alpha \left[\frac{|u_{t-1}|}{\sqrt{\sigma_{t-q}^2}} - \sqrt{\frac{2}{\pi}} \right] \quad (15)$$

$\log(\sigma_t^2)$ is the natural logarithmic return of the conditional variance whilst ω is a constant. γ measures the asymmetric effect due to leverage occurring when negative shocks result in more volatility than good news. α measures the impact of absolute standardised shocks on current volatility whilst β determines the influence of past logged volatility on the current log volatility. α and β measure the ARCH effect and the GARCH effect respectively. u_{t-1} is the lagged innovation shock at a time thus $\frac{|u_{t-1}|}{\sqrt{\sigma_{t-q}^2}}$ is the standardised absolute size of past shocks. $\sqrt{\frac{2}{\pi}}$ is a constant that ensures that the absolute residual is zero to help correct the mean from deviating.

$$\sigma_t^2 = \omega + \sum_{j=1}^p \beta_j \sigma_{t-j}^2 + \sum_{i=1}^q \alpha_i u_{t-i}^2 + \sum_{k=1}^r \gamma_k u_{t-k}^2 \overline{I_{t-k}} \quad (16)$$

σ_t^2 remains the conditional variance whilst ω is the constant. $\alpha_i u_{t-i}^2$ is explaining the ARCH effect measured as the lag of squared residuals in the equation whilst $\beta_j \sigma_{t-j}^2$ is the GARCH term, namely the last period forecast variance. $\gamma_k u_{t-k}^2$ is the asymmetric effect due to leverage multiplied by the impact of good or bad news. Since I_{t-k} captures the leverage effects, if $\gamma_k > 0$ then bad news generates more volatility than bad news. Bad news implies a negative shock, while good news implies a positive shock. $\overline{I_{t-k}}$ is a dummy variable that equals 1 if $u_{t-k}^1 < 0$ implying a negative shock and 0 when otherwise. The dummy variable is centred to have a mean of 0.

4.7.3 Determining the GARCH model for each variable

Before generating the conditional volatility series using the GARCH models, the variables will go through iteration to determine which model would be the best fit to generate the series. The models

that will be tested are the ARCH, GARCH, EGARCH and TARCH models. Both the EGARCH and TGARCH models allow us to the asymmetry effects of financial market variables meaning if they exhibit asymmetry with a significant negative coefficient, then negative news generates more volatility for the market than good news. The criteria for selecting the best-fit model involves looking at whether the model removes the ARCH effect for heteroskedasticity. The ARCH-LM test of Engle (1982) will be used for this test and is hypothesised as follows:

$H_0: Var(u_t) = \sigma^2$ (residuals are homoscedastic)

$H_1: Var(u_t) \neq \sigma^2$ (residuals are heteroscedastic)

If the probability value, where probability value $< \alpha = 10\%$, then reject H_0 , therefore it means residuals are heteroscedastic.

Another criterion of selection is to assess whether the model does not violate the non-negativity constraint of the series which the EGARCH tries to remove. This will be done by checking if either the absolute residual coefficient (the ARCH coefficient) and the log of the lagged GARCH term coefficient are either negative or positive. If either of them is negative, then there is a breach of the constraint. The stationarity of the series will be assessed by looking at the past squared residual (ARCH) coefficient and the lagged GARCH term coefficient. If both coefficients add up to more than 1 then the series generated by the model for the variable is non-stationary and less suited. Furthermore, if a conclusive decision is not reached as per the given criteria, the Hannan-Quinn and Schwarz information criteria can be used to reach a conclusion for which the model with the least values for both is considered the best fit for the variable. Finally, the root mean squared error will be evaluated to determine the forecasting power of the model and the higher the value of the root mean squared error, the better the model is suited to the variable for forecasting. The model that meets most of the criteria above will be selected to generate the volatility series. A similar approach was used in the study of Kambadza and Chinzara (2012).

4.7.4 The Vector Autoregression (VAR) model

The VAR has been a popular model for its forecasting capabilities given it does not require the researcher to specify the exogenous variables and the endogenous variables in contrast to the other structural models containing simultaneous equations (Sims, 1980). The specifications for the spillover index start with the p th order for the stationary N -variable VAR model is given by:

$$x_t = \sum_{i=1}^p \phi_i x_{t-1} + \varepsilon_t \quad (17)$$

Where:

x_t is the vector of N endogenous variables⁹

ϕ_i is the $N \times N$ matrix of the estimated parameters

t is 1 and t represents the time index

N remains the variable index

$\varepsilon \sim (0, \Sigma)$ is a vector of the error term independently and identically distributed over time

The moving average of equation (17) for the VAR system is thus given as:

$$x_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i} \quad (18)$$

A_i are the $N \times N$ coefficient matrices recursively derived as $A_i = \sum_{t=1}^p A_{i-t} \phi_t$, with A_0 being the $N \times N$ identity matrix and $A_i = 0$ for $i < 0$. An advantage of using the moving average coefficients within the VAR model is that it remains invariant to the ordering of the variables (Diebold and Yilmaz, 2009,2012).

Using the VAR model does have limitations. The model uses Cholesky decomposition to orthogonalise the innovations making the forecast error variance decomposition (FEVD) based on the Cholesky factorisation highly sensitive to the ordering of the variables (Nyopa and Khumalo, 2022).

The DY spillover index (2009) uses Cholesky factorisation meaning that it succumbs to the same limitation with the VAR. To address this drawback, Diebold and Yilmaz (2012) extended the model to the credit of Koop *et al* (1996). The DY (2012) spillover index is based on the forecast error variance decomposition (FEVD) under the generalised vector autoregressive (GVAR) framework of Koop *et al* (1996) and Pesaran and Shin (1998). Contrary to the traditional VAR model that requires the orthogonalisation of shocks, the generalised VAR does not require the orthogonalisation of shocks whilst allowing for correlated shocks. The Generalised Impulse Response Functions (GIRFs) under the GVAR produces FEVDs that are independent of the ordering of variables.

⁹ Every variable in the VAR model is considered endogenous

4.7.5 Lag length selection criteria

Prior to estimating the VAR model, an optimal lag length p should be set first. The lag length is obtained from the VAR lag information criteria. A key feature of the autoregressive process with lag length p is that the time series under study will be dependent on its lagged p values. Since the p value is always unknown, the study adopts the use of Akaike's information criterion (AIC) (Akaike 1973) or Schwarz information criterion (SC) (Schwarz 1978) or (HQ) Hannan and Quinn (1979) criterion to decide on the optimal lag length. All three help to minimise model overfitting and improve goodness of fit by imposing penalties on the parameters. SC imposes a stiffer penalty when selecting a lag length than the AIC while HQ lies in between the two hence SC may opt for the simpler version of a model (Brooks, 2008: 233). It is crucial to select the optimal lag length as an inaccurate lag length will negatively affect estimating the VAR and is likely to result in autocorrelated regression.

4.8 DIAGNOSTIC TESTS

The models being used to generate the volatility series and the spillover index went through diagnostic tests such as serial autocorrelation and heteroskedasticity tests.

4.8.1 Autocorrelation

Autocorrelation occurs when the error terms across the observations under study are correlated with each other. If autocorrelation is present, both the t -test and the F -test become invalid as the standard errors will be incorrectly calculated owing to the inefficiency of the unbiased estimates in a model and an overstated R^2 (Brooks, 2008). The Breusch- Godfrey LM was used to check for autocorrelation for this study. The hypothesis for the test is as follows:

$H_0: \rho=0$ (no autocorrelation)

$H_1: \rho \neq 0$ (autocorrelation)

If the probability value $< \alpha$, where $\alpha = 10\%$, we reject H_0 , meaning the model does contain autocorrelation.

4.8.2 Heteroskedasticity test

Similar to autocorrelation, the presence of heteroskedasticity in a time series renders both the t -test and the F -test invalid as the standard errors will be incorrectly calculated (Brooks, 2008). This

research will adopt the ARCH-LM test to determine whether a residual is heteroscedastic or homoscedastic. The hypothesis for the test is as follows:

$H_0: Var(u_t) = \sigma^2$ (residuals are homoscedastic)

$H_1: Var(u_t) \neq \sigma^2$ (residuals are heteroscedastic)

If the probability value $< \alpha$, where $\alpha = 10\%$, we then reject H_0 meaning the residuals are heteroscedastic.

4.9 SUMMARY

The chapter focused on outlining the analytical framework for the empirical presentation of results and analysis in the next section. The specification of the GARCH models has been adopted from Chinzara (2010) enabling for the generation of the volatility series. To analyse, directional spillovers, total spillovers and pairwise spillovers, the Diebold and Yilmaz (2009, 2012) spillover index derivative of Koop *et al* (1996) and Pesaran and Shin (1998) generalised VAR model, was used offering better prospects and adding another dimension to volatility spillover analysis than the VAR. The next chapter will focus on the presentation, interpretation and analysis of the results.

CHAPTER FIVE

RESULTS AND ANALYSIS

5.1 INTRODUCTION

The goal of this research is to investigate the volatility spillover effects of macroeconomic variables and commodities on financial markets in South Africa. This study will shed light on whether financial markets in South Africa are net transmitters or receivers of volatility spillovers from macroeconomic variables and commodities. This will establish how well financial markets in South Africa are connected with the real side of the economy and help investors in determining the trends in risk exposure of financial markets. What emerged from the literature reviewed in Chapter Three of this research is that there exist bi-directional volatility spillover effects between the real side of the economy and the financial markets for both the developed and developing economies. The connectedness of financial markets and the real economy depends on whether the economy is either a net exporter or net importer of a commodity and how robust the economy is. Given this information, there exist gaps in literature to showcase the dynamics of spillovers from the real economy to the financial markets and to also assess whether they follow a similar trend as observed in developing economies where they are net receivers of spillovers. To this end, this chapter will present all the findings of the techniques, procedures and models mentioned in Chapter 4.

5.2 PRELIMINARY DATA ANALYSIS

Table 5.1 gives the descriptive statistics for the monthly data of the stock market returns for the JSE All-Share, JSE Retail sector, JSE Mining sector and JSE Financials 15 sector, foreign exchange market proxied by the USD/ZAR exchange rate, macroeconomic variables which are money supply and consumer price index and commodities represented by gold price and oil price. The statistical report includes the means with their corresponding minimum, maximum and standard deviations for the observations. The Jarque-Berra test statistic, Skewness and kurtosis examine the distribution properties.

5.2.1 Summary Descriptive Statistics

Table 5.1

Summary Descriptive Statistics

	<i>CPI</i>	<i>EXR</i>	<i>GOLD</i>	<i>M3</i>	<i>RALSH</i>	<i>RFIN</i>	<i>RMIN</i>	<i>RRET</i>	<i>WTI</i>
Mean	5.5563	0.5694	1.3616	4.4704	0.7729	0.5272	0.5695	0.5116	783.35
Median	5.3000	0.0901	1.6453	2.4274	0.9808	0.9791	0.5151	1.0422	714.06
Max	13.700	20.124	21.080	41.494	12.346	16.515	23.640	17.958	1807.0
Min	2.0000	-9.7097	-14.396	-22.622	-15.031	-36.795	-26.793	-39.925	279.51
Std. Dev.	1.9677	3.6653	5.5277	13.632	4.4743	5.7378	8.4389	6.9238	316.86
Skewness	1.6349	0.9104	0.1588	0.4455	-0.2400	-1.2215	-0.2085	-0.8764	1.0744
Kurtosis	6.9248	6.1918	3.6622	2.5386	3.7705	10.140	3.3467	7.2704	3.8333
Jarque-Bera	249.01	128.28	5.1249	9.6094	7.8296	541.05	2.7957	202.44	50.689
Probability	0.0000	0.0000	0.0771	0.0081	0.0199	0.0000	0.2471	0.0000	0.0000
Observations	229	229	229	229	229	229	229	229	229

Source: Author's computation from EViews

Notes: Inflation (CPI), USD/ZAR exchange rate (EXR), gold price (GOLD), money supply (M3), JSE All-Share returns (RALSH), JSE financials 15 returns (RFIN), JSE mining sector returns (RMIN), JSE retails sector returns (RRET) and oil price (WTI). The table above shows a summary of the descriptive statistics for the macroeconomic variables, commodities and financial markets data.

The unconditional means for all the variables are positive. The means for the stock market returns and the exchange rate percentage changes are hovering around 0.5 percent. Of interest is the mean for the CPI data which is at 5.5 percent. Given that South Africa has an inflation target that falls between 3% and 6%, this is considerably on the higher end of the target bracket. The rand-denominated oil prices have remained relatively on the lower side considering the maximum and the minimum prices.

With regards to the risk associated with the financial markets, the mining sector shows more risk given it has the highest standard deviation amongst the stock market indices whilst the RALSH JSE-All Share index exhibits the lowest standard deviation which can be expected as in campuses other sectors of the economy. The USD/ZAR exchange rate has considerably lower variability in the unconditional rate in comparison to the stock market returns indices. Between the macroeconomic variables, money supply (M3) has continued to be more volatile than inflation as measured by the consumer price index (CPI).

