UNIVERSITY OF CAPE COAST

COMMODITIES, EXCHANGE RATES, AND EQUITY MARKETS IN COMMODITY-DEPENDENT SUB-SAHARAN AFRICAN COUNTRIES

BY

JOHN KINGSLEY WOODE

Thesis submitted to the Department of Finance, School of Business, College of Humanities and Legal Studies, University of Cape Coast, in partial fulfillment of the requirements for the award of Master of Commerce degree in Finance.

JUNE 2024

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature …… Date ……...

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature …… Date …….

Name: Mr Seyram Kawor

Co-Supervisor's Signature ……..…… Date …….

Name: Dr Anthony Adu-Asare Idun

ABSTRACT

The transmission of risk across markets occurs when information flow is neither immediate nor complete. This infers that a market's response to adverse sentiment spreads to other markets, irrespective of the prevailing conditions. Accordingly, the global metal market encountered chaos in 2022, coupled with surges in commodity prices, and the IMF disclosed an escalated devaluation of currencies in sub-Saharan Africa. Amidst such occurrences, it becomes vital to acknowledge the potential transmission of risks within these markets, and this stems from the continent's heavy reliance on commodities and the close link between stock market performance and economic progress. By utilising the multivariate wavelet and the Barunik and Křehlík spillover index, this study examines the interdependence and volatility transmission among commodities, exchange rates, and equities in selected sub-Saharan African countries. The study utilised daily prices spanning 2012 to 2022 as a proxy for commodities and equities, with daily nominal indirect quotations proxying for the sample currencies. The study found weak interdependencies between commodity and equity markets in the short and medium term and a bidirectional risk transmission among all sampled markets in the long term. It is recommended that central banks and equity market regulators within these markets strengthen and implement robust risk management policies that take into account these linkages. It is further recommended that governments diversify the economy to ease the burden on commodities, improve production, and enhance value. This will reduce the region's susceptibility to commodity and currency market shocks and enhance economic growth and equity market development.

KEY WORDS

Commodities

Commodity-dependent

Equity Markets

Exchange Rates

Sub-Saharan Africa

Volatility Transmissions

ACKNOWLEDGEMENTS

I would like to express my profound appreciation to my supervisors, Dr. Anthony Adu-Asare Idun and Mr. Seyram Kawor, both esteemed members of the Department of Finance, for their exceptional expertise, motivation, and astute feedback that influenced the development of this thesis. I am immensely thankful. Additionally, I extend my gratitude to all the lecturers at the Department of Finance, University of Cape Coast Business School, for their constructive critiques and suggestions during seminar presentations, which refined this thesis. My heartfelt thanks also go to my scholarly mentors for their invaluable recommendations that have shaped the current form of this thesis.

Furthermore, I express my gratitude to the management of the College of Distance Education, University of Cape Coast, for granting me a comprehensive scholarship that ultimately facilitated the completion of this work. I must confess that without this remarkable opportunity, my presence here today would have been improbable. I am profoundly appreciative. I would particularly like to acknowledge the contributions of Professor Isaac K. A. Galyuon, Professor Anokye Mohammed Adam, and Mr. Isaac Eliot Nyieku. Lastly, I am very grateful to my brother for his counsel and guidance throughout this academic journey. May divine blessings be bestowed upon you.

DEDICATION

In memory of my grandmother

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AfCFTA	African Continental Free Trade Area
ADF	Augmented Dickey-Fuller
APT	Arbitrage Pricing Theory
ARDL	Autoregressive Distributed Lag
CFARI	Chartered Financial Analyst Research Institute
CDDC	Commodity Dependent Developing Countries
GARCH	Generalised Autoregressive Conditional Heteroscedasticity
GDP	Gross Domestic Product
GFEVD	Generalised Forecast Error Variance Decomposition
IMF	International Monetary Fund
IPM	International Portfolio Model
MODWT	Maximal Overlap Discrete Wavelet Transform
MPT	Modern Portfolio Theory
OECD	Organisation for Economic Cooperation and Development
SSA	Sub-Saharan Africa
UNCTAD	United Nations Conference for Trade and Development
VMD	Variational Mode Decomposition
WMC	Wavelet Multiple Correlation
WMCC	Wavelet Multiple Cross Correlation

CHAPTER ONE

INTRODUCTION

The performance of stock markets is closely tied to economic progress, but the development of these markets within the sub-Saharan African scene is largely dependent on the resilience of the foreign exchange markets. The majority of these economies and their respective equity markets are heavily dependent on commodities for foreign exchange, notwithstanding the market's susceptibility to external price shocks. These fluctuations further translate into the exchange market, which further impacts equities. The aforementioned analogy has spurred numerous studies within the sub-region. Nevertheless, the majority of these studies focused on crude and treasured alloys, despite the relevant contributions of industrial metals coupled with recent plunges in the market. In light of the aforementioned, the current study examines the interdependencies of return and volatility among commodities, exchange rates, and the equity market in sub-Saharan Africa.

Background to the Study

The stock market functions as a network for investors to access publicly traded company shares, playing a crucial role in promoting democratic principles and facilitating the allocation of financial resources (Henriques-de-Brito, 2018). The stock market serves as an important measure of a nation's economic health, with rising stock market indices during a period of market prosperity indicating favourable economic conditions (Jacobsen, Marshall, & Visaltanachoti, 2019; Singhal, Choudhary, & Biswal, 2019; Ogotseng, 2017; Woode, Owusu Junior, Adam, 2024). According to previous studies (Boako & Alagidede, 2017; Mollick

& Sakaki, 2019; Siddiqui & Roy, 2019), the favourable performance of the stock market closely coincides with the progress of the predominant economy.

In recent years, African economies and financial markets have experienced radical transformations, driven by initiatives such as equity market equalisation and the African Monetary Union (Bossman & Agyei, 2022; Ogotseng, 2017). These efforts aim to reduce investment restrictions, enhance income repatriation, and attract foreign capital flows to the region (Bossman & Agyei, 2022; Woode et al., 2024a). Remarkably, African equity markets have encountered substantial direct influxes of capital from developed economies, underscoring their escalating prominence in the management of global financial assets. Correspondingly, capital inflows into the African equity market attained a unique sum of $81 billion in 2022, a significant rise from $39 billion in 2020. This accounted for 5.2% of worldwide foreign capital inflows, as delineated in the United Nations Conference on Trade and Industry's World Investment Report (UNCTAD, 2022).

The report also divulged that the southern, eastern, and western African equity markets witnessed augmentations in capital inflows, while the Central (Northern) African markets experienced a static (declining) trend in equity capital influxes. As a result, the Western sub-region accounted for $48 billion, representing 59.3% of total inflows, while the Southern and Eastern regions recorded $24.8 billion (30.6%) and $8.2 billion (10.1%), respectively. Furthermore, at an industry level, it was disclosed that despite the overall decrease in some sub-regions, the extractive sector observed an upswing, notably with the Ghanaian and South African extractive industries experiencing substantial growth of $2.9 billion (39%)

and $4.6 billion (22%), respectively. Subject to the immediate report and the International Monetary Fund (IMF, 2023), the current study emphasised SSA equities in commodity-dependent countries with pressure currencies, including the stock exchanges in Botswana (BSE), Ghana (GSE), Nairobi (NSE), Namibia (NASE), and Johannesburg (JSE) Stock Exchange. A summary of the equity market capitalisation, rank, dominant sector, weight of the extractive sectors, and listed firms are highlighted in Table 1.

Table 1: Equity Market Development in sub-Saharan Africa

SSA Equities	Rank	Capitalisation in $billion	Listed Firms	Dominant Sector	Extractive Cap. / Market Cap
JSE	1	1360.25	354	Extractive	22.1%
NASE	2	133.64	40	Extractive	42.48%
BSE	5	43.94	29	Extractive	59.4%
NSE	8	20.64	56	Financial	6.82%
GSE	10	12.68	31	Extractive	55.7%

Source: Equity Market Reports (2023)

The findings elucidated in Table 1 underscore the JSE as the apex of equity market development within the SSA, boasting an impressive market capitalisation totalling $1.3625 trillion, constituting a staggering 63% of all equities across the region. Delving into sectoral delineations, the NSE is dominated by the financial sector, as evidenced by both its substantial listing of firms (12) and commanding capitalisation (25.1%). Meanwhile, the mining sector stands as an immutable force in terms of capitalisation across multiple equity markets, exerting its dominance on the BSE (59.4%), GSE (55.7%), NASE (42.48%), and JSE (22.1%). Despite the financial sector's primacy within the NSE's domain, the extractive sector asserts its relevance, underscored by a notable capitalisation of $45.36 million, exemplifying

its pivotal role in the market's holistic development. Similarly, the agricultural sector assumes a pivotal stance across each equity market, delineating its substantial monetary contributions to the GSE ($22.19 million), BSE ($83.64 million), NASE ($131.99 million), NSE ($332.5 million), and JSE ($3.79 billion). Moreover, ancillary sectors such as food and beverage and manufacturing exhibit a symbiotic link with both the extractive and agricultural sectors, underpinning their operational dependencies and illustrating the ripple effect of these sectors' contributions to the overarching growth trajectory of equity markets.

Trend analysis of sample sub-Saharan African equity market

Figure 1 and 2 highlights the comparative growth trajectory of the sampled SSA equity markets, contextualised within the scene of burgeoning capital inflow and the undulating patterns of commodity and currency oscillations. This graphical representation emanated from the collated dataset. It is relevant to acknowledge that, despite the original denomination of the equity index in the native currencies of the sampled SSA market, a subsequent conversion to the USD was conducted to augment comparative evaluations.

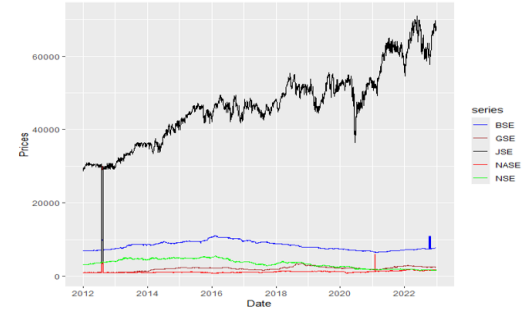

Figure 1. Sample SSA equity index expressed in domestic currency

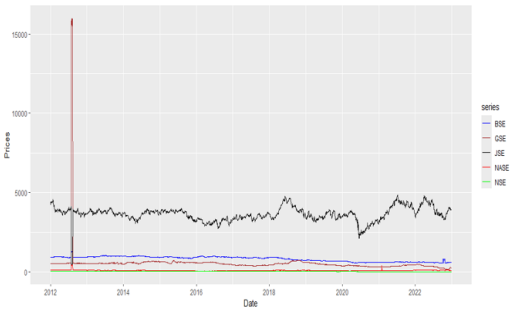

Figure 2. Sample SSA equity index expressed in USD

Source: EquityRT

The disparities in growth patterns evident between Figure 1 and 2 indicate the influence of currency fluxes on equity market dynamics. This is underscored by

the persistent downward trajectory in Figure 2. A cursory glimpse of Figure 1 reveals an upward path for BSE (blue), JSE (black), and GSE (brown), indicating growth trends spanning from 2012 to 2020. However, exceptions are noted with NSE (red) and NASE (green), which display erratic growth patterns alongside GSE's downturn between 2021 and 2022. Despite the prevalent upward trends in most equities in Figure 1, Figure 2 portrays a mix of trend, notably observed in JSE, BSE, and GSE, while NASE and NSE had static fluxes.

It is pertinent to further recognise that the variations observed in the cases of NSE and NASE can be attributed to the consistent nature of currency fluctuations throughout the sample period, as depicted in Figure 1. The insights gleaned from Figure 2 underscore the growing prominence of the region's equity markets on the global financial stage, notwithstanding recent impacts stemming from fluctuations in commodity prices on global equity market dynamics. Conversely, Figure 2 underscore equity market vulnerability to currency fluctuations and the need for strengthened native currencies, especially for individual firms within these markets in accessing capital (Oyelami & Yinusa, 2019; UNCTAD, 2022). Also, as earlier highlighted, the commodity markets persist as a substantial facet within the designated equity markets, with numerous listed enterprises within these markets relying heavily on said commodities for their operational frameworks. This interdependency renders them susceptible to the vicissitudes inherent in commodity markets, particularly evident during recent episodes of turmoil and price volatility.