The stock market returns succumb more to negative shocks as shown by the negative skewness for all the indices. The financial sector seems to be the most receptive of these negative shocks among

the stock market returns indices. This means the stock market exhibits an asymmetric distribution of returns with a longer left tail. This might be unattractive for risk-averse investors despite the frequent small investment gains. It is no surprise then that the stock market indices are leptokurtic in distribution due to the risk associated with them particularly the financial sector with 10% and the retail sector with 7% kurtosis. The macroeconomic variables, the commodities and the foreign exchange rate market exhibit positive skewness meaning a longer right tail for all. This means that investors who have invested in commodities like gold are likely to experience frequent small losses and rare large gains.

To confirm the results of the skewness and kurtosis of the data, the Jarque- Bera tests shows whether a time series dataset is normally distributed. All the variables except the returns for the mining sector are not normally distributed at 10%. The normality of the returns for the mining sector could be due to heavily invested investors in the sector making it a more efficient market. However, due to the non-normal distribution of the data of the variables, this validates the use of the GARCH models which are capable of capturing volatility clustering.

What has emerged from the results above is that the stock market comes with it a degree of guaranteed returns although coupled with great risk which is expected of financial markets. The foreign exchange market carries lower risk in comparison to the stock markets hence characterised by the frequent small losses and rare large gains from economic shocks. Both the macroeconomic variables and the commodities exhibit non-normal distribution of the data meaning a great deal of volatility clustering which could spill over to both the financial markets. Below is a presentation of how these financial markets, commodities and macroeconomic variables are correlated with each other.

5.2.2 Ordinary Pair-wise Correlations

Table 5.2

Ordinary Pair-wise Correlations

	<i>CPI</i>	<i>EXR</i>	<i>GOLD</i>	<i>M3</i>	<i>RALSH</i>	<i>RFIN</i>	<i>RMIN</i>	<i>RRET</i>	<i>WTI</i>
<i>CPI</i>	1.0000								
<i>EXR</i>	0.1215	1.0000							
<i>GOLD</i>	0.0092	0.0020	1.0000						
<i>M3</i>	-0.0784	-0.1799	-0.0347	1.0000					
<i>RALSH</i>	-0.2327	-0.2385	-0.1442	0.0426	1.0000				
<i>RFIN</i>	-0.1310	-0.3455	-0.1438	0.1040	0.6702	1.0000			
<i>RMIN</i>	-0.1724	-0.1549	-0.1519	0.0543	0.7354	0.2574	1.0000		
<i>RRET</i>	-0.1216	-0.3859	-0.0645	0.0930	0.5108	0.7563	0.1375	1.0000	
<i>WTI</i>	0.2254	0.0630	-0.0552	0.2902	-0.1369	-0.0110	-0.1506	-0.0505	1.0000

Source: Author's computation from EViews

Notes: Inflation (CPI), USD/ZAR exchange rate (EXR), gold price (GOLD), money supply (M3), JSE All-Share returns (RALSH), JSE financials 15 returns (RFIN), JSE mining sector returns (RMIN), JSE retails sector returns (RRET) and oil price (WTI). The table above shows ordinary pair-wise correlation coefficients for the study data on financial markets, commodities, and macroeconomic variables from January 2005 to January 2024. Since the RALSH is the proxy for the JSE- All Share index and campuses all the other stock indices, they are likely to be highly collated.

The stock returns indices for the mining sector, the retail sector and the financial sector are positively highly correlated with the returns for the All-Share index with the mining sector having the highest correlation percentage at 73%. This could reflect how significant the mining sector is both on the JSE and the economy. The stock market indices are likely to be affected by economic activity in the same way although the magnitude of the effects may differ. The USD/ZAR exchange rate has a negative correlation with the stock market returns with the retail sector having the highest negative correlation with the exchange rate at (-38.59%). The strength of the Rand is therefore crucial for both the stock market and retail sector growth.

There is a negative correlation between the stock market returns indices and inflation showing the negative impact high inflation has on the stock returns. The correlation between the stock returns indices and money supply is however positive with the highest at 10.4% for the financial sector which is to be expected given the positive impact that money supply has on trading activities, banking and other commercial activities. The exchange rate is positively correlated with inflation showing how the local currency depreciates against other currencies in times of high inflation. The exchange rate is however negatively correlated with money supply at (-17.9%). An increase in

broad money supply in the economy would result in the loss of value of the South African Rand against the Dollar.

Both commodities are negatively correlated with the stock market returns with gold and oil at (-14.4%) and (-13.6%) respectively against the JSE-All Share Index. A rise in the price of either of the two commodities would lower the JSE stock returns. The exchange rate is positively correlated with gold prices and oil prices at 0.2% and 6.3% respectively. The positive correlation between gold prices and the exchange rate is indicative of how gold prices rise as the currency loses its value. A major cause of this is inflation and investors often find the precious metal to be a haven to hedge inflation. As for oil prices, the positive correlation with the exchange rate means that an increase in oil prices would weaken the Rand exchange rate which is expected for a major oil-importing economy.¹⁰

It is worth noting that the correlations provided above fall in line with what has been uncovered for the relationships between macroeconomic variables, commodities and financial markets in the literature in Chapter Three in the papers of Nisha (2015), Gay (2016), Ouedraogo (2018) and Ramasamy and Abar (2015). Whilst correlation does not imply causation, these results build well for this study.

5.2.3 Unit Root Test

Table 5.3

Unit root test for non-stationarity results (Augmented Dicky-Fuller)

<i>Variables</i>	<i>Model</i>	<i>ADF Level form (t-stats)</i>	<i>ADF 1st Difference (t-stats)</i>	<i>Order of Integration</i>
<i>RALSH</i>	Intercept	-15.87579*		I (0)
	Trend and intercept	-15.96549*		
<i>RFIN</i>	Intercept	-16.05666*		I (0)
	Trend and intercept	-16.04601*		
<i>RMIN</i>	Intercept	-15.95028*		I (0)
	Trend and intercept	-15.94646*		
<i>RRET</i>	Intercept	-14.27506*		I (0)

¹⁰ See [Ding et al 2023](#).

	Trend and intercept	-14.29560*		
WTI	Intercept	-2.130876	-11.45992*	I (0)
	Trend and intercept	-3.185167***	-11.43574*	
GOLD	Intercept	-16.05332*		I (0)
	Trend and intercept	-16.11530*		
CPI	Intercept	-2.830419***	-10.78621*	I (1)
	Trend and intercept	-2.991579	-10.78417*	
EXR	Intercept	-11.61377*		I (0)
	Trend and intercept	-11.58811*		
M3	Intercept	-3.614752*		I (0)
	Trend and intercept	-3.953384**		

Source: Author's computation from EViews

Notes: Significant at the 10%; (***), Significant at the 5%; (**), Significant at the 1%; (*). *t*-statistics are used to decide the order of integration. The decision as to whether a variable is stationary or not is made with regard to the significance of the *t*-stats for the trend and intercept and not just the intercept for the variable. Inflation (CPI), USD/ZAR exchange rate (EXR), gold price (GOLD), money supply (M3), JSE All-Share returns (RALSH), JSE financials 15 returns (RFIN), JSE mining sector returns (RMIN), JSE retails sector returns (RRET) and oil price (WTI).

From the estimation techniques described in Chapter 4 for the data and methodology section, the null hypothesis for the stationarity test using the ADF is that the series has a unit root hence it is non-stationary. From Table 5.3 above, both the variables for the financial markets of the stock market and the foreign exchange market have a *t*-statistic that is significant at the 1% in level terms meaning that we reject the null of non-stationarity and conclude that the variables are stationary for the both the intercept and trend.

For the macroeconomic variables, money supply is stationary at the 5% level of significance in level terms whilst inflation proxied by CPI has a unit root in level terms but is stationary at the 1% when differenced. Between the commodities, gold prices are stationary at level terms at the 1% whilst oil prices are stationary in level terms at the 10% and 1% when differenced. In this case, we reject the non-stationarity of the data

Having a stationary time series improves the forecasting power of the GARCH models. It is important for financial data to return to the long-term mean. All the variables above are integrated

with order $I(0)$ or $I(1)$ which is acceptable to generate a volatility series under the GARCH family of models.

5.3 THE GENERAL AUTOREGRESSIVE CONDITIONAL HETEROSKEDASTICITY (GARCH) MODELS

This study follows a two-step estimation technique to determine the volatility spillover effects of macroeconomic variables and commodities on financial markets. The first step involves generating the conditional volatility series that will be used for the second step which will be estimating the DY (2009, 2012) spillover index under the generalised VAR framework.

5.3.1 Heteroskedasticity Test

To further warranty the use of the GARCH family of models on top of the reasons provided for in the descriptive statistics (Table 5.1), the study puts the variables through an ARCH heteroskedasticity test. The generation of the GARCH model volatility series requires that the data have a non-constant mean for volatility clustering¹¹.

Table 5.4

Heteroskedasticity ARCH-LM Test

<i>Variable</i>	<i>RALSH</i>	<i>RFIN</i>	<i>RMIN</i>	<i>RRET</i>	<i>EXR</i>	<i>GOLD</i>	<i>WTI</i>	<i>CPI</i>	<i>M3</i>
<i>F-stats</i>	6.4050	6.4836	3.0222	9.0897	4.8170	8.8900	10.3573	3.6277	9.2407
<i>Probability</i>	0.0000	0.0116	0.0117	0.0029	0.0003	0.0000	0.0000	0.0036	0.0026

Source: Author's computation from EViews

Notes: Inflation (CPI), USD/ZAR exchange rate (EXR), gold price (GOLD), money supply (M3), JSE All-Share returns (RALSH), JSE financials 15 returns (RFIN), JSE mining sector returns (RMIN), JSE retails sector returns (RRET) and oil price (WTI). The above table shows the F-stats and their probability values for all the variables under the ARCH tests for heteroskedasticity.

The null hypothesis for the heteroskedasticity ARCH test as indicated in Chapter 3 is that there are no ARCH effects in the residuals. This implies that the residuals' variance is homoscedastic and independent of past squared residuals. From the table above, if the probability is less than 10%, prob value < 10%, we reject the null hypothesis. All the *F-stats* values for the variables above are significant at 5% hence we fail to reject the null hypothesis. The variables are thus heteroskedastic and fit for estimation with the heteroskedastic GARCH models as volatility clustering exists.

¹¹ Variables must be heteroskedastic to justify the use of the GARCH family of models.

5.3.2 ARCH Removal Test

To estimate the DY (2009, 2012) spillover index under the GVAR framework, the time series data used must be homoscedastic meaning a constant variance of the residuals. What warranted the use of the GARCH family of models was that the data exhibited heteroskedasticity hence an opportunity to capture volatility clustering. The chosen GARCH model from the GARCH family of models must remove the ARCH effects from the time series to be able to estimate the spillover index. Again, we employ the ARCH-LM test to test whether a subjected GARCH model can remove heteroskedasticity. Below are the results of the tests:

Table 5.5

Heteroskedasticity ARCH-LM Test

<i>Variable</i>	<i>RALSH</i>	<i>RFIN</i>	<i>RMIN</i>	<i>RRET</i>	<i>EXR</i>	<i>GOLD</i>	<i>WTI</i>	<i>CPI</i>	<i>M3</i>
<i>Model</i>	TARCH (1,1)	EGARCH (1,1)	EGARCH (1,1)	EGARCH (1,1)	EGARCH (1,1)	EGARCH (1,1)	ARCH (1,0)	EGARCH (1,1)	EGARCH (1,1)
<i>F-stats</i>	0.09371	0.131503	1.551962	0.627592	0.226819	0.667938	1.193022	1.170034	0.658274
<i>P-values</i>	0.9931	0.9850	0.1750	0.6789	0.9506	0.6482	0.3136	0.3249	0.6555

Source: Author's computations from EViews

Notes: Inflation (CPI), USD/ZAR exchange rate (EXR), gold price (GOLD), money supply (M3), JSE All-Share returns (RALSH), JSE financials 15 returns (RFIN), JSE mining sector returns (RMIN), JSE retails sector returns (RRET) and oil price (WTI). The table above shows the F-stats accompanied by their probabilities to test whether the selected model has removed the ARCH effect.

The null hypothesis for the heteroskedasticity ARCH test as indicated in Chapter 4 is that there are no ARCH effects in the residuals. This implies that the variance for the residuals is homoscedastic and independent of past squared residuals. From the table above, if the probability is less than 10%, prob value < 10%, we reject the null hypothesis. All the probabilities (p-values) for the *F-stats* are above 10% meaning we fail to reject the null. The selected GARCH model for each variable has removed the ARCH effect and thus made the residuals to have a constant conditional variance¹².

5.3.3 Model robustness

As indicated in Chapter 4, it would be premature of us to select a model solely on its ability to remove the ARCH effect. The selection criteria in the chapter state that despite removing the ARCH effect from the time series, the model would be tested to see whether the models would capture asymmetric features of the data, address the non-negativity of coefficients and produce a stationary series.