Commodities comprise basic materials that possess a general homogeneity in quality and are traded in substantial quantities (Bianchi, Fan, &Todorova, 2020).

According to prior studies (Bianchi et al., 2020; Tröster & Küblböck, 2020; Woode et al., 2024a), their usefulness lies in the production of other goods or direct consumption and encompass agricultural (e.g., cocoa, coffee, corn, and cotton), energy (e.g., crude oil and natural gas), metals (e.g., gold, silver, copper, and zinc), as well as livestock-related. Their exchange predominantly occurs on both organised and over-the-counter trading platforms, and their prices are susceptible to shocks from multifaceted elements, including those from supply and demand, geopolitical events, climatic conditions, and the trajectory of global economic patterns (Bianchi et al., 2020; Maitra & Dawar, 2019).

According to the commodity statistical analyses delineated in the literature (Bianchi et al., 2020; Zaremba et al., 2021), the projected values for the markets are anticipated to reach $131.3 trillion by 2024 and $139.3 trillion by 2028, with metallic components attaining an estimated valuation of $8.13 trillion in 2022. Notably, copper ($183 billion), aluminium ($153 billion), nickel ($69 billion), and zinc ($31 billion) persist as the most traded industrial metals globally, and their contributions within SSA equity markets have been highlighted in Table 1. Furthermore, UNCTAD's (2022) report emphasised a notable upsurge in global agricultural commodity trade, escalating from $1.1 to $3 trillion between 1990 and 2020, thereby stressing their relevance in global trade discussions. Cocoa (GSE), coffee (NSE), corn (JSE), and cotton (BSE) remain the dominant agricultural commodities traded within these equity markets and further serve as the basic materials for the production processes of some listed firms, given their diverse usefulness, which motivates their emphasis in the current study.

According to extant literature (Jacobsen et al., 2019; Sokhanvar & Bouri, 2023; Siddiqui & Roy, 2019; Woode et al., 2024b), commodity price movements facilitate economic growth and forecast equity returns. However, historically, the interdependence of equity markets and commodities within the largest economies worldwide has been linked to the subject of market confidence during turbulence (Bianchi et al., 2020). Nevertheless, an established perspicuity is that metals hedge against inflation and provide opportunities for investors to achieve diversification due to their extensive utilisation across multiple sectors (de Boyrie & Pavlova, 2018; Woode et al., 2024b). This has led to increased integration of asset-class markets, driven by the low commodity-equity correlations (Addison, Ghoshray, & Stamatogiannis, 2016; de Boyrie & Pavlova, 2018). However, as studies (Hegerty, 2018; Julien, Robert, & Grace, 2017; Ogbulu, 2018) have shown, commodity price volatility impacts exchange rates of commodity-dependent economies.

The exchange rate represents the expense entailed in swapping the currency of one nation for that of another (Mollick & Sakaki, 2019). Commodity prices, currency distribution, and the balance of payments are just a few of the factors that affect its value. Exchange rate fluctuations represent the incessant downspiral and appreciation of the native currency, while a severe form of these fluctuations is termed volatility. As highlighted by the IMF (2023), the currency markets in most SSA states, including the Botswanan Pula (BSP), Ghanaian Cedi (GHS), Kenyan Shilling (KSH), Namibian Dollar (NAD), and South African Rand (ZAR), were branded “high-pressure” due to their ceaseless volatility owing to their free-floating systems, with the BSP standing as the solitary outlier. Despite this exception, the

BSP is directly pegged to the ZAR, underscoring its susceptibility to fluctuations in the ZAR and global commodity price fluctuations. Nevertheless, a myriad of these exchange rate policy was implemented to stimulate economic growth in emerging economies and also to favour financial market liberalisation. Yet such laurels seem to be depleted, especially within the SSA scope, and this impacts equity market liquidation and expansion due to investor fear of depleting returns (Goldberg, 2019; Ogbulu, 2018).

Comparative trend analysis of exchange rate fluctuations in SSA

Figure 3, depicted below, has been derived from the sampled data acquired by the Author from the websites of the respective central banks of the SSA states.

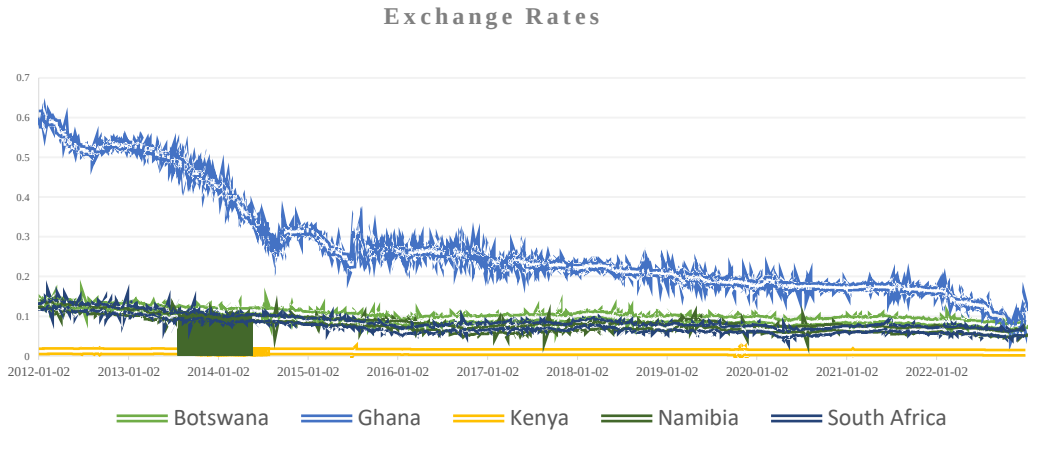

Figure 3: Comparative trend analysis of exchange rate fluctuations in SSA

Source: Central Bank of sample SSA economies

The consistent downward trajectory in the movement of these currencies against the US dollar supports the claim that the currencies of SSA are eroding (Figure 3). Notably, the KSH stands out as an exception with a stagnant movement while exhibiting the weakest resilience. A comparative analysis of currency trends reveals that, despite the simultaneous decline in currency values, the GHS has

demonstrated relatively superior performance to other currencies. However, it also exhibited the highest volatility, thereby validating the above findings, which highlighted the prevalence of high-pressure currencies in the sub-region.

The existing body of literature explains the connectedness among equities, commodities, and exchange rates markets from diverse perspectives. This include but not limited to shocks and contagion (Ahnert & Bertsch, 2022; Trevino, 2020; Katusiime, 2018; Moradi et al., 2021; Sokhanvar & Bouri, 2023), stock valuation (Enwereuzoh et al., 2021; Oyelami & Yinusa, 2019; Zankawah & Stewart, 2020), and arbitrage pricing (Jacobsen et al., 2019; Maitra & Dawar, 2019; Mollick & Sakaki, 2019; Ogbulu, 2018; Siddiqui & Roy, 2019). In line with the valuation viewpoint, changes in commodity prices (agricultural commodities and industrial metals) affect the cost structure of firms, profitability, and valuation of stocks, while currency fluxes influence the revenue structure of these firms and the desire to invest (Enwereuzoh et al., 2021). Accordingly, commodity prices perform a pivotal function in determining the movements of the exchange rate and equity through investor reactions to variations in equity prices due to currency fluctuations, while firms also respond to the same through commodity price flux.

In a similar vein, equities, commodities, and currencies are competing assets, and information systems modify investors' perceptions of their attractiveness (Ahnert & Bertsch, 2022). Hence, in response to content that enhances the equity markets, investors may acquire more equities and divest others, while the reverse occurs with unfavourable information on equities. This, per studies (Hurd, 2016; Sokhanvar & Bouri, 2023), shifts investor interest to adjust their allocations in other

markets, with the prospect of risk transmissions. Drawing upon the cross-asset trade conduits underscored by Trevino (2020), the potential for inter-market risk transmission within the sample markets emerges as plausible, particularly with the advent of burgeoning information systems, risk management avenues, and the continental trade accord (forecasted to amplify internal trade by 52%). Within this framework, shocks stemming from currency and commodity dynamics in each of these economies possess the capacity to instigate margin calls, prompting investors to divest assets in alternate jurisdictions while readjusting their investment portfolios. This also indicates that in a market made of assets with varying risk and return, market integration based on an effective information system plays a role in determining how shocks transmit across these asset classes.

Per the arbitrage pricing theory (APT), asset predictability can be realised by analysing its projected return and various economy-wide factors that encapsulate systematic peril (Nordin et al., 2014; Ouma & Muriu, 2014; Roll & Ross, 1984). Thus, one can track the possible fluctuations in the value of an asset through a critical assessment of the various macroeconomic indicators that emphasise risk. Given that the model failed to specify these risk indicators, studies (Hegerty, 2018; Maitra & Dawar, 2019; Siddiqui & Roy, 2019) have emphasised exchange rates and commodities with simultaneous fluxes while also providing justifications for their predictive capacities on equities. Conversely, studies (Katusiime, 2018; Ogbulu, 2018) established a causal nexus between commodity prices and exchange rates, with the latter as the predictive sources for the commodities, signifying the mutual awareness possessed by these markets in terms of risk and returns.

Recent occurrences concerning the dynamics of the global financial market following the process of commodity financialisation have sparked intriguing debates regarding the link between primary commodity prices and exchange rate fluctuations. These discussions have focused on commodity-dependent developing nations that are vulnerable to external shocks. For instance, the contemporary report on the acceleration of economic growth in SSA by the World Bank and a thorough investigation by Ngouhouo and Nchofoung (2022) have confirmed the ongoing vulnerability of a sizable portion of SSA economies to the negative effects resulting from unexpected fluxes in commodity prices and the volatilities in currency markets. These vulnerabilities were ascribed to the inherent constraints imposed by limited financial capital development, thereby exerting a profound impact on the overall advancement of stock market infrastructure within these economies.

Sokhanvar and Bouri (2023) additionally asserted that the foreign exchange rate serves as a portal through which one can discern the complex interaction between economic stability and the comparative state of financial soundness within a given nation. Therefore, monitoring and studying its fluxes and interdependence structure with equally viable variables such as commodities and the equity is very important. In light of this, the prevailing study examines the volatility transmission and interdependence structure of commodities, exchange rates, and the equity markets of selected commodity-dependent SSA countries. The study seeks to ascertain whether there are interdependencies in the returns and volatilities among the sampled commodities, including agricultural (cocoa, coffee, cotton, and corn) and metals (aluminium, copper, nickel, and zinc), currency (BSP, GHS, KSH,

NAD, and ZAR), and equities (GSE, NSE, BSE, NASE, and JSE). It is envisaged that the insights from the study will offer valuable guidance for shaping pertinent policies aimed at addressing incessant currency fluxes and fostering investor diversification prospects.

Statement of the Problem

The convergence of financial markets gives rise to complexities in the dynamics of returns and volatility. However, the transmission of risk across equities, commodities, and foreign currency markets occurs when the flow of information among these markets is neither instantaneous nor complete (Maitra & Dawar, 2019). This phenomenon also implies that a market's exaggerated response to negative sentiment spreads to other markets, irrespective of the underlying economic climate. Accordingly, the global industrial metal market encountered tumultuous upheaval in 2022, eliciting a surge in investor sentiment (Burton, 2022; Woode et al., 2024b). As reported by Burton (2022), who documented the unbridled state of affairs at the Bloomberg hub, this unprecedented chaos has not been witnessed since the great recession. Consequently, base metal prices, ranging from copper to nickel, experienced a precipitous decline, resulting in a 26% drop in the industrial metals spot index within a single quarter (Woode et al., 2024b). The repercussions of this substantial plunge reverberated throughout other markets, with the average price of aluminium plummeting by 11%.