¹² All the generated conditional variance volatility series are homoscedastic.

For the asymmetric effects as represented by γ in equations (15) and (16), the coefficient needs to be statistically significant to conclude that the generated series for a variable exhibits asymmetric effects. In instances where the past squared residual coefficient (the ARCH term) plus the lagged GARCH term coefficient is less than 1, then conditional variance stationarity is met. In any situation where either of them is negative, then this violates the non-negativity constraint. The information criteria of HIC and Schwarz will be used only if there are competing models after considering the criteria of stationarity, asymmetry and the non-negativity breach constraint. The forecasting power of a model using the root mean squared is also considered to determine the forecasting power of a model. The results for the GARCH model selection are as follows:

Table 5.6

GARCH Model selection results

<i>Variable</i>	<i>Selected Model</i>	α	β	γ	<i>HIC</i>	<i>Schwarz</i>	<i>Forecasting Performance</i>
<i>GOLD</i>	<i>EGARCH (1,1)</i>	0.106556	0.870582	(0.2336) [0.0011]	19.79288	19.82866	9601.130
<i>EXR</i>	<i>EGARCH (1,1)</i>	0.569330	0.082987	(0.2102) [0.0375]	2.974803	3.028475	4.460277
<i>WTI</i>	<i>ARCH (1,0)</i>	0.995822			13.24005	13.26689	341.6985
<i>CPI</i>	<i>EGARCH (1,1)</i>	0.300400	0.665060	(0.0656) [0.7017]	3.104939	3.149665	1.965332
<i>M3</i>	<i>EGARCH (1,1)</i>	-0.017131	0.796131	(0.3010) [0.0000]	6.856670	7.189087	22.34218
<i>RALSH</i>	<i>TARCH (1,1)</i>	0.027052	0.558125	(0.5431) [0.0148]	5.725480	5.779315	4.466460
<i>RFIN</i>	<i>EGARCH (1,1)</i>	0.398186	0.608187	(-0.3349) [0.0000]	6.196119	6.251953	5.724877
<i>RMIN</i>	<i>EGARCH (1,1)</i>	0.037544	0.819782	(-0.2387) [0.0052]	7.103217	7.157051	8.420321
<i>RRET</i>	<i>EGARCH (1,1)</i>	0.074970	0.396057	(-0.3774) [0.0003]	6.670316	6.724150	6.910500

Source: Author's computation from EViews

Notes: Inflation (CPI), USD/ZAR exchange rate (EXR), gold price (GOLD), money supply (M3), JSE All-Share returns (RALSH), JSE financials 15 returns (RFIN), JSE mining sector returns (RMIN), JSE retail sector returns (RRET) and oil price (WTI). The table above shows the results of the GARCH models to generate the conditional volatility series for the variables in this study. (.) represents the coefficient for the asymmetric effect whilst [.] are the p-values for the coefficients of the asymmetric effects. (α) represents the ARCH term coefficient, (β) is the GARCH term coefficient for the models and (γ) captures the asymmetric effects from equations (15) and (16). Hannan-Quinn (HQ) and Schwarz are the information criteria. The forecasting performance indicates the root mean squared errors of the model.

For the commodity variables, EGARCH (1,1) is the best fit for capturing volatility clustering for gold prices. For gold prices, both α and β are positive and their summation is less than 1 meaning the model generates a stationary series for the variable which does not breach the non-negativity constraint. It also has significant positive asymmetrical effects meaning good news generates more volatility for gold than bad news. The ARCH (1,0) best-suited oil prices volatility clustering although this can be an indication of the variable having short-term memory and mostly depends on the recent lag residual from the mean as it is driven by recent shocks.

The EGARCH (1,1) was selected for both the macroeconomic variables. The summation of α and β for money supply is less than 1 meaning conditional variance stationarity is met although non-negativity is breached. The asymmetry effect for money supply is significant at the 1% meaning good news generates more volatility for the variable than bad news. $\alpha + \beta < 1$ as well for inflation hence both the non-negativity constraint and conditional variance stationarity are met. CPI does not however exhibit any asymmetrical effects given a prob value $> 10\%$ for the coefficient.

The EGARCH (1,1) was again dominantly selected for both the financial markets data except for the JSE-All Share index for which the TARARCH (1,1) was selected. For the JSE-All Share index, $\alpha + \beta < 1$ and are both positive meaning the conditional variance stationarity is met and the non-negativity constraint is not breached. RALSH has a significant positive asymmetrical effect at the 5% meaning that good news generates more volatility for the returns than bad news. For the financial sector, $\alpha + \beta < 1$ and are both positive meaning the conditional variance stationarity is met and the non-negativity constraint is not breached. The sector has significant negative asymmetrical effects at the 1% meaning that bad news or negative shocks tend to generate more volatility for the returns in comparison to positive shocks. The same results apply to both the mining sector returns and the retail sector returns of South Africa. Lastly, regarding the USD-based foreign exchange rate, $\alpha + \beta < 1$ and are both positive meaning the conditional variance stationarity is met and the non-negativity constraint is not breached. The exchange rate exhibits positive asymmetrical effects at the 5% meaning positive shocks generate more volatility for the Rand in comparison to bad news.

While the need to use information criteria and forecasting power of a model did not arise to select a model, the chosen models did provide a significant merit in most cases when considering these criterions. The results of how the non-selected models performed for each variable and paired

against the selected model are in [Appendix A.2](#). All models have thus been adequately specified in this regard and inference may ensue.

5.4 THE GENERALISED VECTOR AUTOREGRESSION (GVAR) MODEL

5.4.1 Optimal Lag length selection

Similar to the VAR model, the GVAR model requires an appropriate lag length for estimation. It is crucial to select the optimal lag length as an inaccurate lag length will negatively affect estimating the VAR by producing spurious results and is likely to result in an autocorrelated specified model.

Table 5.7

GVAR lag length selection

<i>Lag</i>	<i>LogL</i>	<i>LR</i>	<i>FPE</i>	<i>AIC</i>	<i>SC</i>	<i>HQ</i>
0	-10619.29	NA	7.41e+30	96.62082	96.75965	96.67688
1	-9608.158	1930.344	1.58e+27	88.16507	89.55337*	88.72570
2	-9458.387	273.6711	8.46e+26*	87.53989*	90.17766	88.60509*
3	-9400.886	100.3659	1.06e+27	87.75351	91.64076	89.32328
4	-9309.814	151.5115	9.80e+26	87.66194	92.79866	89.73628
5	-9238.437	112.9046*	1.10e+27	87.74943	94.13562	90.32834
6	-9188.221	75.32406	1.52e+27	88.02928	95.66495	91.11277
7	-9131.953	79.79911	2.01e+27	88.25411	97.13925	91.84217
8	-9074.668	76.55284	2.70e+27	88.46971	98.60432	92.56233

Source: Author's computation from EViews

Notes: * Indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion and HQ: Hannan-Quinn information criterion. The table above shows the lag length selected by each information criterion where Inflation (CPI), USD/ZAR exchange rate (EXR), gold price (GOLD), money supply (M3), JSE All-Share returns (RALSH), JSE financials 15 returns (RFIN), JSE mining sector returns (RMIN), JSE retails sector returns (RRET) and oil price (WTI) are the endogenous variables.

The study will be using the HQ, AIC and SC information criteria to select the optimal lag length for estimating the GVAR. From Table 5.7 above, lag length 1 was selected by the SC while lag length 2 was selected by AIC and HQ. It is no surprise that SC chose lag 1 as opposed to the other information criteria which chose lag 2 as SC imposes a stiffer penalty when selecting a lag length than the AIC while HQ lies in-between the two (Brooks, 2008: 233). However, since lags 1 and 2 were selected by these criteria this could indicate short-term to medium-term dependencies of own lags by the variables.

To confirm that there are short-term to medium-term dependencies between the endogenous variables, the sequential modified likelihood ratio test statistic (LR) chose lag 5 meaning adding

more lags to the model does not improve the goodness-of-fit of the nested models. To measure the capability of a model to forecast out-of-sample data, we consider the results of the final prediction error (FPE). The smaller FPE is at lag length 2 suggesting that using lag length 2 provides better predictive accuracy for the model while minimising both overfitting and underfitting the data.

Given the results above, it is sagacious to select lag length 2 for estimating the GVAR to generate the DY spillover index. However, this lag length still must be tested further to assess whether autocorrelation amongst the endogenous variables is eliminated at the chosen lag length.

5.4.2 Autocorrelation Test

Table 5.8

The Breusch- Godfrey Autocorrelation Test

<i>Lag</i>	<i>LRE* stat</i>	<i>Prob.</i>	<i>Rao F-stat</i>	<i>Prob.</i>
1	76.00365	0.6362	0.936572	0.6372
2	86.01173	0.3307	1.064871	0.3318
3	95.30750	0.1323	1.185106	0.1330
4	75.10470	0.6636	0.925106	0.6646
5	81.08182	0.4765	1.001524	0.4777
6	84.13391	0.3839	1.040708	0.3850

Source: Author's computation from EViews

Notes: LRE* stat is the Likelihood Ratio-Based Test statistic for testing the presence of autocorrelation at different lags. The Rao *F-statistic* tests the presence of serial correlation in the residuals of a model.

The null hypothesis for the Breusch- Godfrey Autocorrelation Test is that no autocorrelation exists at any specified lag in the model. Since both the p-values > 10% for the LRE* statistics and the Rao *F-statistics* at lag length 2, we fail to reject the null and conclude that there is no serial correlation at lag length 2 for the restricted model. Since the results of all the tests above have thus far been satisfactory, we proceed to estimate the DY spillover index.

5.5 THE DIEBOLD-YILMAZ SPILLOVER INDEX

It is important to remember that many changes took place over the sample period time from January 2005 to January 2024. Financial markets integration and structural changes can be attributed to these changes especially given the fast-paced transfer of technology. Taking this into account, it is thus important as pointed out in the methodology (Chapter 4) to estimate the model under rolling window conditions to account for the time-varying effects. The results below are

divided into sections to meet the objectives of the study and to enable comparison with previous literature. First, we focus on the total, directional and net spillovers of all the endogenous variables as an overview before subdividing them as per the literature categories. Lastly, the results for the time-varying pairwise spillovers for the endogenous variables will be presented and discussed.

Table 5.9

Rolling spillover (connectedness) for macroeconomic variables, commodities and financial markets

	<i>CPI</i>	<i>EXR</i>	<i>GOLD</i>	<i>M3</i>	<i>RALSH</i>	<i>RFIN</i>	<i>RMIN</i>	<i>RRET</i>	<i>WTI</i>	<i>From Others</i>
<i>CPI</i>	55.0	1.3	19.4	0.2	2.9	6.7	4.8	8.3	1.4	45.0
<i>EXR</i>	13.3	45.8	9.9	0.8	16.4	2.4	7.2	3.1	1.1	54.2
<i>GOLD</i>	7.0	0.5	68.6	1.8	6.4	3.2	7.5	4.3	0.6	31.4
<i>M3</i>	0.3	0.2	1.6	81.2	6.0	3.9	2.0	0.8	4.0	18.8
<i>RALSH</i>	16.1	3.1	7.6	1.3	33.1	14.1	13.0	9.7	1.9	66.9
<i>RFIN</i>	1.1	0.7	8.0	1.0	22.0	39.5	4.4	23.0	0.4	60.5
<i>RMIN</i>	8.3	2.0	3.8	1.5	15.3	2.8	58.6	1.8	5.9	41.4
<i>RRET</i>	0.9	1.2	9.1	2.4	12.1	22.2	2.9	48.8	0.5	51.2
<i>WTI</i>	1.5	1.5	0.1	1.8	0.6	0.3	4.3	0.3	89.5	10.5
<i>Contribution to others</i>	48.4	10.5	59.6	10.7	81.8	55.5	46.3	51.3	15.8	379.9
<i>Contribution including own</i>	103.4	56.3	128.2	91.9	114.9	95.0	104.9	100.0	105.4	Total = 42.2%
<i>Net</i>	3.4	-43.7	28.2	-8.1	14.9	-5	4.9	0.1	5.3	

Source: Author's computation from EViews

Notes: Inflation (CPI), USD/ZAR exchange rate (EXR), gold price (GOLD), money supply (M3), JSE All-Share returns (RALSH), JSE financials 15 returns (RFIN), JSE mining sector returns (RMIN), JSE retails sector returns (RRET) and oil price (WTI). This table reports the overall forecast error variance under the generalised VAR framework for the South African foreign exchange market, stock market, macroeconomic variables and commodities explained by each other generated through the DY spillover index.

The diagonal elements where $i = j$ represent own shocks for the variables. Pairwise directional spillover is represented by the off-diagonal elements in the table. The 'contribution to others' row measures the spillover effect of a variable transmitted to all the other variables. Subsequently, the 'from others' column shows the total spillovers received by a variable from all the other variables in the model. The 'contribution including own' is the summation of 'contribution to others' and own variable shocks on the diagonal. 'Net' spillovers are derived by subtracting the 'from others' column from the 'contribution to others' row where if the 'Net' is positive then the variable is a

net transmitter of directional volatility spillovers to other variables and if negative then the variable is a net receiver of directional volatility spillovers from other variables.

The results from Table 5.9 indicate that there is a 42.2% total spillover amongst all the endogenous variables in the model meaning that 57.8% (100%-42.2%) of the volatility for the variables is explained through own shocks. Oil prices have the highest own connectedness at 89.5 followed by money supply and gold prices at 81.2% and 68.6% respectively signifying low integration with the other variables. This should come as no surprise as was indicated in Chapter Two that South Africa is a big oil importer meaning it does not control oil prices to a larger extent. The JSE-All Share returns have the lowest own connectedness at 33.1% followed by the financial sector returns and the USD/ZAR exchange rate both at 39.5% and 45.8% respectively meaning they are more integrated with the other variables.

The JSE-All share returns have the highest effect on and from all the other variables contributing 81.8% to the forecast volatility while receiving 66.9% justifying why it is the most integrated variable in the model¹³. Oil prices are the lowest recipient of spillovers at only 10.5% followed by money supply at 18.8% and gold prices at 31.4% making a commodity like gold less risky to invest in as it has low exposure. Overall, the USD/ZAR exchange rate is the highest net directional recipient of the forecast volatility at (-43%) whilst gold is the highest net directional transmitter at 28.2% amongst the endogenous variables in the model. Gold price is the biggest contributor of volatility spillover to inflation while inflation is the biggest contributor of spillover to the exchange rate meaning both have direct and indirect directional spillover effects on the exchange rate.

5.5.1 Cross-market spillovers: Commodities and the Stock Market

To allow us to specifically examine the volatility spillover effects of commodities and macroeconomic variables on financial markets, we look at each case in isolation allowing us to directly analyse the spillover dynamics and add to the specific groups in our empirical literature review. The same interpretation method for Table 5.9 also applies to the tables below.

¹³ [Boakye et al \(2023\)](#) found that the ZAR was the most integrated variable when they did their study. However, that was only for the COVID-19 period.

Table 5.10

Rolling total, directional and net spillover (connectedness) of commodities and the stock market

	<i>GOLD</i>	<i>WTI</i>	<i>RALSH</i>	<i>RFIN</i>	<i>RMIN</i>	<i>RRET</i>	<i>From Others</i>
<i>GOLD</i>	68.4	1.3	15.0	1.9	11.0	2.4	31.6
<i>WTI</i>	0.2	94.6	2.9	0.3	1.6	0.4	5.4
<i>RALSH</i>	7.3	0.5	49.1	8.2	29.3	5.6	50.9
<i>RFIN</i>	8.8	0.2	19.2	42.4	4.8	24.6	57.6
<i>RMIN</i>	0.9	2.5	21.9	1.5	72.2	1.1	27.8
<i>RRET</i>	9.8	0.5	11.0	23.2	3.4	52.0	48.0
<i>Contribution to others</i>	27.0	5.0	70.0	35.1	50.1	34.1	221.3
<i>Contribution including own</i>	95.4	99.6	119.1	77.5	122.3	86.1	Total = 36.9%
<i>Net</i>	-4.6	-0.4	19.1	-22.5	22.3	-13.9	

Source: Author's computation from EViews

Notes: This table shows the DY spillovers index between the commodities of gold prices (GOLD) and oil prices (WTI) and stock market indices returns of the JSE-All Share returns (RALSH), JSE Financials 15 sector returns (RFIN), JSE mining sector returns (RMIN) and the JSE retails sector returns (RRET).

Table 5.10 shows the results of the volatility spillovers between commodities and the stock market of South Africa. Overall, in this context, own variable shocks explain 63.1% of the forecast error variance between commodities and the stock market given that the total spillover is at 36.9%. Oil price has the highest own connectedness at 94.6% followed by the JSE mining sector returns at 72.2% and gold price at 68.4% while the JSE financials 15 returns have the lowest own connectedness at 42.4%.

The JSE-All Share returns have the highest contribution to others at 70%. In particular, directional spillovers from the JSE-All share returns to the commodities are 15% to the gold price and 2.9% to oil prices whilst receiving 0.5% and 7.3% from oil price and gold price volatility respectively¹⁴. The JSE mining sector returns have the second highest effect on others at 50.1% whilst more specifically it receives 0.9% from gold prices and 2.5% from oil prices subsequently spilling 11% and 1.6% to gold price and oil price directional spillovers respectively.

The JSE financials returns are the highest recipient of directional spillovers from others at 57% making it the most exposed sector within this context. Given the risk-return nexus of financial markets, this sector might be accompanied by greater returns given the risk. Individually, the sector receives 8.8% and 0.2% volatility spillovers from gold price and oil price respectively whilst

¹⁴ Confirmation of the weak bidirectional volatility spillovers between oil prices and the South African stock market as was found by [Fowowe \(2017\)](#).

transmitting 1.9% to gold price and 0.3% to oil price. The retail sector is quite a high recipient of directional spillovers from others at 48% with 9.8% and 0.5% coming from gold price and oil price respectively. Amongst the stock market sectors, the JSE mining sector is the least recipient of contribution from others deeming it the safest investment sector in this context for hedging and risk-averse investors as noted in Morema and Bonga-Bonga (2020).

Overall, the JSE mining sector returns are the largest net directional volatility spillover transmitters at 22.3% to others in this context followed by the JSE All-Share returns at 19.1%. Both gold price and oil price are net receivers of forecast volatility spillovers at (-4.6%) and (-0.4%) respectively. This paints a picture of the commodities being the net directional recipient of forecast spillovers from the stock market in South Africa with the overall net at 4.9% from the stock market indices in comparison to the commodities.¹⁵

5.5.2 Cross-market spillovers: Commodities and the Foreign Exchange Market

Table 5.11

Rolling total, directional and net spillover (connectedness) of commodities and the foreign exchange market

	<i>EXR</i>	<i>GOLD</i>	<i>WTI</i>	<i>From Others</i>
<i>EXR</i>	83.0	16.8	0.2	17.0
<i>GOLD</i>	8.2	90.6	1.3	9.4
<i>WTI</i>	0.0	0.5	99.4	0.6
<i>Contribution to others</i>	8.2	17.3	1.5	27.0
<i>Contribution including own</i>	91.2	107.9	100.9	Total = 9.0%
<i>Net</i>	-8.8	7.9	0.9	

Source: Author's computation from EViews

Notes: This table shows the rolling forecast volatility spillover as per the DY spillover index between the foreign exchange market proxied by the USD/ZAR exchange rate (EXR) and the commodities which are gold price (GOLD) and oil price (WTI).

In Table 5.11, which shows the shock effects between commodities and the foreign exchange market, the total own shock effects account for 91% of the spillovers, given that the total spillovers between the two markets are 9%. This significantly shows that there is low integration between the commodities market and the foreign exchange market in comparison to the stock market. Oil price has the highest own connectedness at 99.4% followed by gold price at 90.6% and the

¹⁵ $22.3\% + 19.1\% + (-22\%) + (-13.9\%) = 4.9\% > (-4.6\%) + (-0.4\%)$

USD/ZAR exchange rate at 83.0% again showing low connectedness for commodities and the foreign exchange market.

Gold price has the highest effect on others at 17.3% followed by the USD/ZAR exchange rate at 8.2%. More specifically, gold price spills over 16.8% to the USD/ZAR exchange rate and only 0.5% to oil price. Oil price contributes a low 0.2% directional spillover to the exchange rate and 1.3% to gold price. Oil price has the lowest contribution from others at 0.6% while gold continues to be a haven from the directional spillovers from the financial markets at 9.4%. The USD/ZAR exchange rate is the highest recipient of direction spillovers from others at 17%. It thus comes as no surprise that the USD/ZAR exchange rate is a net recipient of directional volatility spillovers from the commodities at (-8.8%). This guarantees a great deal of systematic risk for the forex market of South Africa as was found in Boakye *et al* (2023).

5.5.3 Macro-financial spillovers: Macroeconomic Variables and the Stock Market

Table 5.12

Rolling total, directional and net spillover (connectedness) of macroeconomic variables and the stock market

	<i>CPI</i>	<i>M3</i>	<i>RALSH</i>	<i>RFIN</i>	<i>RMIN</i>	<i>RRET</i>	<i>From Others</i>
<i>CPI</i>	59.3	0.1	1.8	11.8	11.5	15.5	40.7
<i>M3</i>	0.7	85.5	7.4	3.7	2.0	0.7	14.5
<i>RALSH</i>	19.7	0.9	34.6	16.9	14.1	13.8	65.4
<i>RFIN</i>	1.2	0.6	24.1	43.2	3.7	27.2	56.8
<i>RMIN</i>	13.8	0.8	15.2	2.4	65.3	2.5	34.7
<i>RRET</i>	1.6	1.9	14.5	26.3	1.9	53.9	46.1
<i>Contribution to others</i>	36.9	4.3	63.1	61.0	33.2	59.6	258.1
<i>Contribution including own</i>	96.2	89.7	97.7	104.3	98.6	113.5	Total = 43.0%
<i>Net</i>	-3.9	-10.2	-2.3	4.2	-1.5	13.5	

Source: Author's computation from EViews

Notes: This table shows the DY spillovers index between the macroeconomic variables which are inflation (CPI) and money supply (M3) and stock market indices returns of the JSE-All Share returns (RALSH), JSE Financials 15 sector returns (RFIN), JSE mining sector returns (RMIN) and the JSE retails sector returns (RRET).

In Table 5.12, the stock market continues to show persistent integration with the real economy given the high total spillovers between the stock market and the macroeconomic variables at 43%. Money supply shows the highest own connectedness at 85.5% hence most of the volatility for money supply is not through shocks from the other variables in the table. The mining sector returns have the second highest own connectedness at 65.3% while the JSE All-share returns are the most

integrated variable in the table given only 34% of the forecast error variance of the JSE All-share returns are a result of its own shocks.

As was the case with the commodities, the JSE All-Share returns once again have the highest effect on the other variables at 63.1% with the financial sector returns right beneath at 61%. More specifically, the JSE All-Share returns spills 1.8% to inflation and 7.4% to money supply whilst simultaneously receiving a contextual relatively high 19.7% from inflation and only 0.9% from money supply of directional spillover. Overall inflation has greater directional spillover effects on the overall returns of the stock market. Both inflation and money supply have little directional spillover effects on the individual JSE stock market sectors returns with the highest only at 13.8% coming from inflation to the JSE mining sector returns. The JSE All-Share returns are the highest recipient direction forecast error variance from others standing at 65% followed by the JSE financial sector returns at 56.8%. Amongst the JSE stock sectors, the JSE mining sector returns are the least recipient of the forecast volatility spillovers from the others including the macroeconomic variables making them the perfect take for minimising risk.

Overall, both macroeconomic variables are net directional volatility spillover recipients from the stock market returns in this context. Between the macroeconomic variables and the JSE All-Share returns, the JSE All-Share returns are the least net directional volatility spillover recipient at (-2.3%) compared to the (-3.9%) for inflation and (-10.2%) for money supply.

5.5.4 Macro-financial spillovers: Macroeconomic Variables and the Foreign Exchange Market

Table 5.13

Rolling total, directional and net spillover (connectedness) of macroeconomic variables and the foreign exchange market

	<i>EXR</i>	<i>CPI</i>	<i>M3</i>	<i>From Others</i>
<i>EXR</i>	86.3	12.4	1.3	13.7
<i>CPI</i>	3.5	96.42	0.1	3.6
<i>M3</i>	0.6	0.7	98.8	1.2
<i>Contribution to others</i>	4.0	13.1	1.4	18.5
<i>Contribution including own</i>	90.3	109.5	100.1	Total = 6.2%
<i>Net</i>	-9.7	9.5	0.2	

Source: Author's computation from EViews

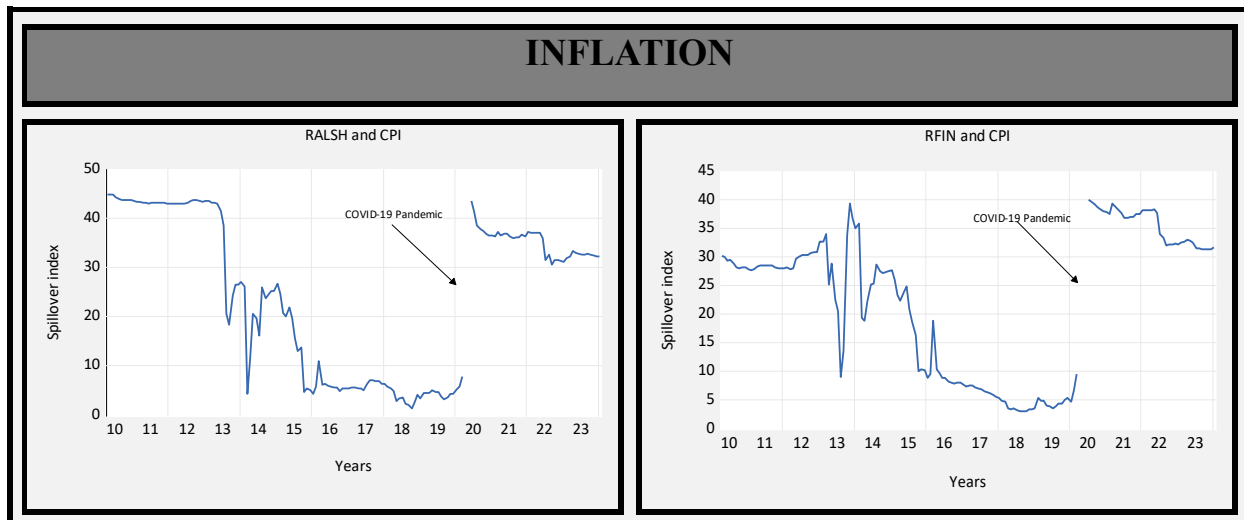
Notes: This table shows the rolling forecast volatility spillover as per the DY spillover index between the foreign exchange market proxied by the USD/ZAR exchange rate (EXR) and the macroeconomic variables which are inflation (CPI) and money supply (M3).