Nevertheless, the interdependence between the market for metals such as aluminium, copper, nickel, and zinc and economic dynamics suggests that the recent decline in metal prices signifies the onset of recessionary apprehensions

permeating the market (Burton, 2022; Woode et al., 2024b). According to the report, this chaos has also permeated other financial markets, disproportionately affecting economies and markets that heavily rely on these commodities. On the other hand, studies (Tröster & Küblböck, 2020; Woode et al., 2024b) affirmed that the majority of SSA economies, together with their equity markets, are primarily metal-dependent and spring a generous fraction of their income from the exportation of primary commodities, while others exhibit a high volume of imports, exposing them to shocks from global commodities and currency markets.

Accordingly, Boako and Alagidede (2017) reiterated that the extractive industry contributes to 23% of the top 100 listed firms in SSA, while several other listed firms also possess significant investments in the market, as highlighted in Table 1, thereby exposing the equity markets to vulnerabilities stemming from the sector. For instance, against this backdrop, the Ghana Stock Exchange (GSE, 2022) reported a decline in the composite (financial) index of 12.38% (4.61%). The Botswana Stock Exchange (2022) unveiled a notable downturn in the capitalisation and trading volume (value) of the mineral sector, amounting to 3 million and 483.9 million (638.4 million), respectively, while the liquidity ratio experienced a further decline of 2%, despite a 10.9% surge in the composite index. This trend was corroborated by the Nairobi Stock Exchange (NSE, 2022) report, indicating that the market's performance was significantly impacted by macroeconomic developments at local and international levels. Consequently, the market witnessed a substantial decline of 31% (10.74%) in turnover (composite index) due to reduced equity trading activity, leading to a comparative revenue decline of 72 million in 2022.

Similarly, the composite index of the Namibian equity market experienced a comparative decline of 5%, particularly during the first half of 2022.

Contrary to the aforementioned, the Johannesburg Stock Exchange (2022) reported an improvement in market performance indicators. Nevertheless, the market experienced an increase in foreign capital outflows, which could further explain the recent incessant fluctuations of the native currency. These assertions concerning the performance of the SSA equity market in recent years elucidate the inherent structural imbalances and the formidable challenges, despite recent surges in commodity prices and their favourable consequences, as earlier emphasised.

Sub-Saharan African composite equity market growth pattern

Figure 4 depicts the average performance patterns of the SSA equity market as determined by the proportional fluctuation of average equities expressed in millions of US dollars. The data below originates from the informational repository of the World Federation of Exchange via the official web page of the World Bank.

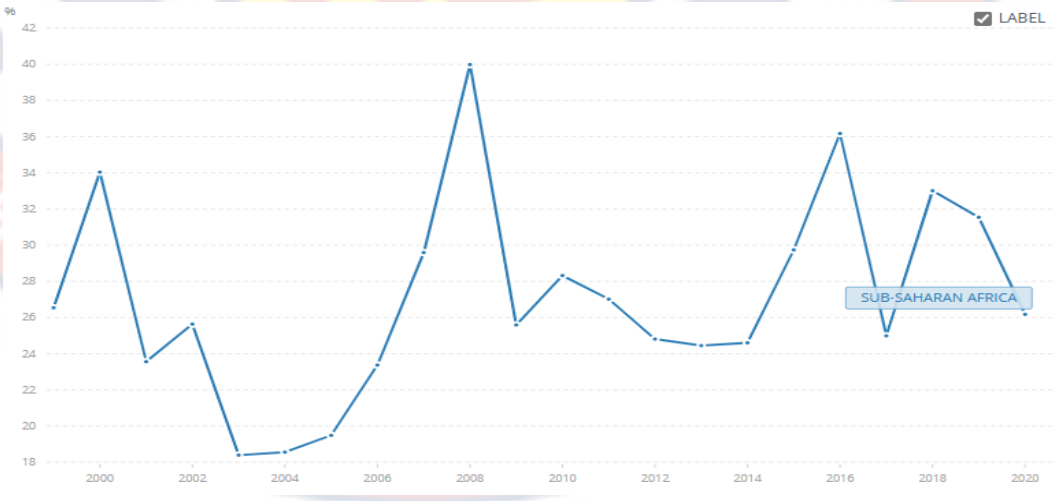

Figure 4: Plots of growth pattern of sub-Saharan Africa equity market

Source: World Federation of Exchange database

Figure 4 accentuates the composite performance of the SSA equity market, characterised by a blend of upward and downward trajectories throughout the designated sample period. Consequently, the performance of equity markets has exhibited inconsistency, particularly during periods of economic upheaval such as the global financial crisis (2008–2010) and the global financial health crisis (2019–2021), demonstrating a discernible downward trend that further substantiates the notion of the equity market's vulnerability to external shocks. Notwithstanding the influx of capital, recent years have witnessed a deceleration in the average growth rate of the SSA equity market, as underscored by the World Federation of Exchange database (Figure 4) and the World Bank (2022). Accordingly, these slumps reflect global perils and enduring supply shocks in the global commodity market and reveal that the region's outstanding economic industries remain sluggish.

Furthermore, a report from the Organisation for Economic Cooperation and Development (OECD, 2021) revealed that the escalation of global risk-driven price pressures is anticipated to amplify the commodity export earnings of nations reliant on commodities. Consequently, this is expected to translate into increased revenues and economic growth through equity market progress, with the resulting favourable impact on domestic currencies. Contrary to the above suppositions, recent reports from the IMF (2023) have revealed that the majority of the SSA states currencies underwent an average depreciation of 7% while most of the study markets surpassed the 20 percent threshold and were characterised as high pressures. This resulted in higher volatility in the currency market against the backdrop of global commodity price pressure as exhibited in Figure 3.

Preceding the aforementioned arguments and coupled with the deleterious economic performance of most SSA countries in the contemporary period, it can be inferred that the most noteworthy challenge facing the region is the volatility in domestic currencies coupled with those from global commodity prices and their respective bearing on equity markets. Despite the above restraints and the growing pacts between African economies and the global market, commodities, exchange rates, and stock market-related studies are deemed narrowly researched. Previous studies within the SSA context have considered these variables in isolation, while most studies (Julien et al., 2017; Musawa & Mwaanga, 2017; Ogbulu, 2018; Oyelami & Yinusa, 2019; Zankawah & Stewart, 2020) concentrated primarily on crude oil and treasured alloys. Additionally, in an attempt to reveal the risk and return nexus within these markets, several of these studies employed static models including but not limited to VAR, GARCH, and ARDL with little emphasis on the dynamic nature of market participants. Furthermore, most of these previous studies have neglected most agricultural commodities and industrial metals altogether despite the established relevance of these commodity markets.

The above assertions stand as a restraint given the industry's contribution towards equity market development and the heavy reliance of most SSA economies on these commodities. Accordingly, SSA has enormous mineral reserves, ranking first in the world for bauxite and phosphate rocks, as well as over 20% of the ecosphere's aluminium, copper, and nickel (Woode et al., 2024b). This presupposes that metal price fluctuations significantly impact these economies, notwithstanding the contributions to export revenue from agricultural commodities.

Subject to the immediate assertion and prior limitations in the literature, the current study emphasises the interdependencies among the narrowly researched industrial metals, agricultural commodities, and equity markets in sampled commodity-dependent SSA countries while also considering the effect of the augmented currency depletion on the aforementioned markets in the SSA context. Also, considering the diverse nature of market participants and the constraints in the static models employed in prior studies, the current study addresses these gaps through the implementation of time-varying models such as the multivariate wavelet, the Barunik and Křehlík index, and the non-parametric causality test of Diks and Panchenko.

Contrary to the static models, the utilisation of time-varying models in the present study proves to be more efficient in analysing the interdependence with greater intricacy, as they possess the capacity to concurrently accommodate a larger market's dynamics at varying times. Moreover, the inherent superiority of the volatility-based model lies in its ability to comprehensively account for systemic interdependencies in the transmission of risks among markets while simultaneously uncovering significant transmitters and receivers of shocks within the system (Barunik & Křehlík, 2018; Fernández-Macho, 2012). Nevertheless, in contrast to the prevalent employment of linear causality tests in previous studies, which suffer from inherent limitations such as the exclusion of nonlinear causality and the neglect of structural breaks, among others, the adoption of a nonlinear causality test in the present study addresses these limitations. Furthermore, despite the recognised superiority of the employed models, it is pertinent to acknowledge that their

concurrent utilisation in the current study is subject to the study's diverse objectives and the necessity for efficient model implementation, considering that none of these models can serve as an all-encompassing solution.

Subject to the aforementioned suppositions and the established limitations, empirical evaluations of the risk transmission and dynamic interdependence structure among commodities, currencies, and equity markets in the sampled commodity-dependent SSA states are equally pertinent given the vulnerabilities of these economies to shocks, the emergence of commodity financialisation, and stock market equalisation. This stimulates an augmented incentive on our part to assess these markets' dynamic risk and return interdependence framework.

Purpose of the Study

Examine the interdependence structure between the risks and returns of commodities, exchange rates, and equity markets while also assessing the impact of commodity and exchange rate volatility on the equity markets of commodity-dependent nations in the sub-Saharan African region.

Research Objectives

The foremost objective of this study is to examine the interdependence structure and dynamic risk transmissions among commodities, exchange rates, and equity markets within sampled commodity-dependent economies in Sub-Saharan Africa. The subsequent delineation highlights the specific focal points of the study:

1. Examine the interdependence structure between commodities and equities
2. Evaluate the dynamic interconnections in the transmission of volatility among commodities, exchange rates, and equity markets

3. Analyse the effect of volatility in commodities and exchange rates on equity markets

Research Hypotheses

Subject to an extensive exploration of existing extant literature and the detailed exposition of the comprehensive theoretical framework previously presented, the following hypotheses are hereby presented:

$H1_1$: There is interdependence between commodity and equity market

$H1_2$: There are interdependencies in the transmission of risk across commodities, exchange rates, and equity markets

$H1_3$: There is a significant effect of commodity and exchange rate volatilities on equity markets

Significance of the Study

The clamour for liberalisation and commodity securitization has resulted in phenomenal growth in international trade; however, the nature of the exchange rate in the SSA region has exacerbated a downward spiral in stock market development in recent years due to poor economic growth. Subject to the aforementioned, the study holds significant relevance for various stakeholders in the SSA regions, including governments, policymakers, academicians, and investors. It aims to provide valuable insights to commodity-dependent governments, central banks, and equity market regulators, equipping them with evidence on the risk transmissions and dynamic interdependence structures within the sampled markets. This knowledge will enable them to comprehend how fluxes in these variables impact equity market development in the sub-region, both in the immediate and enduring

term. Furthermore, the outcome will serve as a guide for the regulators of central banks and equity markets in the sampled SSA countries in formulating appropriate policies to mitigate the periodic volatility-based shocks spilling into these markets.

Secondly, investors constitute a sizeable portion of every economy and examining the key factors affecting their investment portfolios both in normal and turbulent times cannot be overlooked. This will help them to understand the extent to which volatility in their respective currencies coupled with commodity prices impact their respective investment portfolios. This will aid in portfolio diversification decisions. Finally, given the paucity of research examining the simultaneous interdependencies among the sampled markets in the SSA region, the pertinence of the study cannot be overstated. It will make a substantial contribution by filling the identified gap in the existing literature, thereby augmenting knowledge in the field of finance.

Delimitations

The study's focus is restricted to commodity-dependent countries in the SSA region, with a predominant emphasis on variables about SSA. It adopts a contextual approach primarily centred around the monetary and fiscal aspects of the selected economies. The study is limited to commodities, exchange rates, and the equity market, which was proxied by the stock indexes of the designated nations. Also, notwithstanding the presence of several viable equity markets, the study prioritised those distinguished by their reliance on the sample industrial metals, agricultural commodities, and associated pressure currencies. In a similar vein, considering the limited predictability of interest rate differentials and other conventional monetary

factors on equity markets, this study is further limited to essential and all-encompassing risk parameters, particularly those from currency and commodities.

Limitations of the Study

The contemporary study examines the volatility transmission and interdependence structure of commodities, exchange rates, and equity markets in selected commodity-dependent SSA countries. The study was limited in terms of commodity and equity market coverage and focused largely on commodities exported by the selected SSA countries. Also, the study neglected to include other prominent trading currencies, such as the Euro and the Pound Sterling, despite their role as primary currency units facilitating international trade transactions within the designated countries. The use of the United States Dollar (USD) as the major benchmark of exchange rate volatility for the selected domestic currencies is due to the global influence of the USD as the major trading currency. Methodically, the study was limited in choosing causality tests, considering the numerous tests with the similar capacity. This is notwithstanding the established capabilities.