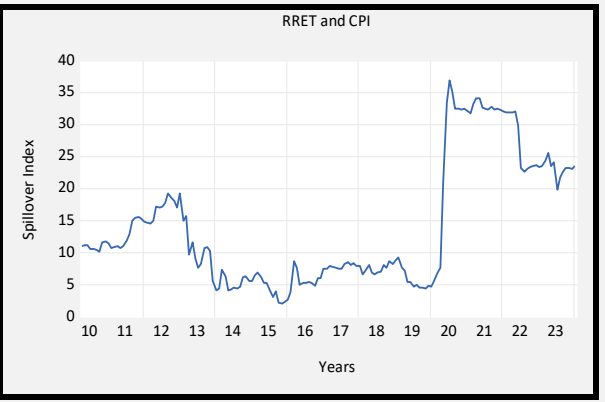
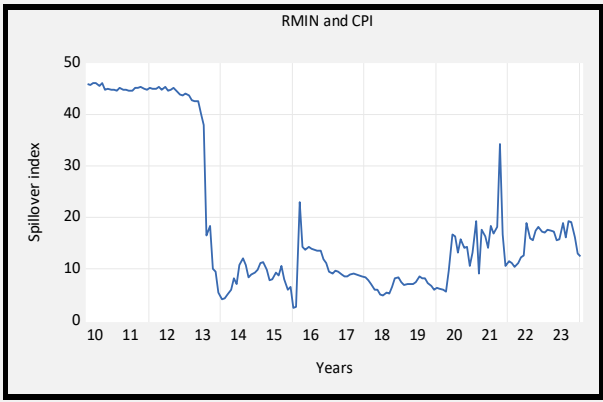
Table 5.13 reports the forecast error variance through the GVAR for the macroeconomic variables and the exchange rate. A high 93.8% own variance is responsible for the volatility of the variables given that the total spillover amongst the variables is only 6.2%. As was the case with the commodities, there is low integration between the exchange rate and the real economy although it is more connected with the commodities. Money supply has the highest own connectedness at 98% as was the case with the stock market, followed by inflation at 96.4% and the exchange rate at 86%.

Inflation has the highest total contribution to others at 13.1%. More specifically, inflation-directional spillovers are only at 0.7% to oil price and 12.4% to the exchange rate. Money supply has the least directional contribution to others at 1.4%. More specifically, money supply contributes 1.3% directional spillovers to the exchange rate and a low 0.1% to inflation. The exchange rate is the highest recipient of volatility spillovers from the others standing at 13.7%. It is thus no surprise that the USD/ZAR exchange rate is the net directional volatility spillover recipient at (-9.7%) from the macroeconomic variables with inflation being the highest contributor.

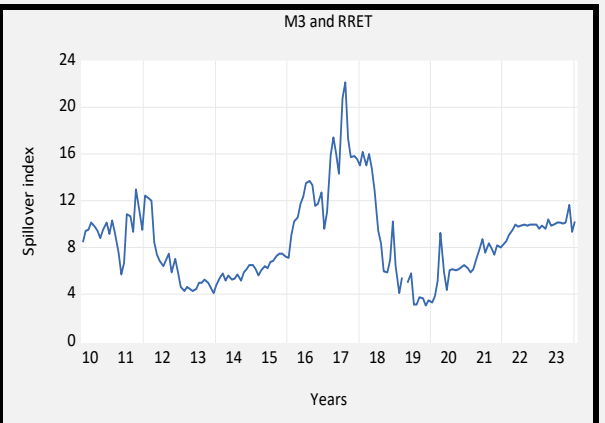
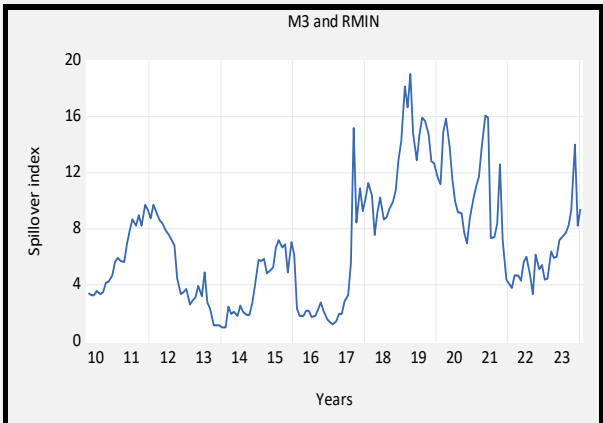
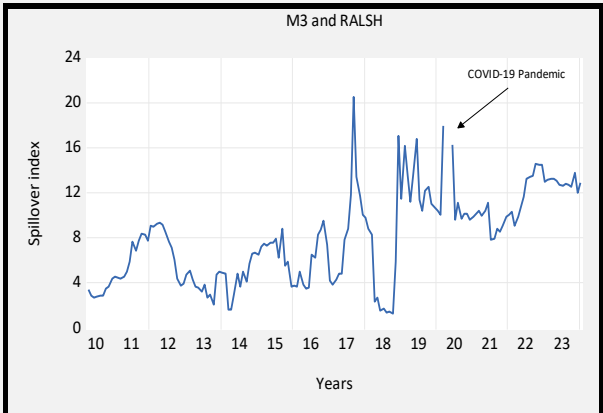
FIG 5.1

Time-Varying Pairwise Spillover Analysis for the Stock Market

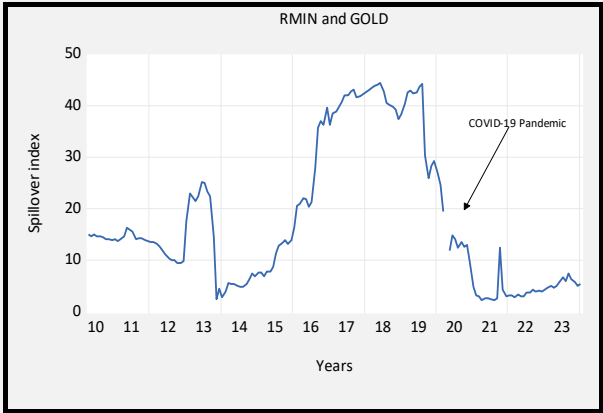
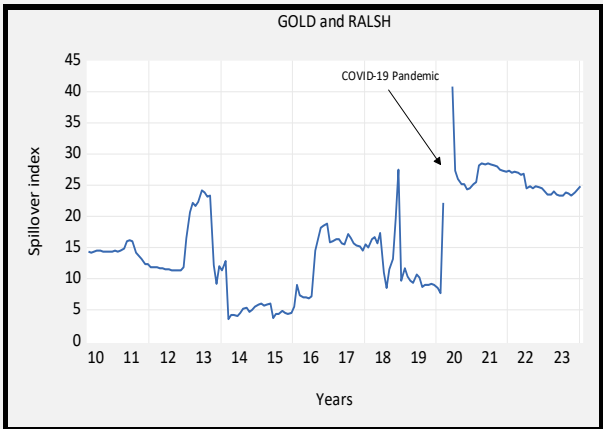




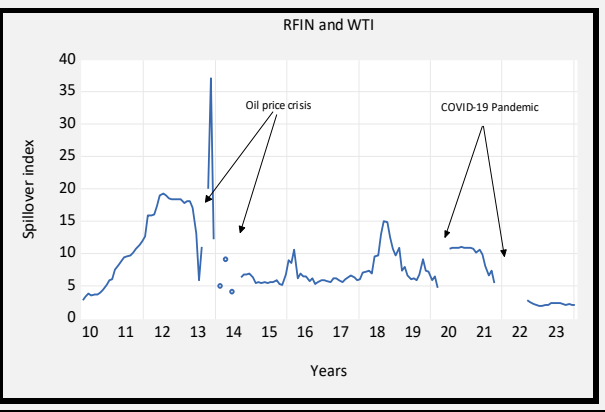
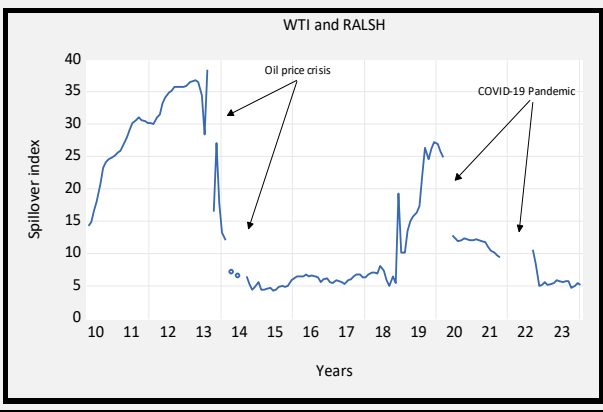
MONEY SUPPLY

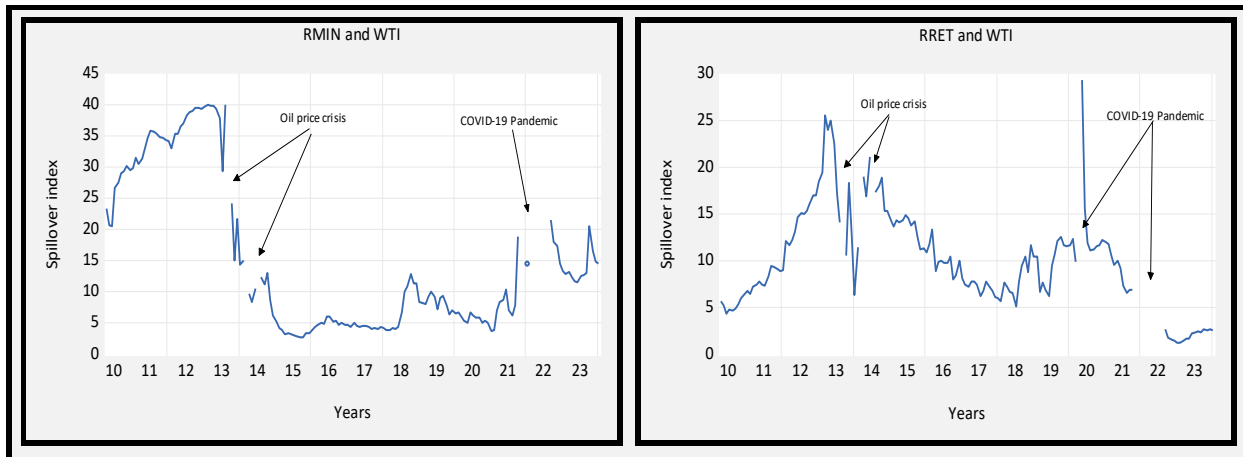


GOLD PRICE



OIL PRICE





Source: Author's Computation from EViews

Notes: Inflation (CPI), gold price (GOLD), money supply (M3), JSE All-Share returns (RALSH), JSE financials sector 15 returns (RFIN), JSE mining sector returns (RMIN), JSE retails sector returns (RRET) and oil price (WTI). Fig 5.1 above shows the time-varying pairwise spillovers between i) macroeconomic variables and stock market indices ii) commodities and stock market indices for the period 2010 to 2024. The stats start from 2010 because of the 60-month rolling window chosen for the analysis from 2005.

5.5.5 Rolling pairwise nexus of the stock market

Inflation

From Fig 5.1, the time-varying pairwise spillovers between the JSE All-Share returns and inflation were high post the Global financial crisis of 2008 until 2013. From 2015 until the COVID-19 pandemic, the forecast error variance spillovers between the two were relatively low. We notice a break between the spillovers on the onset of the COVID-19 pandemic before returning to the post-Global Financial Crisis of 2008 spillover levels and remaining high above 30% into 2023. A similar trend occurred between inflation and the financials 15 sector returns. However, there were no breaks in volatility spillovers between inflation and the mining sector returns and the retails stock returns suggesting stronger linkages between these variables. The spillovers between the mining sector returns and inflation were the most resistant to the effects of the COVID-19 pandemic averaging below 20% signifying the importance of precious metals like gold during periods of economic uncertainty.

Money supply

Post the Global financial crisis, the volatility spillovers between the JSE All-Share returns and money supply were relatively low in comparison to the post-COVID-19 pandemic period where they became more connected. Overall, the spillovers between the two are relatively low with the

highest being in 2017 at just above 20%. Again, we notice a break between the spillovers at the onset of the pandemic at the end of 2019 as was the case with inflation. A similar trend is seen for money supply and financials 15 index returns. Both the mining sector returns and the retail sector returns did not have a break of volatility spillover effects with money supply at the onset of the pandemic signifying closer linkages for these variables. Overall, only the retail sector returns breached the 20% mark for pairwise spillovers with money supply amongst the stock market indices showing a stronger connection between the two.

Gold price

The pairwise spillovers between the JSE All-Share returns and gold price were relatively low post the global financial crisis of 2008 in comparison to the post-pandemic period from 2022 onwards. The pairwise spillovers between the two were lowest from 2014 to 2016 peaking in 2020. Again, we notice a break in the pairwise spillovers between the gold price and the stock returns at the onset of the COVID-19 pandemic remaining persistently high around 25%. We notice a similar trend with the financial sector returns and the retail sector returns although there was no break in the pairwise spillovers between gold prices and the retail sector returns. Pairwise spillovers between gold prices and the mining sector reached their peak in 2018 above 40% which was the highest connectedness with any of the stock market indices although the linkages dropped after the COVID-19 pandemic to below the post-GFC levels.

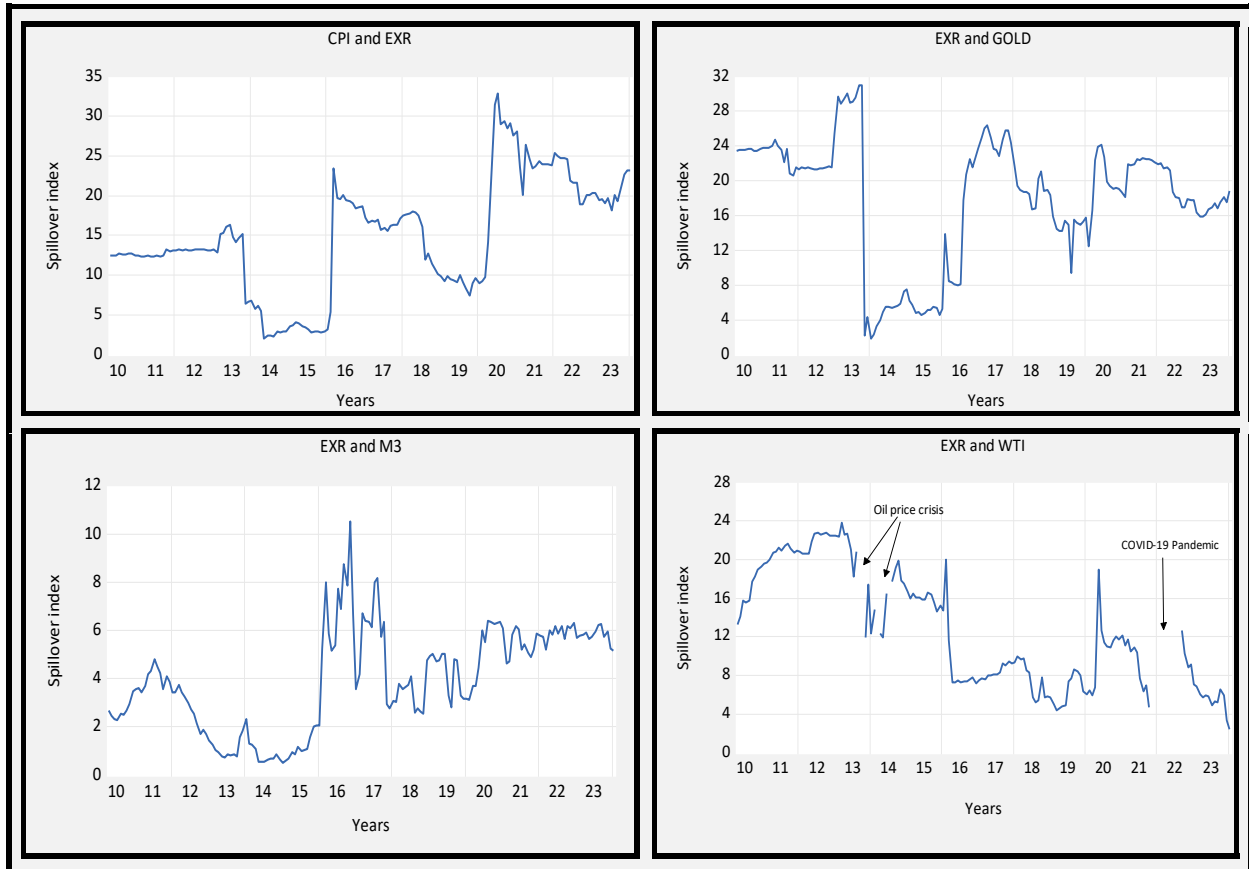
Oil price

From Fig 5.1, the rolling pairwise forecast error variance spillovers between the JSE All-Share returns and oil price experienced a sharp rise post the GFC from 2010 peaking in 2013. However, this time we notice the breaks in the rolling pairwise spillovers between oil price and the stock market which can be attributed to the oil price crisis of 2014 to 2016. Due to oversupply, the crisis brought oil prices closer to the other industrial commodities' low-price averages in the long term due to economies of scale growth in the United States (World Bank, 2018). The pairwise spillover effects were relatively low after 2014 to the end of 2018 hovering around 8% to 11%. As was the case with the macroeconomic variables and gold price, there was a break in pairwise volatility spillovers at the onset of the pandemic and the beginning of 2022. Volatility spillovers between oil prices and the JSE All-Share returns were high during the COVID-19 period as was found by Chen *et al* (2024). Post the COVID-19 pandemic, pairwise spillovers between oil prices and the JSE All-

Share returns have reverted to the levels experienced between 2015 and 2018. A similar trend was experienced with the financial sector returns, the retails sector returns and the mining sector returns although it has remained relatively higher in the latter.

FIG 5.2

Time-Varying Pairwise Spillover Analysis for the Foreign Exchange Market



Source: Author’s Computation from EViews

Notes: Inflation (CPI), USD/ZAR exchange rate (EXR), gold price (GOLD), money supply (M3) and oil price (WTI). Fig 5.2 above shows the time-varying pairwise spillovers between i) macroeconomic variables and the USD/ZAR exchange rate ii) commodities and the USD/ZAR exchange rate from 2010 to 2024. The stats start from 2010 because of the 60-month rolling window chosen for the analysis from 2005.

5.5.6 Rolling pairwise nexus of the foreign exchange market

Inflation

The pairwise spillover between inflation and the USD/ZAR exchange rate in Fig 5.2 was relatively low post the GFC to 2013 hovering around 13%. There was a large dip in the pairwise spillovers in 2013 which can be attributed to the challenging year the Rand faced due to a stalled mining industry, a struggling European economy, the unfavourable US data and to some extent the passing

of Nelson Mandela (Goko, 2014). 2016 exhibited evidence of asymmetric effects in the exchange rate in the pairwise spillover due to the surprise sacking of the former finance minister, Nhlanhla Nene, before gradually coming down until the end of 2019. Post the COVID-19 pandemic, the connectedness of inflation and the exchange rate remained relatively high above 20% signifying the time-varying effects that significant global shock can have on financial markets.

Money supply

From Fig 5.2, money supply and the USD/ZAR exchange rate are less well integrated than the exchange rate and inflation. Post the GFC, pairwise spillovers between the two remained low below 5% before the huge spike in 2016 which was caused by the surprising removal of the former finance minister of South Africa by former President Zuma. Similar to the case with inflation, the exchange rate has remained more connected post the COVID-19 pandemic compared to the immediate period after the GFC although it is still very low below 8% in this case.

Gold price

The pairwise forecast error variance effects between gold price and the exchange rate were relatively high post the GFC peaking at the beginning of 2013 at around 30%. There is again evidence of the global economy's impact on the Rand coupled with the passing of Mandela as shown by the huge dip in spillovers in 2013. We again notice the impact of domestic politics on the Rand in 2016 with the huge spike to above 20% as was the case with the macroeconomic variables. Pairwise spillovers in this case have stayed relatively lower post the COVID-19 pandemic in comparison to the immediate period post the GFC of 2008.

Oil Price

The pairwise spillovers between oil price and the USD/ZAR exchange rate averaged the highest post the GFC to the beginning of 2016. There were breaks in the pairwise spillovers in 2013 and 2014 caused by the global economic outlook and the oil price crisis. Again, the pairwise volatility spillovers in this case show a dip in 2016 due to the drop in the Rand value caused by domestic politics. There was again another break in the spillovers between the two during the COVID-19 pandemic and the pairwise spillovers have remained lower post the COVID-19 pandemic in comparison to post the GFC suggesting lower connectedness.

Since our primary focus is on the volatility spillover nexus of macroeconomic variables and commodities on the financial markets, the time-varying pairwise connectedness of macroeconomic variables, commodities or financial markets will not be discussed in this study. However, the results for these linkages are in [Appendix A.3](#) for perusal purposes.

5.6 CONCLUSION

This chapter presents, interprets and discusses the results based on the volatility spillover framework outlined in Chapter Four. The GARCH family of models were used to generate the conditional volatility series for all the variables in the study. To analyse the total, directional, net and pairwise spillovers, we employed the Diebold and Yilmaz (2009,2012) spillover index under the GVAR framework of Koop *et al* (1996) and Pesaran and Shin (1998).

The descriptive statistics confirmed the properties of financial data with the presence of kurtosis causing non-normality in the distribution of the data. Most of the variables did not exhibit non-stationarity in level terms besides a few that exhibited a significant trend. The presence of the ARCH effects in the data warranted the use of the GARCH models to generate the conditional volatility series. All the stock indices exhibited negative asymmetry meaning more volatility for the returns is generated due to negative shocks in comparison to positive shocks.

Our results from the spillover analysis show the stock market, specifically the JSE All-Share returns as the most integrated with all the variables and having more significant directional spillovers to the real economy variables in comparison to the foreign exchange market which is more of a net recipient of the forecast error variance from the others hence more exposed to risk. The results confirm the well-documented bi-directional volatility spillovers between macroeconomic variables, commodities and the financial markets.

CHAPTER SIX

SUMMARY OF FINDINGS AND CONCLUSION, IMPLICATIONS AND RECOMMENDATIONS FOR INVESTORS AND POLICYMAKERS AND AREAS FOR FUTURE RESEARCH

6.1 INTRODUCTION

There has been growing interest in understanding the dynamics of cross-market volatility spillovers and macro-financial spillovers specifically to establish how well they are connected. This interest was perpetuated by the events of the GFC 2008 that saw significant spillovers from market to market both in the developed economies and the developing economies¹⁶. The need to understand the connectedness of the real economy and the financial markets and the implications for policy and financial stability has become of paramount importance to both investors and portfolio managers for portfolio management.

The studies for the interactions between the real economy and the financials came in two streams. The first stream of literature sought to establish the relationship between financial markets and other economic fundamentals. This included establishing whether the linear dependencies were positive or negative for both developed and developing economies. On the backbone of these first-moment linkages, the second-stream or moment linkages came to uncover the effects of volatility spillovers between economic fundamentals and financial markets for policy implications and investment. While a considerable number of studies have been carried out for both developed and developing economies using similar techniques, none to our knowledge have added the dimensions in this research specifically with regards to the technique used. Most of these studies have however been for developed economies, especially with the use of the DY spillover index. It is thus the author's view that adding another time-varying dimension in analysing spillovers as done by the DY spillover index offers more critical information for drawing investment and policy conclusions.

This research contributes to the second-moment linkages literature that seeks to uncover to what extent real economic shocks influence financial market returns and how well these two are connected. The fundamental objectives of this research were (1) to uncover the directional and total spillover effects of macroeconomic variables and commodities on financial markets (2) to

¹⁶ See [Chinzara \(2010\)](#) and [Dlamini \(2018\)](#).

determine the net directional spillover effects of macroeconomic variables and commodities on financial markets and determine the significance of pairwise volatility spillover between them.

This concluding chapter will first give a summary of the key empirical findings in Chapter Five. Secondly, the implications and recommendations for investors and policymakers will be discussed before identifying areas for further research.

6.2 SUMMARY OF KEY EMPIRICAL FINDINGS AND CONCLUSION

This study adopted a widely used analytical framework for developed economies to analyse the volatility spillover effects of macroeconomic variables and commodities on financial markets. The main advantage of the model used was its ability to add more dimensions to the study in comparison to what the previous literature on this phenomenon in this context focused on. As per the literature review, the summary of the key findings of this study is divided into four categories.