Definition of Terms

The subsequent operational delineations of the fundamental concepts employed in this investigation are explicated as follows:

Commodities: Commodities epitomise essential entities that exhibit interchangeability during transactions involving goods of analogous nature. Commodities find pervasive utilisation as elemental constituents in the fabrication of diverse goods or services. They may also be necessities such as agricultural products or industrial components such as metallic alloys.

Exchange rate: The exchange rate denotes the valuation at which the monetary unit of a particular nation is exchanged in return for the currency of an alternate nation. Consequently, it signifies the quantified proportion of exchange between the monetary units of two distinct countries.

Exchange rate volatility: Exchange rate volatility is operationally characterised as the altered or oscillating dynamics that epitomise the varying patterns in the value of local currencies in relation to foreign currencies across temporal intervals.

Equity Market: The equity market is a complex network of exchanges where investors can trade shares of publicly traded companies. These exchanges serve as meeting points for buyers and sellers, enabling democratised investor trading and capital exchange.

Organisation of the Study

The study is organised into five chapters from chapter one to chapter five. Chapter one deals with the introduction and the specific issues discussed are the background of the study, the statement of the problem, the purpose of the study, research objectives and hypotheses, the significance of the study, delimitations, and the definition of key terms. Chapter two looks at the literature review where the theoretical conceptual and empirical reviews are discussed. Chapter three deals with the research methods and the issues regarding the research design, data collection procedure, and data process and analysis techniques are delineated. Chapter four deals with the analysis and discussion of data collected and chapter five considers the summary, conclusion and recommendations of the study.

CHAPTER TWO

LITERATURE REVIEW

Introduction

The second chapter emphasises conducting a comprehensive literature review to examine the dynamic interdependence and risk transmission framework between commodities, exchange rates, and equity markets in the sampled commodity-dependent SSA countries. The section specifically emphasises the theoretical underpinnings as well as the discussions of major concepts. The section proceeds with a comprehensive analysis of the empirical work in line with the study objectives.

Theoretical Review

The study is underpinned by diverse theories, among which are modern theory of portfolio, arbitrage pricing and the contagion theory, which equally offer explanations for the interactions among the study variables. Portfolio theory constitutes the vital basis for the administration of securities, endowing investors and fund managers with erudite mechanisms of analysis and securities curation that facilitate optimal returns (Biswas, 2015; Leković, 2021). Yet in advance of the applicability of these techniques, investor holdings comprised diverse individual assets with variational risk elements, with some transcending their acquisitions across domestic boundaries, making constant analysis of individual risk challenging (Leković, 2021). These shortfalls were emphasised by critiques, which led to the growth of modern portfolio theory (MPT).

Harry Markowitz invented MPT with diverse assumptions and concepts (Leković, 2021). The theory assumes that the average distribution of yields on assets is normal, which implies that investors are rational and do not engage in impulse buying or herding behaviour. The second assumption relates to the first, with the only difference inherent in risk. Thus, investors are mostly risk-averse and sensitive to any form of risk and will effectively assess the risk level of each asset in a portfolio before subscribing to it. The third assumption was that the ultimate objective of investors within each of the unique circumstances generated is to optimise returns. This assumption stands out the most with any rebuttal inherent in diverse human nature.

Nevertheless, these assumptions further coincide with the key concept, which envisages that investors prioritise maximising return for an assumed peril. The last relates to the symmetric nature of investor information, which complements almost all the remaining assumptions because, absent accurate information, most of these previous assumptions may not hold. The theory also capitalised on concepts that explained its tenets, the first of which holds that risk can be mitigated by diversifying a portfolio with disparate securities, which stands as the premise of the study's first objective. Thus, we seek to assess how combining unrelated asset classes, such as industrial metals and agricultural commodities, with SSA equities can aid in portfolio diversification and risk mitigation. For instance, the proponents of commodity investment (Addison et al., 2016; de Boyrie & Pavlova, 2018) affirmed this assertion when they argued that the most relevant aspect of commodity investment lies in its lower correlation with other investments

like stocks. Thus, the MPT suggests that a rational investor will always choose the less volatile asset for a given return.

According to the MPT, investors are either as high peril and high return or low risk and low yield, which presupposes that their desire for high yield will coincide with their risk tolerance (Bossman & Agyei, 2022; Woode et al., 2024a). In this context, investors must determine their optimal level through the utilisation of the efficient frontier by constructing a portfolio at any given level of return that offers the least risk conceivable or, at any given level of risk, a portfolio that yields the highest return, with emphasis on the upper segment of the frontier since it delivers the extreme projected return given a specified level of peril. We examine whether a combination of the above-stated asset classes could help investors reduce their risk levels, which is in line with the efficient frontier and low correlation among diverse markets.

Prior studies (Biswas, 2015; Bossman & Agyei, 2022; Woode et al., 2024a) assert that global investors shifted from equities towards safe investments, including commodities, during the global recession. In essence, portfolio managers examined risk transmission across asset classes to identify opportunities for diversification across markets (Bossman & Agyei, 2022). This is to affirm that markets can transform due to erratic proceedings and radical shifts, and investors are likely to respond to these dynamics during periods of decline, particularly in the search for an optimal portfolio, which motivates the current study in the SSA context. Despite the uniqueness of the MPT, Leković (2021) provided insights into the theory's development, concluding that the assumptions of normalised

dispersion and persistent correlation may not hold in real-world scenarios. Woode et al. (2024a), on the other hand, assessed the link between African equities and agricultural commodities and revealed the efficiency of the MPT in explaining the short- and medium-term diversification prospects. Bossman and Agyei (2022) shed light on the dynamics of commodities and their influence on equity markets, while Bianchi et al. (2020) highlighted the evolving nature of commodity markets and the need for adaptations to MPT to capture these dynamics. This highlights the relevance of MPT in explaining the interdependence structure between commodities and equity returns of commodity-dependent SSA countries, which stands as the first objective of the study.

Despite the effectiveness of the MPT in explaining the diversification prospect within assets of different classes and risk levels, it is relevant to acknowledge its limitations in explaining the risk transmission mechanism. Hence, the rationale for embracing the contagion theory as a supplementary framework to this effect. Contagion, in its broad sense, explains how risks and shocks transmit across diverse markets due to cross-market integration (Hurd, 2016; Trevino, 2020; Von Furstenberg, Jeon, Mankiw, & Shiller, 1989). Per studies (Ahnert & Bertsch, 2022; Trevino, 2020), the key tenet revolves around the risk of curtailing vital investments and diversification due to suboptimal choice. Drawing from the insights of Hurd (2016), the notion that each nation grapples with acute ailments prone to the shocks from emerging economies explains the complexities inherent in the theory.

Hurd (2016) further highlighted the nuances of market contagion (pure and shift contagion). The former denotes the dissemination of shocks across markets via mechanisms beyond basic transmission channels, while the latter implies a modification in the intensity. In adherence to the principal channels as highlighted by the proponents, including bilateral trade, financial integration, and investor conduct, the sample SSA equity markets are susceptible to such risk, especially at the onset of the metal market crash and global commodity price hikes. Increasing market interdependence within the SSA region has heightened the prospect of transmissions from the currency and commodity markets towards the equity markets. In terms of bilateral trade and cross-market integration, it is relevant to acknowledge that several metal-driven firms in the JSE, such as Gold Fields Limited, Glencore PLC, Anglogold Ashanti, Anglo-American Plc, Minergy, and B2Gold corporations, have subsidiaries in both the NASE (Anglo-American PLC and B2Gold Corporation), BSE (Anglo-American PLC, Minergy, and Glencore PLC), and GSE (Anglogold Ashanti), while Seedco International and Letshego Holdings Limited (MTN), which have listings on the BSE (JSE), respectively, have further listings on the NSE (GSE), which explains how shocks from the metal market transmit towards the JSE and further have ripple effects on the GSE, BSE, and NASE.

Drawing upon the cross-asset trade conduits underscored by Trevino (2020), the potential for inter-market risk transmission within the sample markets emerges as plausible, particularly with the advent of burgeoning information systems, risk management avenues, and the continental trade accord (forecasted to

amplify internal trade by 52%). Within this framework, shocks stemming from currency and commodity dynamics in each of these scrutinised economies possess the capacity to instigate margin calls, prompting investors to divest assets in alternate jurisdictions while readjusting their investment portfolios. Hurd (2016) further highlighted that the financial sector remains the basic conduit for the transmission of shocks across interconnected markets, a phenomenon typified by the link between multilateral institutions like Access Bank, Standard Chartered Bank, Stanbic, and ABSA, boasting listings across nearly all sample equity markets. For instance, recent currency decimation within SSA at the onset of commodity price fluctuations, which informed the high-pressure characterization, might instigate panic withdrawals among financial asset investors and account holders, redirecting investments towards commodities amid fears of eroded returns due to currency devaluation. This scenario could precipitate a chain reaction of panic and contagion, manifesting as liquidity shortages or market halts, thereby obstructing capital flow and exacerbating the dissemination of risk across markets (Ahnert & Bertsch, 2022; Seth & Panda, 2018).

Drawing upon the contagion theory, numerous empirical inquiries (Agya, Samuel, & Amadi, 2022; Moradi, Jabbari, Nooghabi, & Rounaghi, 2021; Owusu Junior, Alagidede, & Tweneboah, 2020) have scrutinised the potential for shock and risk transmissions across a diverse array of emerging and established equity markets, spanning the BRICS, G7, and SSA, yielding diverse findings that augment the theory's application. For instance, Moradi et al. (2021) posited that market stability and liquidity are contingent upon the presence of investors with varying

time horizons; however, during periods of market pessimism, investors tend to adopt short-term objectives, reacting sensitively to news and price fluctuations. Zankawah and Stewart (2020) underscored the detrimental impact of currency volatility on equity and commodity markets, accentuating the amplification of future market risks, while Owusu Junior et al. (2020) contended that the theory furnishes a novel framework for the accurate projection of the turbulence and discontinuities inherent in financial markets. It is within this backdrop that the present study investigates the transmission of risk among the sample commodities (both agricultural and industrial metals), currencies (BSE, GHS, KSH, NAD, and ZAR), and equities (BSE, GSE, NSE, NASE, and JSE), with the aim of informing pragmatic investor decision-making.

The study adopts the arbitrage pricing theory (APT) in a quest to explain the causal nexus among the sample markets since such prospects precede the capacity of the contagion theory. The APT is grounded in the notion that an asset's probable yields can be predicted by examining the link between its projected return and the various macroeconomic factors that capture systematic risks (Elshqirat, 2019; Nordin et al., 2014; Ouma & Muriu, 2014; Roll & Ross, 1984). Among the several assumptions underpinning the APT is that the average portfolio distortion is non-existent and that investors will maintain their non-existent risky portfolios. The theories presume that investors keep a substantial number of securities in their portfolios and have the capacity to execute short transactions with sufficient resources for replenishment (Biswas, 2015).

APT justifies that investors require different rates of return from different securities because each asset has different levels of riskiness (Elshqirat, 2019; Nordin et al., 2014). Accordingly, since the APT does not specifically identify what variables are to be included in the model, the selection of variables is usually based on past empirical studies (Elshqirat, 2019). Nevertheless, prior studies have substantiated that the economy-wide indicators that exhibit the highest level of reliability in forecasting equities encompass key variables such as commodity prices and indexes, gross national output, and exchange rates, among others (Elshqirat, 2019; Idan, 2022; Ouma & Muriu, 2014). Elshqirat (2019) further asserted that for firms to produce efficiently, there is a need for commodity prices and exchange rates to be less volatile to mitigate their respective perils within the global space. Furthermore, increased commodity prices on the global market coupled with deteriorating exchange rates increase the cost of operations for local firms that heavily depend on imports for the majority of their production factors, and that negatively impacts their cashflows and ability to invest in growth prospects. Exporting firms, on the other hand, suffer from domestic currency appreciation and reduced commodity prices through reduced cashflows, with the overall impact being depleted stock returns, affecting investors and stock market development.

Subject to the above assertions, several studies have been steered to assess the nexuses between stock returns, economy-wide variables (interest, credit, and exchange rates), and commodity indexes and prices. Contrary to the numerous assertions of Mollick and Sakaki (2019), interest rate differentials and other

economic fundamentals have poor predicting abilities for stock markets, resulting in the need to fixate on currencies and commodity-related parameters given their pervasiveness. In light of these claims and coupled with restrictions established by prior literature, we, therefore, utilise the above theory as the basis for analysing the causal nexus between the study variables. Specifically, we seek to examine how commodities and exchange rate movements cause changes in the equity markets of the selected SSA economies. Subject to these assertions, the study's third hypothesis was that changes in commodity prices and currency exchange rates exert a noteworthy impact on the equities of the sample SSAs.

Conceptual Review

This section reviews relevant concepts supporting the study. The major concepts like exchange rates, commodity financialisation, and the African equity exchange market will be discussed. Further consideration will be given to minor concepts including exchange rate volatility in sub-Saharan Africa and the commodity-dependent sub-Saharan African countries.

Commodities

Commodities are essential materials that exhibit interchangeability during transactions involving goods of analogous nature (Bianchi et al., 2020; Woode et al., 2024a). Commodities find pervasive utilisation as elemental constituents in the fabrication of diverse goods or services. They may also be necessities such as agricultural products (cocoa, coffee, corn, and cotton) or industrial components (copper, aluminium, nickel, and zinc) which are emphasised in the current study.

The relevance of commodities to the global financial markets has increased commodity financialisation, which signifies a surge in credit growth and investor engagement in commodity spatial and futures markets (Bianchi et al., 2020). The act of investing in commodities has experienced a notable surge in prominence and appeal during the past decade, leading to an unprecedented influx of institutional capital into commodity markets. According to the global commodity statistical analyses delineated in the literature (Bianchi et al., 2020; Zaremba et al., 2021), the projected values for the global commodity market are anticipated to reach $131.3 trillion by 2024 and $139.3 trillion by 2028, with metallic components attaining an estimated valuation of $8.13 trillion in 2022. Notably, copper ($183 billion), aluminium ($153 billion), nickel ($69 billion), and zinc ($31 billion) persist as the most traded industrial metals globally.

Furthermore, UNCTAD's (2022) emphasised a notable upsurge in global agricultural commodity trade, escalating from $1.1 to $3 trillion between 1990 and 2020, thereby accentuating the relevance of these markets. The burgeoning trade, predominantly attributable to tripled prices, is anticipated to augment the revenues of commodity-dependent economies, encompassing those in SSA. However, rather than reaping the benefits of heightened prices, such economies seem to be experiencing depletion of their luxuries rather than currency enrichment amidst these elevated market valuations.

An expanding body of literature on the financialisation of commodities attributes these behavioural patterns to the burgeoning prominence of commodities as an asset class, which has garnered substantial attention from institutional

investors seeking to capitalise on diversification advantages (Bianchi et al., 2020; Zaremba et al., 2021). According to Zaremba et al. (2021), institutional investors have witnessed a rapid escalation in their allocations to commodity futures since the beginning of the twenty-first century, with an augmented surge of $200 billion in 2008 from a mere 15 billion in 2003. The growth of commodity trading has spurred a considerable amount of research devoted to comprehending the extent and nature of commodity market financialisation and its connections with exchange rates, and equity markets. According to studies (Bianchi et al., 2020; Tang & Xiong, 2012), financialisation is driven by an increase in commodity index investments and intensifying correlations with the equity market. This instigates our impetus to examine the intricate interplay and interdependencies among commodity, exchange rates, and equity markets.

Exchange rates in sub-Saharan Africa

The exchange rate serves as the valuation at which the currency of one nation is exchanged for another. When contemplating the complexities of the exchange rate, it becomes crucial to scrutinise the diverse exchange rate regimes and their consequential impact on interconnected parameters such as commodities and the equities. The predominant currency regimes encompass the static (floating) and pegged (flexible) regimes, each with its own distinct characteristics and implications (Nandi, 2017). A country's currency is allowed to move within a defined range by benchmarking it against the currency of another country or a measure of value such as gold in the fixed or pegged regime. With a fixed exchange rate, a country's currency could only be devalued and revalued within a certain

range (Goldberg, 2019; Nandi, 2017). In contrast, the floating (or flexible) exchange regime pertains to a system of freely fluctuating rates in response to market shocks (Goldberg, 2019). This system is not subject to commodity or external currency benchmarking from the monetary authorities. In the contemporary market, the floating exchange rate is commonly perceived as an efficient mechanism; however, participants engaging in transactions involving highly volatile currencies encounter considerable risks (Goldberg, 2019).

Accordingly, given that domestic currencies in most SSA countries are relatively volatile due to floating currency exchange system implementation, this poses a risk to international trade parties, governments, and economies alike (Katusiime, 2018; Zankawah & Stewart, 2020). For instance, the GHS, KSH, NAD, and ZAR uniformly employ free-floating exchange rate systems, with BSP standing as the solitary outlier. Despite this exception, BSP is directly pegged to the ZAR, underscoring its susceptibility to fluctuations in the ZAR. This linkage exposes these currencies to global shocks, given the exposed character of the currencies resulting from equity market liberalisation. Furthermore, exchange rates are subject to the influence of various macroeconomic factors, including but not limited to interest rates, money supply, and inflation, among a plethora of other determinants. Nonetheless, Mollick and Sakaki (2019) acknowledged that due to the feeble predictability of credit rate disparities and other usual pecuniary rudiments, it is pertinent and pervasive to fixate on peril factors, predominantly those gleaned from commodity and exchange markets. These assertions necessitate the need to

examine the above concept in the SSA paradigm, given the incessant currency fluctuations coupled with commodity price hikes and equity shocks.

Exchange rate volatility in sub-Saharan Africa

Exchange rate volatility pertains to the potential for significant oscillations in the real exchange rate within a brief timeframe (Ofori, Obeng, & Mwinlaaru, 2022). These fluctuations have broad implications for macroeconomic policies, investment decisions, and international trade. In SSA countries, the management of exchange rates is crucial, and according to studies (Ofori et al., 2022; Okot, 2022), there have been noteworthy variations in the adopted regimes and monetary policies, especially in the contemporary century. This transition towards more flexible exchange rates has heightened the magnitude and economic significance of exchange rates as an economy-wide component and a critical factor influencing investment decisions (Katusiime, 2018).

Furthermore, undiversified export structures and commodity prices continue to be the main factors driving exchange rate movements in many nations. However, the liberalisation of capital accounts and foreign exchange markets has increased the influence of financial factors and international market conditions on exchange rates (Okot, 2022). This raises the risk of greater exchange rate volatility in the SSA setting since most governments within the region heavily rely on revenue from commodity sales and foreign currency financing, making them vulnerable to fluctuations in commodity prices and their impact on foreign exchange earnings and economic growth (Ogbulu, 2018; Ogundipe, 2020).

According to the IMF (2023), which provides insights into the role of foreign exchange intervention in SSA policy, the region exhibits prevalent characteristics such as shallow markets, limited credibility in monetary policy, and substantial foreign exchange liabilities. These factors imply that significant movements in exchange rates pose a risk of destabilising inflation expectations and jeopardising the overall monetary stability in the region. In such instances, the flexibility of the exchange rate may function as an amplification mechanism for shocks rather than a cushioning mechanism. Furthermore, because the region dominates foreign currency pricing, the potential efficacy of exchange rate in mitigating shocks is attenuated. It was also discovered that, when compared to other emerging markets, the region is more vulnerable to temporary financial and commodity price shocks, both of which are detrimental to structural evolution.

In addition, exchange rate volatility is a problem in commodity-dependent SSA because the majority of raw materials used by the stock market's manufacturing firms are imported (Danmola, 2013; Katusiime, 2018). Since adopting flexible currency regimes as part of economic recovery programmes, the currencies of most SSA countries have experienced consistent depreciation and volatility compared to major currencies. Among them, the US dollar stands out due to its strength and widespread use in international markets (Katusiime, 2018). These challenges can be partly attributed to the import overdependence of SSA industrial enterprises and the limited availability of technologies within these industries, which calls for relevant examination. For instance, in 2022, the sample currencies experienced incessant volatility with GHS (-31%), KSH (-22%), NAD (-19%), and

ZAR (-11.5%), while the BSP, despite its pegged nature, further exhibited a 10.2% decline in value, further earning the tag “pressure currencies.” The current study emphasises these pressure currencies and their respective equity markets and commodities.

African equity markets

Stock markets are networks of exchanges where investors can trade shares of publicly traded companies (Woode et al., 2024a). These exchanges function substantially in a free-market economy as they facilitate inclusive investor trading and capital flow. The Egyptian Exchange, which was founded in 1883, is the oldest exchange in Africa with the Johannesburg and Namibia exchange established in 1887 and 1904 toppling the triad of pioneering exchange market. On the African continent, there are a total of 29 distinct exchanges that align with the capital markets of 38 individual countries. At the core of these markets' development is the desire to lure sizable private capital inflows (Boako & Alagidede, 2017). Nevertheless, the equity markets in Africa are predominantly smaller compared to more developed regions, and some have fewer than 10 listed companies and capitalisations below $50 billion. However, over time, the cumulative value of these markets has experienced substantial growth, with their value rising from $113 billion in 1992 to around $1.6 trillion by September 2021.

Among these markets, South Africa stands out as the largest, boasting a capitalisation of $1360.25 billion and 354 listings. Following closely are Namibia with $137 billion and Nigeria with $114 billion (Chartered Financial Analyst Research Institute [CFARI], 2021). At the sectoral level, the mining sector

contributes 23% of the top 100 corporations' market value. It is noteworthy that SSA stock markets, apart from South Africa, are characterised by their limited liquidity and relatively small size. Despite having relatively limited capitalisation, African equities are now included in the benchmark indices for emerging frontier and Africa-focused markets maintained by the Russell Frontier Index and Standard and Poor Africa Frontier.

Furthermore, Boako, Omane-Adjepong, and Frimpong (2016) asserted that emphasis is being directed towards African markets as prospective options for safeguarding investors against global commodity and equity shocks due to their potential decoupling from contagion and other markets. In contrast, Boako and Alagidede (2017) further postulated that global shock pestilence is predicted to amass cross-market interrelationships during market turmoil, diminishing any diversification options. Also, integration of the financial markets may simultaneously improve global stock listings while amplifying shock waves, with repercussions for both the domestic and global economies.

Hegerty (2018) contends that because developed stocks frequently move in lockstep with commodities, they are ineffective for hedging commodity price shocks, an attribute found non-existent in African equity markets. Also, despite restrictions on non-resident international investors' ownership of local exchanges, it is noteworthy that stock markets throughout the continent are open to foreign participation, making the nexus between exchange rates and equities a pertinent subject worthy of realisation (Boako et al., 2016). This is because cross-border equity flows increase along with the supply and demand for the currencies used to

calculate the value of global stocks (Boako & Alagidede, 2017). In light of the above suppositions, the current study emphasises equities in commodity-dependent SSA economies, including the Johannesburg, Namibia, Nairobi, Botswana, and Ghana stock exchanges.

Johannesburg stock exchange

Established in 1886, the JSE remains Africa's preeminent equity market, boasting a substantial market capitalisation of $1360.25 and a roster of 354 listed companies as of November 2023. The market landscape is characterised by a diverse array of industries, with the extractive sector commanding the largest share at 22.1%. Globally, the JSE ranks 19th in terms of capitalisation, underscoring its significance in discussions surrounding equity markets, particularly within the SSA context. In terms of listed entities, the financial sector dominates the market with 97 firms, followed by consumer goods and services (58), industrial and extractive (46), basic materials and agriculture (45), and telecommunications and technology (21). Recent years have witnessed notable growth in the JSE, attributable to its inclusion in global index listings such as the FTSE 100, emerging equity market listings, and major global indexes. Given the market's reliance on industrial metals and agricultural commodities, facilitated by the direct and indirect operations of listed firms like Bidvest Group, Barloworld Ltd., and Hudaco Industrial Limited, alongside the impact of currency depreciation on equity market development, characterised by excessive repatriation, the present study incorporates the JSE into its sample of SSA equities to analyse the transmission of risk from currency and commodity markets to equity markets.