Cross-market volatility spillovers for the stock market

In an attempt to uncover the connectedness of the stock market returns and commodities, we found that bi-directional volatility spillover effects existed between South Africa's stock market returns and commodities. Although bi-directional volatility spillovers exist, the stock market dominated the volatility spillovers to the commodities as was confirmed by the net directional spillovers. Between the two commodities, gold price volatility contributed the most to the stock market. The mining sector returns were the most shielded from the risk of commodity price movements among the JSE stock sectors returns. The pairwise spillover analysis shows that gold prices became more connected with the stock market post the COVID-19 pandemic as opposed to post the GFC of 2008. The opposite is true for oil prices.

Macro-financial volatility spillovers for the stock market

Bi-directional volatility spillover effects were found between macroeconomic variables and the stock market returns. Stock market returns volatility emerged as a net transmitter, particularly the financials 15 sector returns and the retail sector returns onto the macroeconomic variables. Between the macroeconomic variables, inflation is the larger contributor to the stock market, particularly to the JSE All-Share returns. The mining sector returns are the least recipient of

volatility spillovers from the macroeconomic variables, particularly from inflation, suggesting that precious metals such as gold have remained a haven in times of persistently high inflation. The JSE All-Share index returns, the JSE financials returns and the JSE retailers returns are the largest contributors in this context. Both money supply and inflation became more connected with the stock market post the COVID-19 pandemic which is a different outcome from the period after the GFC in which money supply stayed less connected with the stock market whilst the spillovers between the JSE All-Share returns and inflation were high post the GFC. The JSE All-Share returns remain the most integrated variable in the context of the spillovers between the real economy and the stock market painting a picture of how well the market is established in South Africa and has proven to be on par with other international stock exchanges. This makes the JSE crucial to the stability of capital markets and the real economy.

Cross-market volatility spillovers for the foreign exchange market

Consistent with the literature, bi-directional volatility spillovers were found between the USD/ZAR exchange rate and commodities prices. The exchange rate is the dominant recipient of volatility spillovers from the commodities both in terms of pairwise directional spillovers and net directional spillovers showing the dependency of the foreign exchange market on commodity prices. Between the two commodities, gold price contributes the most spillovers to the exchange rate in the short to medium term. The time-varying pairwise spillover analysis showed that the exchange rate is also sensitive to shocks from political instability and global economic trends making the value of the Rand exposed to more than just economic fundamental data. The exchange rate and gold price have stayed well-connected post the COVID-19 pandemic as per the pairwise spillover analysis in comparison to the exchange rate and oil price whose connectedness has dampened.

Macro-financial volatility spillovers for the foreign exchange market

Lastly, we consider the spillover interactions between the macroeconomic variables and the foreign exchange rate market. As was the case with the commodities, the exchange rate is both a pairwise directional and net directional volatility spillover recipient from the macroeconomic variables despite the unsurprising existence of bi-directional spillovers. Inflation has the most spillovers to the exchange rate between the macroeconomic variables while most of the spillovers from the exchange rate fall onto inflation. It comes as no surprise then that the exchange rate has stayed

more connected to inflation in comparison with money supply over time establishing inflation as a more crucial catalyst for the exchange rate.

Conclusion

As per our literature review, our expectations for this study were that given the level of development of the South African financial markets, they are like to be more connected with the real economy hence bi-directional volatility spillovers were expected. Constant with the findings of Chinzara (2010), Bonga-Bonga and Morema (2020), and Boakye *et al* (2023), our study found that there are bi-directional volatility spillovers between the real economy and financial markets in South Africa. Our study also concluded that the stock market dominantly spills over to the macroeconomic variables and the gold market prices whilst oil prices are isolated given the country is a net importer of the commodity. The Foreign Exchange Market has remained a net receiver of volatility spillover effects from both the commodities and macroeconomic variables as was concluded in Dlamini (2018) and Hlongwane *et al* (2022).

6.3 IMPLICATIONS AND RECOMMENDATIONS FOR INVESTORS AND POLICYMAKERS

Besides adding to the existing pool of literature and understanding of the real economy and financial markets, the findings of this study pose implications for investors and policymakers.

Implications for investors

The primary goal of investments in financial markets is to maximise returns on investments whilst minimising risk or exposure that may hamper these returns. The well-documented literature on the determinants of the volatility of returns in financial markets makes it more important to continue to monitor economic fundamentals and risk exposure given there exists some form of efficient market capable of adequately absorbing and distributing information.

Firstly, with regard to the stock market, the empirical findings of this research show that the JSE is well integrated with the real economy of South Africa meaning it is highly exposed to domestic economic activity due to its size. Between the commodities, the gold price had the most spillovers to the stock market meaning that investors need to continue to monitor precious metals price movements such as gold as they have a significant impact on the JSE returns. Gold prices have

continued to be a good benchmark of economic activity and hedge against inflation, our research finds that is still the case and investors can continue to rely on gold prices as an indicator of economic trends. From the macroeconomic variables, inflation continues to be the largest macroeconomic contributor of spillovers to the stock market which poses great hedging implications for the stock market. This key finding supports the need to hedge inflation risk for investments by investors to shield their portfolio returns from being eroded of their value. The findings of this study also give great insights into what types of derivatives investors can tap into to protect their investments.

The USD/ZAR exchange rate has shown it is a net directional recipient of volatility spillovers from both the commodities and the macroeconomic variables. Given these findings and the fact that most of the trading for forex is over the counter, it is crucial for investors in the forex market to closely monitor and hedge the price of commodities such as gold which the Rand is heavily reliant on. South Africa is a huge oil importer hence a negative shock in oil prices is likely to have a significant negative impact on the ZAR exchange rate making it important to hedge against oil price movements. Since the mining sector appears to be the least exposed to spillovers from the real economy, investors can invest in precious metals as a haven in their portfolios.

Implications for policymakers

The primary goal of monetary policy in South Africa is to continue to regulate the financial system in a manner that promotes employment, economic growth, dampens high inflation and ensures the stability of financial markets. It is thus important in this regard to understand the sources of volatility for financial markets for robust policy construction and maintaining a sound financial system which in the case of South Africa is central to capital markets and economic stability. In this regard, this research examined the spillovers of idiosyncratic risk that macroeconomic variables and commodities have on the financial markets.

Firstly, with regards to the stock market, inflation proved to be the biggest contributor at 19.7% of directional spillovers to the JSE returns despite the JSE having a greater net directional spillover effect. This means that taming inflation is of critical importance for financial stability which South Africa has been targeting since 2000. The descriptive statistics for inflation however showed inflation to have been above average when considering the sample period mean. Overall, the policy

has thus been effective in providing certainty to the investors and policymakers should continue to pursue it.

The foreign exchange market proved to be more of a receiver than a giver of spillovers from commodities and macroeconomic variables. Since the exchange rate is more reliant on the gold price, the South African Reserve Bank (SARB) needs to ensure there are adequate reserves to carry out its primary mandate of protecting the value of the Rand which it has been doing successfully over the years. From our root cause analysis, gold price is the biggest contributor of volatility spillover to inflation while inflation is the biggest contributor of spillover to the exchange rate. This means there needs to be policy alignment for commodities and macroeconomics that does not jeopardise the other as their connectedness could spell doom for the Rand if no proper oversight is in place. Lastly, since South Africa is a big exporter of gold which explains the Rand's reliance on gold prices and a big importer of oil, there is a greater need to monitor the price movements of both commodities to ensure financial system stability and trade balances.

6.4 AREAS FOR FUTURE RESEARCH

A major challenge for the study was the unavailability of data post the COVID-19 pandemic enough to fully compare with post the GFC of 2008. It is important to understand the time-varying pairwise connectedness of macroeconomic variables, commodities and financial markets in the long run given this research has revealed some changes in the immediate period after the pandemic. Since the dynamics of spillovers differ between the financial markets, it would be important for future research purposes to include other financial markets such as the bond market and the derivatives markets and see how they pair with real economic fundamentals in terms of connectedness. More specifically, future research could investigate the connectedness of financial markets and the real economy in quantile terms of spillover, an approach that would differentiate the spillovers in different quantiles.

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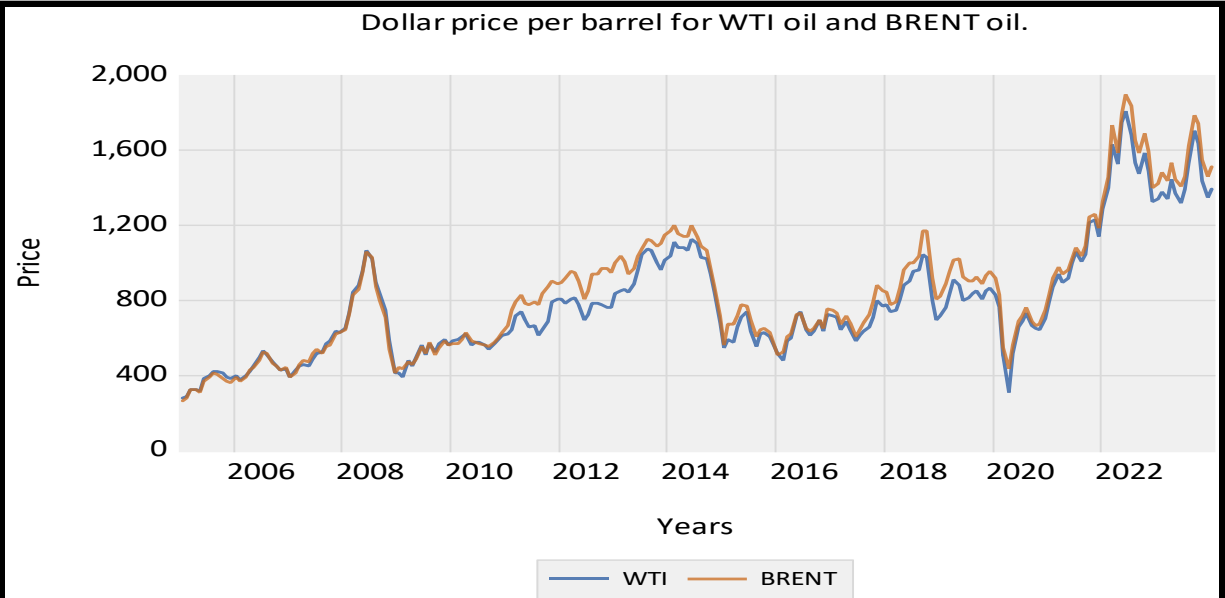
ZHU, H., LI, S. and HUANG, Z., 2023. Frequency domain quantile dependence and connectedness between crude oil and exchange rates: Evidence from oil-importing and exporting countries. *The Quarterly Review of Economics and Finance* 90 (1): 1-30. DOI.org/10.1016/j.qref.2023.05.001

APPENDICES

APPENDIX A.1

TRENDS ANALYSIS

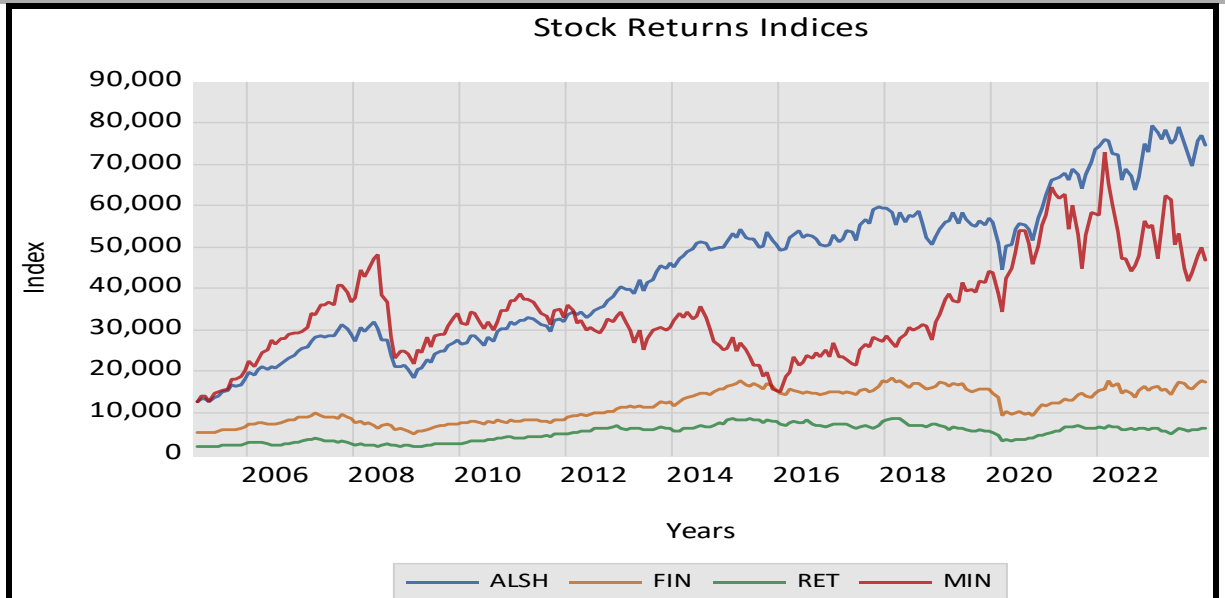
International Oil Prices Trends (2005-2024)



Source: Author's computation based on data obtained from the World Bank

Notes: WTI is the Western Taxes Intermediate crude oil and BRENT is the Brent crude oil.