Namibia stock exchange

The NASE stands as the second-largest equity market across the African continent, boasting a formidable market capitalisation (listed firms) of $133.64 billion (40). Established in 1904, NASE remains the sole equity market in Namibia, holding the distinction of being the third oldest on the continent. The market's complexion is marked by a diverse spectrum of sectors, with mining commanding a notable 42.48% share of market capitalisation. Predominantly, the financial sector leads the market in terms of listed firms (14), followed by mining (9), insurance (4), agricultural (3), trade (3), and food processing (2) entities. In the context of equity market integration within the SSA landscape, approximately 24 listed firms on NASE concurrently hold listings on the JSE, with local enterprises accounting for 10 of this aggregate. Given the market's preponderance of extractive firms focusing on industrial metal mining, notably copper, nickel, and tin, coupled with recent downturns in currency markets poised to exert influence on equity market evolution, the current study integrates NASE into its sampling of SSA equities to assess the transmission of risk from currency and commodities to equity domains.

Botswana stock exchange

Situated in Gaborone, Botswana, the BSE was established in 1989 and officially incorporated in 1994. Despite its position as the 5th largest market on the African continent and the 4th in SSA, boasting a robust capitalisation of $43.94 billion as of November 2023, the BSE features a relatively modest count of 29 listed firms. Interestingly, several of these entities are subsidiaries of firms listed on the JSE. Performance evaluation of the BSE hinges on indices such as the all-share

index, the domestic company index (BSE-DCI), and the foreign index (BSE-FCI). The exchange also offers avenues for investment in debt and equity-traded funds, which have significantly contributed to its expansive growth.

The market landscape is characterised by a diverse array of sectors, with the extractive sector commanding a substantial 59.4% share of market capitalisation. Notably, the financial sector takes precedence, encompassing 8 firms, followed by mining (7), property (6), retail and wholesale (4), tourism (2), agricultural (1), and security (1). In terms of equity market integration within SSA, approximately six listed firms on the BSE concurrently maintain listings on the JSE, including notable entities such as Sefalana Holdings, Seed Co. International, Sechaba Brewery Holdings, and RDC properties (Anglo American PLC and Choppies). The BSE's emphasis on extractive firms specialising in metals mining, spanning industrial diamonds, copper, silver, and aluminium, among others, coupled with recent currency market downturns poised to influence equity market dynamics, warrants its inclusion in the current study's sampling of SSA equities to scrutinise the transmission of risk from currency and commodity markets to the equity domain.

Nairobi stock exchange

The NSE ranks as the 8th largest equity market in Africa, boasting a formidable capitalisation of $20.64 billion and a listing of 56 firms. In its pursuit of expansion beyond its current bounds, the NSE introduced the FTSE NSE 15 and FTSE NSE 25 Indices in November 2011, with a strategic focus on fostering diverse domestic investment. Furthermore, the exchange gained membership in the Financial Information Services Division (FISD) in March 2012. Complementing

its offerings, the NSE facilitates investment in debt and equity-traded funds, which have been instrumental in fuelling its remarkable growth trajectory. The market is marked by a diverse sector, with the financial sector seizing a significant 25.1% share with 12 listed firms. Trailing this pack are the commercial services (11), manufacturing and allied industries (9), agriculture (7), insurance (6), investment (5), and mining (4). Noteworthy is the NSE's emphasis on agricultural enterprises, particularly in coffee and cotton, alongside recent downturns in currency markets that hold sway over equity market dynamics. These factors underscore the rationale behind its inclusion in the present study's sampling of SSA equities, aimed at scrutinising the transmission of risk from currency and commodity markets to the equity domain. The study adopts returns, characterised by a logarithmic growth pattern in the all-share index, as a proxy for assessing NSE equities.

Ghana stock exchange

The GSE serves as a pivotal platform facilitating the listing, trading, and accessibility of financial products within Ghana. Positioned as the 10th largest equity market across the African continent, the GSE boasts a substantial market capitalisation amounting to $12.68 billion, with 31 listed firms recorded as of December 2023. By augmenting its offerings, the exchange provides avenues for investment in debt-traded funds, which have been instrumental in propelling its robust growth trajectory. Noteworthy are the accolades garnered by the GSE in the early 1990s, where it showcased remarkable performance within the emerging stock market landscape. In 1993, the GSE secured the sixth-best-performing index status, registering a notable capital appreciation of 116%. Subsequently, in 1994, it

clinched the title of the best-performing index stock market among all emerging markets, exhibiting a remarkable 124.3% surge in its index level. In terms of market composition, the mining sector takes centre stage, commanding a significant 55.7% share of market capitalisation, while the financial sector leads in terms of listings, comprising 13 firms.

The list is closely trailed by food and beverage (5), industrial (4), supply (2), technology (2), insurance (2), agricultural (1), and education (1) entities. The market's emphasis on precious metals including gold, bauxite, aluminium, and copper, along with the recent classification of domestic currencies as "pressure currencies," underscores its pivotal role in influencing equity market dynamics. Such factors underscore the rationale behind its inclusion in the current study's sampling of SSA equities, aimed at scrutinising the transmission of risk from currency and commodity markets to the equity domain. Although operating on both financial and composite indexes, the study employs returns characterised by a logarithmic growth pattern in the latter as a proxy for assessing the equity market.

Commodity-dependent sub-Saharan African countries

A country is considered to be a member of the commodity-dependent developing countries (CDDCs), according to the UNCTAD's special unit on commodities, when the proportion of its commodity exports value to merchandise exceeds 60%. Accordingly, the majority of African countries fall under the classification of CDDCs, with a few exceptions. Regarding the distribution of CDDCs across regions, SSA holds the top rank, accounting for over half of the world's CDDCs. Asia and Oceania follow with 28 countries, followed by Latin

America and the Caribbean with 17 countries. This makes SSA economies susceptible to commodity price shocks, hence our choice of the continent for the study. In light of the above considerations, the study placed particular emphasis on economies reliant on metal and agricultural commodities, encompassing Botswana, Ghana, Kenya, Namibia, and South Africa. This focus stemmed from the current trends observed in industrial metal markets and the escalation in agricultural commodity prices, which were catalysed by the geopolitical tensions arising from the Russia-Ukraine conflicts.

Empirical Review

The pragmatic literature on the nexus between commodities, exchange rates and equity markets are reviewed in this section. Several studies have been presented on the interdependence structure between commodities, exchange rate and stocks likewise the impact of the volatilities in the former on the stock market. Those that established significant interdependence among these variables, as well as their impacts, are assessed in the following reviews.

Commodity and equity markets: global market perspective

The dynamic and complex relationship among economic variables has attracted researchers, policymakers and investors alike. Previous research examining the relationship between the equity market and macroeconomic factors primarily concentrated on utilising crude and treasured alloys as representative indicators for commodities, with a predominant focus on developed and emerging markets. An investigation into the dynamic interconnection between equity and commodity markets within economies reliant on commodities, including New

Zealand, Canada, Chile, and South Africa, was conducted by Rossi (2012). The study revealed that equity market value has a significant out-of-sample predictive ability for the future global commodity price index for commodity-dependent countries. Furthermore, the study revealed that exchange rates demonstrate superior predictive capabilities for commodity prices when compared to equity markets.

Sadiq, Lin, Wang, Trung, and Ngo (2022) on the other hand undertook a comprehensive examination of the dynamic interplay between commodities and equities during the challenging period of the pandemic. Employing DCC-GARCH modeling techniques, the researchers analysed data from Asian economies encompassing China, India, Sri Lanka, Bangladesh, and Pakistan. The study's findings demonstrated a substantial association between commodities (treasured alloy and crude) and equity prices across all Asian stock markets. The outcomes of the study displayed a symmetrical pattern in the constructed relationships. Notably, the strength of the connection intensified with higher frequencies, with the lowest frequency exhibiting the most significant contribution to the overall relationship.

Commodities, exchange rate and equity market: volatility transmissions

The dynamic and complex relationships between economic variables and the stock market have gained traction in recent years. This notwithstanding, there are many variables that influence stock returns, notable being the commodity and exchange rate markets (Mollick & Sakaki, 2019). Nonetheless, real-world arbitrage and transmissions are neither enormously swift nor comprehensive (Maitra & Dawar, 2019; Moradi et al., 2021; Ogbulu, 2018). This demonstrates the well-established assimilation of the global market and the conditional variance

transmission systems that consequence therein. This has implored the need for evaluation and several studies have been conducted subject to these submissions.

In a research endeavour conducted by Jain and Biswal (2016), it was ascertained that governmental authorities implement tax policies and levies as a means to regulate the impact of commodity imports on the exchange rate. These measures have repercussions that reverberate throughout the economy, particularly within the equity market. The study focused on investigating the dynamic interconnections among global commodity prices (specifically treasured alloys and crude oil), exchange rates, and equities in India. Employing the DCC-GARCH, the empirical analyses indicate a direct relationship between commodity prices, exchange rates and the Indian stock market. Vardar et al. (2018) further utilised the VAR-BEKK GARCH model to scrutinise the transmission of shocks and the spillover effects of volatility among the daily stock market indices of prominent economies such as the US, UK, France, and Germany among others. This investigation also encompassed the examination of commodity spot prices, including crude oil, natural gas, platinum, silver, and gold. The empirical findings revealed a two-way transmission of shocks and volatility effects between stock and commodity returns. However, the results also indicated that the transmission of volatility from commodities to stock returns was relatively less pronounced compared to the significant one-sided effects observed from stock returns to commodity returns, particularly in advanced and emerging economies.

Hegerty (2018) explored the nexuses between currency, equity, and commodity markets in specific central and eastern European economies, employing

monthly time-series data. The study revealed that the Czech Republic demonstrates a relatively isolated position with limited international transmissions, whereas Hungary is more vulnerable to global spillover effects and Poland is exposed to events originating within the region. Moreover, Ukraine exhibits bidirectional causality between its exchange rates and equity market, indicating a reciprocal relationship where changes in exchange rates influence equity market dynamics and vice versa. Baruník and Křehlík (2018), on the flip hand, suggested an innovative structure to assess the interconnectivity and overspill between financial market exclusive and from diversified frequency responses to shocks and then used these frameworks to examine the spillover connectedness between U.S financial market variables. The assessment discerned the temporal and spectral characteristics of volatility interrelationships within the U.S financial market, affirming that heightened frequencies align with periods of increased interconnectedness, particularly when stock markets adeptly and serenely absorb information.

According to Siddiqui and Roy (2019), in the context of the growth of emerging economies, commodities hold significant importance. Approaching this perspective, Maitra and Dawar (2019) conducted a wide-ranging study on the propagation of returns and perils among commodity, stock, and exchange rate markets. The investigation sought to examine whether there were any changes in return and volatility spillover patterns during both the crisis and post-crisis periods, as well as any variations in the spillover behaviour between agro-based and non-agro-based commodities. Notably, the study identified a unidirectional spillover of returns from the multi-commodity exchange to stock indices and exchange rates.

Specifically, stock indices were found to exert an influence on exchange rates, while the US dollar solely explained the return patterns in stock indices.

Siddiqui and Roy (2019) on the other hand conducted an extensive analysis to explore the dynamic correlation among commodity prices (specifically gold and crude oil), the exchange rate, and the Indian stock market. The study spanned from April 2014 to March 2018 and employed the VARMA-BEKK-GARCH model to estimate the spillover of returns and volatility across these markets. The findings of the research revealed a bidirectional spillover of returns between the Indian stock market, exchange rates, and the selected commodities. In other words, the interactions and influences between these markets were not unidirectional but exhibited reciprocal relationships, with return spillovers occurring in both directions. Mollick and Sakaki (2019) assessed the volatility impact of commodity prices and exchange rates on stocks, focusing on global equities, multiple major currency pairs, and crude oil, with the latter acting as the commodity. It was revealed that with global equity markets advancing, risk tolerance increases and oil and stock markets impact currencies. Commodity currencies strongly appreciate following positive oil price shocks and depreciate with positive equity shocks.

Sokhanvar and Bouri (2023) further asserted that the confluence of the ongoing conflict in Ukraine and the disruptions in global distribution outlets caused by the most recent pandemic is synergistically driving the demand for commodity exports and subsequently elevating prices. Subject to the aforementioned supposition and established literature on the bearing catastrophes on the international commodity market, Sokhanvar and Bouri (2023) conducted an

extensive analysis of the repercussions of price shocks on commodity markets arising from the prevailing conflict. Their study encompassed four-hour price data spanning from February 1 to April 30, 2022, focusing on three commodities (wheat, crude oil, and natural gas) and two exchange rates (Euro/CAD and CAD/JPY). The dynamically simulated ARDL model unveiled a positive influence of commodity price shocks on the value of the Canadian dollar vis-à-vis the euro and the yen. Moreover, it came to light that price disruptions possess a practically identical consequence on the intensified devaluation of the euro and the yen, with the ongoing turmoil contemplated to have an enormous effect on a global scale.

Commodities, exchange rate and equity market: causality

The literature has extensively recognised the predictive capacity of various macroeconomic variables on the stock market. However, Mollick and Sakaki (2019) conducted a study that conclusively demonstrated the limited predictive ability of conventional economic fundamentals. This finding highlights the imperative to focus instead on commodity and currency rates as more reliable indicators for forecasting stock market movements. In light of the aforementioned, Kumar (2019) examined the causal relationship between oil prices, exchange rates, and stock prices in India. The result demonstrates a bidirectional nonlinear relationship between the exchange rate, stock prices, and oil prices. Haider, Nazir, Jiménez, and Qamar (2021) further examined the exchange rates predictability of commodity prices in selected commodity import- and export-dependent developed and emerging countries. The researchers found that primary commodity prices

better predict exchange rates in almost two-thirds of export-dependent developed countries and revealed the market's predictive capacity.

Commodities, exchange rate and equity market: African market perspective

The interplay among commodity prices, exchange rate fluctuations, and their implications on the SSA stock market has garnered increasing attention in recent years, with a predominant focus on metals and crude oil (Mongale & Eita, 2014). Mongale and Eita (2014) revealed a positive nexus between commodity price increases and stock market performance, along with a positive nexus between the stock market and macroeconomic variables in South Africa. Similarly, Musawa and Mwaanga (2017) explored the impact of commodity and economy-wide variables (interest and exchange rates) on equity returns, with a specific focus on Zambia. The study demonstrated that the sampled economy-wide variables and commodities exert both immediate and enduring effects on the equity market.

Given the observed volatility in international commodity prices in general and crude prices in particular and considering the role of commodities on the Nigerian economy, Ogbulu (2018) examined the impact of crude oil prices and foreign exchange rate movements on stock market prices in Nigeria. The study further examined the extent of volatility transmission between the foreign currency, oil prices and equity market respectively. The results revealed the existence of an enduring dynamic co-integrating nexus among the sampled markets while the crude oil price significantly impacts stock market prices. The Granger causality test reports a bi-directional causality nexus between the stock and crude oil prices and a unidirectional causality running through equities from the currency market. The

GARCH explosiveness analysis demonstrates that stock prices are volatile, and the volatility in Nigerian oil prices is significantly transmitted into the stock market.

Oyelami and Yinusa (2019) delved deeper into the intricate interrelationships between global commodity prices and stock markets in South Africa and Nigeria. Employing the ARDL estimation technique, the study thoroughly examined the influence of global commodity price movements on stock market returns. The findings unveiled a noteworthy and enduring connection between global commodity prices and stock market returns, showcasing a bi-directional causal relationship within the chosen market. Furthermore, the study demonstrated that global commodity prices exert both short-term and long-term effects on stock market returns within the selected markets.

By employing intricate GARCH BEKK and TBEKK models, Zankawah and Stewart (2020) scrutinised the ramifications of perturbation and volatility transmission stemming from crude oil prices on exchange rates and the stock market in Ghana. The inquiry unearthed that oil prices possess noteworthy spillover effects on the currency and equity market; however, the impact on the equity market is contingent upon whether the oil price is exogenously or endogenously determined. Studies (Agya et al., 2022; Queku, Gyedu, & Carsamer, 2022), further delved into the examination of shock and volatility transmission as well the impact of commodities, exchange rates and equities with the focus on Nigeria and Ghana. The inquiry revealed that previous self-originating shocks and volatilities significantly contribute to current volatilities in the exchange rate and oil price domains. Additionally, there exists a bidirectional transmission of shocks and

volatilities between the exchange rate (Naira/USD) and oil price markets. Moreover, there were bidirectional shock and volatility transmissions between the USD/Naira and Brent oil prices, while a unidirectional shock and volatility flow was observed from Brent oil prices to the effective exchange rate market.

Research Gap

The empirical studies reviewed above show that high volatility in commodity and exchange rate markets adversely affect the equity market through a lack of confidence in the domestic economy and foreign trade partners becoming sceptical in terms of investing in the stock markets. This therefore supports our earlier hypotheses on commodities, exchange rates, and the equity market nexus.

Although several studies have investigated the volatility transmission and the interdependence structure between commodities, exchange rates and equity markets, the evidence is far from conclusive, and none of these studies considered the combined influence of the market sampled in this study. Most studies have employed various techniques such as the ARDL, VAR, GARCH-based models, the Copula approach, and quantile cross-spectral, but these methodologies employed are not efficient in capturing the time-frequency domains of the data (Baruník & Křehlík, 2018; Bossman, Junior, & Tiwari, 2022; Owusu Junior et al., 2020). Moreover, none of these studies delved into the unified framework of commodity, exchange rates, and the SSA stock market utilising the time-and-frequency-based index of Baruník and Křehlík (2018) (referred to as BK-18 henceforth) as well as the multivariate wavelet correlations (WMC and WMCC henceforth) technique. This method enables the assessment of uninterrupted alterations in the link between

variables while concurrently introducing frequency dynamics into the estimations. In contrast to the models employed in previous research endeavours, the BK-18 identify nonstationarity, time-varying instability, and asymmetries in returns.

This aligns with the contagion theory, which posits diverse investor responses across various time horizons while accounting for distinct investment preferences. Considering the aforesaid, the utilisation of both the BK-18 indexes and the WMC technique assumes paramount significance in this study. Given the aforementioned premises, coupled with the dearth of studies examining the nexus between commodities, exchange rates, and stock market dynamics within the African context, we aim to address these gaps by expanding the existing body of literature pertaining to the transmission of volatility and the interdependent structure among commodities, exchange rates, and stock market, with a specific focus on the SSA.

Chapter Summary

The second chapter of this study undertook a comprehensive examination of the existing body of literature concerning the intricate interplay and transmission of volatility within the domains of commodities, exchange rates, and equity returns. The theoretical framework of this study is firmly grounded in the APT, MPT, and the contagion theory. Furthermore, in this chapter, thorough discussions were conducted on the fundamental concept surrounding commodities, exchange rates, and the stock market. Ultimately, empirical evidence pertaining to the interdependence and transmission of volatility among the carefully selected variables was meticulously scrutinised.

CHAPTER THREE

RESEARCH METHODS

Introduction

This chapter discusses the research methodology employed in this study. The study examines the volatility transmission and the interdependence structure between commodities, exchange rates and equity market in commodity-dependent SSA countries. Therefore, this chapter discusses the research design, research approach, sample and sampling technique, definition and measurement of variables, data analysis and presentation in light of objective of the study.

Research Design

The explanatory design was employed to examine the interdependence structure among commodities, exchange rates and stock markets as well as the influence of commodities, and currency rates on equities. The research design is essentially a road map for carrying out the full investigation (Zikmund, Babin Carr, & Griffin, 2012). According to Zikmund et al. (2012), choosing a research design is critical since it determines the best strategy to respond to the study hypotheses. Accordingly, it also assists the researcher by addressing concerns such as the importance of the study, the sort of investigation, the level of impediment, the location, the period, and the unit of analysis.

An explanatory study seeks to ascertain the magnitude of influence that one or more variables exert upon another variable and also offers the advantage of replication if necessity arises (Zikmund et al., 2012). Also, the explanatory design is associated with greater levels of internal validity due to systematic selection of

subject in the study (Zikmund et al., 2012). The main pitfalls associated with explanatory study are that coincidence in events may be perceived as cause-to-effect relationships. It can also be difficult to reach appropriate conclusions on the basis of causal research findings. This is due to the impact of wide range of factors and variables in social and economic setting. Notwithstanding the aforementioned limitations of explanatory study, it is considered ideal for the objective of this study since it allows for the assessment regarding the influence of commodity and exchange rate volatility on stock markets of commodity-dependent SSA countries.

Research Paradigm

The research paradigm adopted in this study adhered to a post-positivism framework, characterised by a deductive approach to reasoning based on meticulously collected data aimed at predetermining variables that would yield statistical data used to address the research question. Post-positivism, as a metatheoretical perspective, serves as a progress over and critique of positivism (Bergman, 2016). Unlike positivists, who emphasise the researcher's independence from the unit of analysis, post-positivists argue that theories, hypotheses, contextual factors, and the researcher's perspectives can exert influence on the observed phenomena (Bergman, 2016). Post-positivists acknowledge the potential effects of prejudices to achieve objectivity. For instance, the specific objectives of the current study include examining the interdependence between commodities and SSA equities, assessing the level of risk and return transmission among the sample commodity, currency, and equity markets, and evaluating the causal influence of commodities and currencies on the sample equities. In line with this, and owing to

the post-positivist theoretical perspective, the researcher can carry out the study using several methods depending on the study's objectives while also inferring logical reasoning in analysing and interpreting the results of the study, a trait lacking in the pure positivist approach (Panhwar, Ansari, & Shah, 2017). Nevertheless, the use of the post-positivist approach also decreases the researcher's and participant's prejudices and assumptions by utilising a variety of research approaches (Panhwar et al., 2017).

Research Approach

To achieve its goals, the study used a quantitative research approach. Quantitative research targets to collect statistical data and generalise it across groups or to elucidate an explicit occurrence (Zikmund et al., 2012). The main objective of quantitative research is to discover the link between variables while also discerning the causal relationships that exist among them. Quantitative research is concerned with statistics, reasoning, and an objective viewpoint as well as quantifiable and dynamic data, precise and convergent rather than divergent thinking (Zikmund et al., 2012). Given the aim of expanding the understanding of volatility transmission and the interdependent structure among commodities, exchange rates, and SSA stocks, as well as investigating the impact of commodity and exchange rate volatility on equities, the employment of the quantitative methodology is deemed ideal for this study.

Source of Data Collection

The key variable used in this study includes commodity prices (agricultural and industrial metals), exchange rates and stock returns of selected SSA countries.

Data on commodity and equities are obtained from the Bloomberg Financial database and EquityRT, respectively. Data on exchange rates was acquired from the Trading Economics website as well as the central banks of the chosen SSA nations. The data encompassed eleven (11) years, commencing in January 2012 and concluding in December 2022, daily. The availability of data and the need to account for changes in market conditions drove the selection of the sample period. To improve the effectiveness of the analysis, the response and predictor variables' data sets will be fastened. Furthermore, logarithmic returns are preferred for return estimation in this study for both theoretical and empirical reasons.

Measurement and Definition of Variables

This study solely incorporates response variables (SSA equities) and predictor variables (agricultural commodities, industrial metals, and exchange rates). The selection of equities (BSE, GSE, NSE, NASE, and JSE) is underpinned by the designation of chosen currencies (Ghanaian Cedi, Kenyan Shilling, Namibian Dollar, Botswanan Pula, and South African Rand) as "high-pressure," as delineated by the IMF (2023). The predictor factors comprise the dollar-rated exchange rates of the selected SSA economies in addition to agricultural commodities (cocoa, coffee, corn, and cotton) and metallic alloys (zinc, copper, aluminium, and nickel). Furthermore, the examination delves into the level of reliance these nations and their corresponding equities place on the sampled commodities, with particular attention to industrial metals amidst recent market downturns. Additionally, in light of the food commodity price upsurge in 2022 amid political polarisation, we also consider pivotal agricultural commodities

witnessing price hikes, particularly those bolstering the revenues of the examined countries. Notably, South Africa (63%), Ghana (19%), and Kenya (20%) stand as the primary exporters of corn, cocoa, and coffee, respectively, within SSA.