JSE All Share and Sectors Indices Trends (2005-2024)



Source: Author's computation based on data obtained from LSEG

Notes: ALSH is the JSE All Share index, FIN is the JSE Financials 15 sector index, RET is the JSE Retailers sector index and MIN is the JSE Mining Sector index.

APPENDIX A.2

GARCH MODELS SELECTION

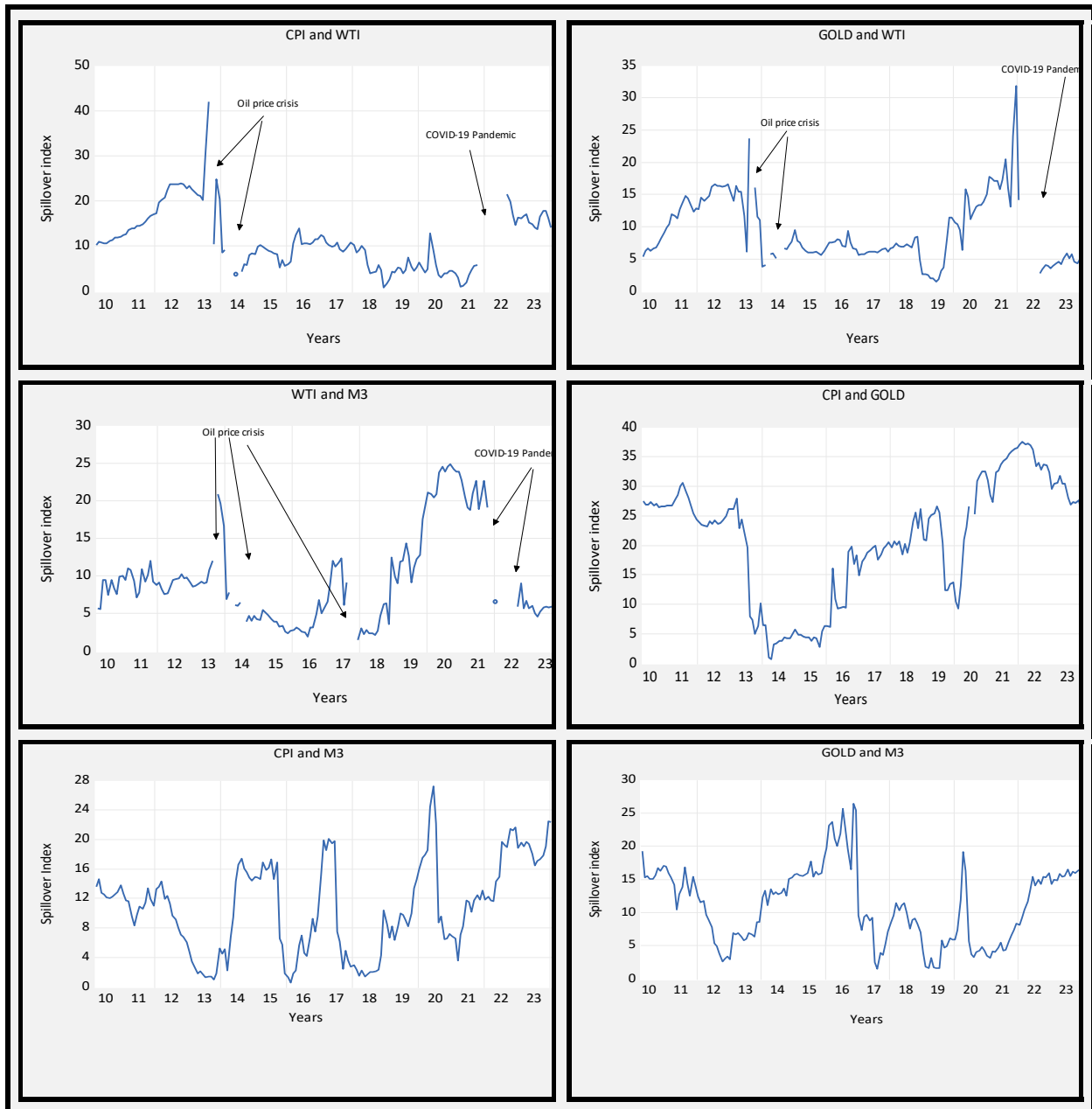
<i>Variable</i>	<i>Model</i>	α	β	γ	<i>HIC</i>	<i>Schwarz</i>	<i>Forecasting Performance</i>
GOLD	<i>ARCH (1,0)</i>	0.022	-	-	6.297	6.324	5.515
	<i>GARCH (1,1)</i>	0.150	0.663	-	6.270	6.306	5.517
	<i>TGARCH (1,1)</i>	0.314	0.798	(-0.314) [0.011]	6.253	6.298	5.515
WTI	<i>GARCH (1,1)</i>	1.001	-0.009	-	13.254	13.29	341.836
	<i>EGARCH (1,1)</i>	1.579	0.768	(0.250) [0.249]	13.295	13.340	341.130
	<i>TGARCH (1,1)</i>	1.074	0.001	(-0.223) [0.648]	13.265	13.310	341.523
CPI	<i>ARCH (1,0)</i>	0.867	-	-	3.023	3.050	1.981
	<i>GARCH (1,1)</i>	0.976	-0.173	-	3.032	3.068	1.987
	<i>TGARCH (1,1)</i>	0.965	-0.174	(0.026) [0.961]	3.047	3.091	1.988
M3	<i>ARCH (1,0)</i>	0.974	-	-	7.699	7.726	14.313
	<i>GARCH (1,1)</i>	0.966	0.009	-	7.714	7.750	14.329
	<i>TGARCH (1,1)</i>	1.092	-0.000	(0.026) [0.961]	7.720	7.765	14.303
EXR	<i>ARCH (1,0)</i>	0.334	-	-	5.425	5.452	3.661
	<i>GARCH (1,1)</i>	0.123	0.717	-	5.461	5.497	3.657
	<i>TGARCH (1,1)</i>	0.280	0.688	(-0.289) [0.005]	5.451	5.496	3.657
RALSH	<i>ARCH (1,0)</i>	0.235	-	-	5.815	5.842	4.471
	<i>GARCH (1,1)</i>	0.283	0.582	-	5.765	5.801	4.470
	<i>EGARCH (1,1)</i>	0.361	0.785	(-0.305) [0.001]	5.709	5.754	4.465
RFIN	<i>ARCH (1,0)</i>	0.568	-	-	6.245	6.272	5.736
	<i>GARCH (1,1)</i>	0.395	0.573	-	6.221	6.257	5.759
	<i>TGARCH (1,1)</i>	0.045	0.443	(0.701) [0.000]	6.179	6.224	5.727
RMIN	<i>ARCH (1,0)</i>	0.059	-	-	7.138	7.165	8.421
	<i>GARCH (1,1)</i>	0.140	0.749	-	7.109	7.145	8.427
	<i>TGARCH (1,1)</i>	-0.034	0.736	(0.322) [0.026]	7.085	7.130	8.421
RRET	<i>ARCH (1,0)</i>	0.233	-	-	6.709	6.736	6.914
	<i>GARCH (1,1)</i>	0.239	0.140	-	6.721	6.757	6.915
	<i>TGARCH (1,1)</i>	-0.156	0.590	(0.497) [0.053]	6.644	6.689	6.909

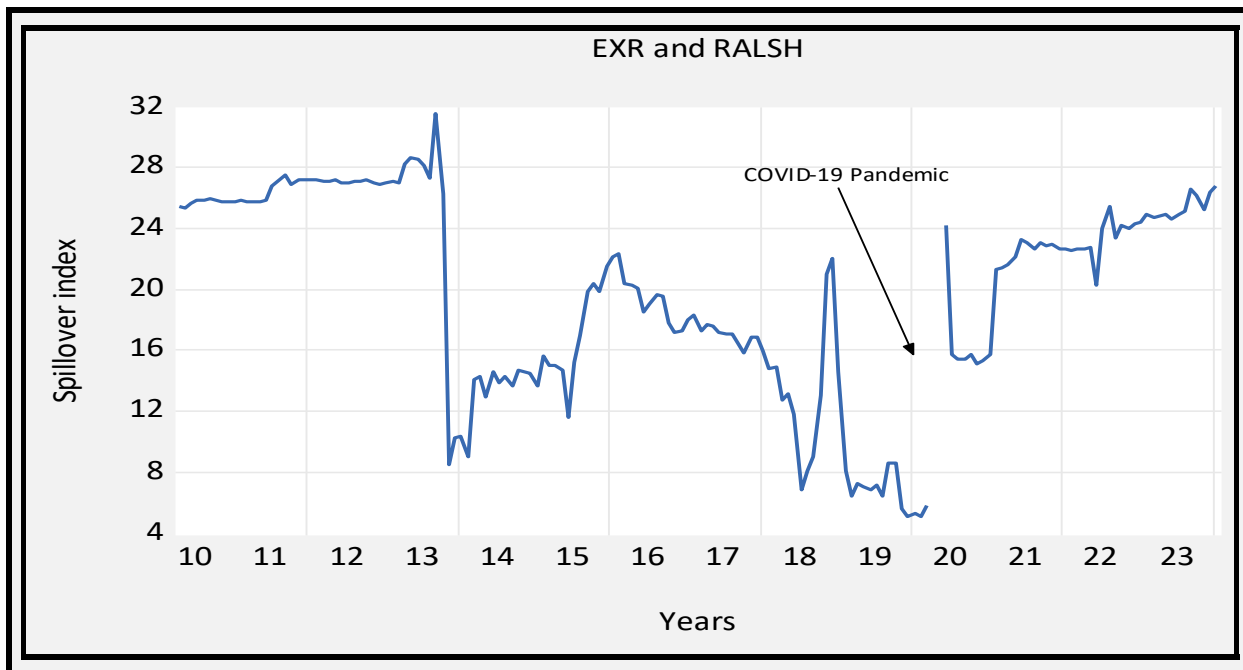
Source: Author's computation from EViews

Notes: Inflation (CPI), USD/ZAR exchange rate (EXR), gold price (GOLD), money supply (M3), JSE All-Share returns (RALSH), JSE financials 15 returns (RFIN), JSE mining sector returns (RMIN), JSE retails sector returns (RRET) and oil price (WTI). The table above shows the results for the non-selected GARCH models to generate the conditional volatility series for the variables in this study. (.) represents the coefficient for the asymmetric effect, [,] are the p-values for the coefficients of the asymmetric effects, (α) represents the ARCH term coefficient, (β) is the GARCH term coefficient for the models and (γ) captures the asymmetric effects from equations (15) and (16). Hannan-Quinn (HQ) and Schwarz are the information criteria. The forecasting performance indicates the root mean squared errors of the model.

APPENDIX A.3

PAIRWISE SPILLOVERS





Source: Author's Computation from EViews

Notes: USD/ZAR exchange rate (EXR), JSE All-share returns index, Inflation (CPI), gold price (GOLD), money supply (M3) and oil price (WTI). Appendix A.3 above shows the time-varying pairwise spillovers of i) macroeconomic variables ii) commodities and iii) financial markets from 2010 to 2024. The stats start from 2010 because of the 60-month rolling window chosen for the analysis from 2005.

APPENDIX A.4

RESEARCH ETHICS DECLARATION

To be included in the Appendices of research papers / dissertations / theses submitted for postgraduate examination where research did not involve interaction with human participants, or the use of animal subjects, and therefore did not require research ethics approval.

Candidates whose research did require ethics clearance must include their ethics approval letter in the Appendix of their examination submission.

Name of Candidate: Harton Taunganirwa Nhidza

Name of Supervisor: Sandisiwe Abongile Bom

Degree: Master of Commerce in Financial Markets

Title of research: Volatility spillover effects of macroeconomic variables and commodities on financial markets in South Africa.

DECLARATION

I declare that my research did not require ethical clearance because (tick all that apply):

I used previously collected data that had already received ethics clearance.	
I analysed documents / open-access digital texts that are freely available in the public domain.	✓
I did a literature review/analysis of theoretical or secondary material only.	✓
I used human datasets of non-sensitive information that are either anonymous (identifiers were never collected) or have been deidentified (identifiers have been completely removed).	
I used commercially produced human biological material (e.g. established human cell lines).	
I observed people in public spaces and natural environments where they had no reasonable expectation of privacy and I did not interact with them or intervene in any way.	
I used non-living animal materials (eg bones of already deceased organisms or fossils) while complying with any custody and/or jurisdiction requirements.	
I did a content analysis of public media (newspapers, advertisements, and social media posts).	
I did a simulation study with no real-world consequences and does not involve disturbing or distressing content.	
I observed flora, fauna, and ecosystems without interfering with or disturbing their natural state while complying with any jurisdiction requirements.	
Other (Please provide details):	

Signature of Candidate:



Date:

12 February 2025

Signature of Supervisor:



Date:

12 FEBRUARY 2025