Commodity returns

Commodities are basic goods that can be bartered for other goods of a comparable or different type. They are recurrently utilised as raw materials in the industrial fabrication of other products and services. They may also include metallic alloys, both treasured and industrial and agricultural products, and other necessities. Given the reliance of the selected economies on diverse commodities, we selected among others the commodities which contributes immensely towards their export revenues as highlighted above. In essence, we proxied SSA commodities with the prices of agricultural commodities (cocoa, coffee, corn and cotton) and metals (aluminium, copper, nickel, and zinc). Given the unique properties of return series above incessant commodity price, the current study utilised the former for all the selected commodities. The logarithmic returns were computed as $\delta_t = ln(\varphi_t - l\varphi_{t-1})$ where, $ln\varphi_t$, and $ln\varphi_{t-1}$ respectively depicts the present and previous commodity prices while δ_t represent the growth (returns) at time t.

Exchange rate returns

Exchange rate denotes the valuation at which the monetary unit of a particular nation is exchanged in return for the currency of an alternate nation. Fluctuations in their value have a cascading consequence on the implementation of policies, economic decisions, and international trade flows. We proxied the daily American dollar-domestic currency exchange as our measure of standard exchange rates given the relevance of the dollar on the global market and the reliance of the

majority of these economies on the foreign currency. Moreover, due to the insignificance of the majority of SSA currencies relative to the dollar, we estimated the return on currency fluctuations using normal instead of logarithmic differencing. The exchange return series for all the selected economies is computed as $\delta_t = ln(\varphi_t - l\varphi_{t-1})$ where, $ln\varphi_t$, and $ln\varphi_{t-1}$ respectively depicts the present and previous exchange rates while δ_t represent the growth (returns) at time t.

Equity returns

The equity market serves as meeting points for buyers and sellers of stock in public corporations. In Africa, there are twenty-nine (29) exchanges, which correspond to the capital markets of 38 countries with twenty-four (24) found in SSA. This study employs five (5) composite indices from the overall SSA equity market. There are diverse modes of assessing the performance of the equity market, with the most notable being industry- and market-wide-level evaluation. The composite (market-wide) index is the best parameter for general assessment given that it represents the average performance of all industries on the exchange and a significant fraction of the country's level of productivity.

According to the CFARI (2021), the respective equity markets of the sampled SSA economies (Botswana, Ghana, Kenya, Namibia, and South Africa) have each contributed an average of 217.4%, 19.35%, 23.48%, 953%, and 270% of their countries' gross domestic product between 2015 and 2020. This exemplifies that the effectiveness of the equity market is directly analogous to that of the entire economy (Ogotseng, 2017). We proxy the logarithmic transformation of the various indices as returns series for all the selected economies, and it is computed as $\delta_t =$

$ln(\varphi_t - l\varphi_{t-1})$ where, $ln\varphi_t$, and $ln\varphi_{t-1}$ respectively depicts the present and previous equity prices while δ_t represent its growth (returns) at time t.

Data Processing Tool and Analytical Technique

Hall and Asteriou (2016) noted that an initial analysis is essential to obtain a comprehensive understanding of the evidence before employing statistical and economic methodologies. This encompasses methodologies for data visualisation and examination, including the utilisation of diverse graph typologies and summary statistics. In accordance with the above assertions, graphs serve as indispensable instruments for comprehending the broader perspective, as they impart copious information pertaining to the series and simplify the identification of anomalies or structural shifts, surpassing the arduous endeavour of scrutinising tabulated data. Line graphs and tables were the principal graphical and descriptive instruments employed in this study. The R statistical tool version 4.2 was the main analytical tool employed in this study for all relevant computations, including preliminary analysis. The tool was also utilised to evaluate diverse econometric requirements, which include testing for the stationarity and normality of the series, assessing the measures for extremity, asymmetry, tailedness, and serial correlation, along with their associated probability thresholds.

To ensure constant variance in the data, the logarithmic values of each series were computed prior to normalising the data. Kaufman (2013) asserted that logarithmic transformations commonly help in rescaling the data to make the variance more constant, addressing the statistical paradox of heteroscedasticity, and speeding up the convergence of positively skewed distributions to a normal

distribution. According to Hall and Asteriou (2016), when converted models become linear in the parameters, the regression model can be projected with ease. The first-order difference is represented by $\Delta Y_t = Y_t - Y_{t-1}$ to achieve stationarity of the series through appropriate transformations (Hall & Asteriou, 2016; Kaufman, 2013). Where Y_t is the observed value of variable Y at time t, and the series of data spans across consecutive period $t = 1$.

Stationarity test

The attainment of stationarity, which is evaluated through the unit root test, is an indispensable preliminary procedure in the examination of any time series within the realm of financial econometrics (Kočenda & Černý, 2015). The application of unit root analysis allows for determining whether trended data should be subjected to first-differencing or regressed upon deterministic temporal functions in order to achieve stationarity. The identification of stationarity or integration of a series was implemented through the utilisation of the Phillips-Perron (PP) and the augmented version of the Dickey-Fuller (ADF) tests. In the context of the ADF, the repudiation of the null hypothesis signifies the presence of stationarity. The ADF test is exclusively employed in cases involving constants as well as constants combined with trends. Nevertheless, the ADF test has the flaw of being unable to distinguish between unit roots and near-unit time series. In other words, a time series containing a structural change will be valued as non-stationary by the ADF test. The PP unit test (Phillips & Perron, 1988) could be adequate to address the problems with the ADF test. In contrast to the ADF test, the PP offers notable advantage including its resilience against commonly occurring forms of

heteroskedasticity within the error terms. The existence of a unit root pertains to the null hypothesis, as opposed to the alternative hypothesis that there is none.

Normality test

According to Alfelt, Bodnar, and Tyrcha (2020), a well-fitting model should exhibit standardised residuals with independent and identical distributions. Therefore, it is crucial to employ normality tests to evaluate the veracity of the fitted model. According to Cain, Zhang, and Yuan (2017), evaluating normality entails analysing the Jarque-Bera (JB) test, which quantifies the skewness and kurtosis of the data series. The JB test was employed in the prevailing study to evaluate the regularity of distribution within the error term (Cain et al., 2012). If the p-value corresponding to the JB statistics is below the predefined significance level, the hypothesis suggesting symmetry in the distribution will be refuted.

Autocorrelation test

The lack of autocorrelation in series is a key fundamental assumptions of regression analysis. Serial correlation, according to Kaufman (2013), happens when errors from various eras are correlated. This means that each time series point has past and present values that are not independent. The study utilises the Ljung-Box (LBQ) test to assess the residuals for first-order serial correlation. The LBQ, other than evaluating randomness at each individual lag, assesses randomness overall, depending on the number of lags. According to Entezami (2021), the LBQ test is preferred over the Durbin-Watson test because it takes lagged dependent variables and higher levels of serial correlation into consideration and not limited with sample size. The alternative and null avowals associated with the LBQ test,

respectively, posit the dependence and independence of the residuals' distribution. According to the decision rule, if the p-value derived from the F-statistics is lower than the predetermined significance level, the assertion of independence must be rejected; otherwise, it should be retained. Given that this study employed daily data for each of the variables over a ten-year period, coupled with the key pertinence of the LBQ algorithm, its adoption became imperative in the current study.

Econometric Model Specification

The econometric models, such as the multivariate wavelet, the BK-18 connectedness and spillover analysis and the non-parametric causality test of Diks and Panchenko (2006) was conducted after addressing the initial statistical and econometric constraints. This study examined the existence of volatility transmissions and interdependence structures among commodities, currency rates, and equities in commodity-dependent SSA nations using historical time-series data.

Wavelet multiple correlation and cross-correlation framework

The study employed the wavelet multivariate model to evaluate the interdependence structure among the sample equity and commodity markets in a systemic way. By determining the magnitude of the joint motion between a series of multivariate variables, the WMC enables one to delineate between a short-, intermediate-, and enduring-term relationship while the WMCC provides a mechanism for identifying a potential set leader who might influence the variables that affect the remaining group members.

The initial stage in constructing the WMC and WMCC, as posited by Gençay, Selçuk, and Whitcher (2001) and subsequently reinforced by Tweneboah

(2019), involves the utilisation of the max overlay discrete wavelet transform (MODWT). Let $\mathfrak{X}_t = \mathfrak{x}_{1t}, \mathfrak{x}_{2t}, \ldots, \mathfrak{x}_{nt}$ be a multivariate stochastic progression and let $\omega_{jt} = \omega_{1jt}, \omega_{2jt}, \ldots, \omega_{njt}$ epitomise the ensuing gauge $\varkappa_j$ coefficients attained through the utilisation of the MODWT. Fernández-Macho (2012) delineates the WMC $\mathfrak{UX}(\varkappa_j)$ as a collection of multiscale coherences computed from $\mathfrak{X}t$ according to the subsequent procedure. At each wavelet scale, the squared coefficient of determination ($\hat{\mathrm{R}}^2$) is computed from the optimal linear combination of $\omega_{ijt}, i = 1, 2, \ldots, n$ variables that yields the maximum $\hat{\mathrm{R}}^2$. The relationship between a variable $\mathfrak{z}_i = \text{SSA equities}$ and a set of its predictors $\{\mathfrak{z}_k, k \neq i\} =$ (agricultural commodities and metals) can be represented by $\hat{\mathrm{R}}_i^2 = 1 - \rho^{-ii}$, where ρ^{ii} represents the ith diagonal element of the inverse of the complete correlation matrix P. Hence WMC is realised as in Eqn. (1), as

$$\mathfrak{UX}(\varkappa j) = \left(1 - \frac{1}{max\ diag P_j^{-1}}\right)^{\frac{1}{2}} \quad (1)$$

where Pj is a correlation matrix of ω_{jt}. In line with regression theory, and the tailored coefficients of z_i as $\hat{\mathfrak{z}}_t$ the WMC can be articulated as Eqn. (2),

$$\mathfrak{UX}(\varkappa j) = \frac{Corr(\omega_{ijt}, \hat{\omega}_{ijt}) Cov(\omega_{ijt}, \hat{\omega}_{ijt})}{\left(Var(\omega_{ijt}) Var(\hat{\omega}_{ijt})\right)^{\frac{1}{2}}} \quad (2)$$

where w_{ij} is selected to maximise $\mathfrak{UX}(\varkappa_j)\ and\ \hat{\omega}_{ijt}$ are the fitted values in the regression of on the remaining wavelet coefficients at scale, the fitted values ω_{ij} and $\varkappa_j$ are obtained. By incorporating a lag π between the observed and fitted values at each scale $\varkappa_j$ below, we can define the WMCC as below.

$$\text{Ʊ}\mathfrak{X},\pi(\varkappa_j) = Corr(\omega_{ijt}, \widehat{\omega}_{ijt+\pi}) = \frac{Cov(\omega_{ijt},\widehat{\omega}_{ijt+\pi})}{Var(\omega_{ijt})Var(\widehat{\omega}_{ijt+\pi})} \quad (3)$$

In the case of n = 2, the WMC and WMCC align with the conventional wavelet correlation and cross-correlation, thereby converging. To estimate the WMCC and WMC we implement the realisation of the multivariate process $\mathfrak{X}_t$ for $t = 1, 2, \ldots, T$ be $\mathfrak{X} = \{\mathfrak{X}_1, \mathfrak{X}_2, \ldots, \mathfrak{X}_T\}$. Relating a MODWT of order J to each of the univariate time series $\{\mathfrak{X}_{1i}, \ldots, \mathfrak{X}_{1T}\}$, for $i = 1, 2, \ldots, n$, the $J\ length - T$ vectors of coefficients of MODWT $\widetilde{\omega}_j = \{\widetilde{\omega}_{j1}, \widetilde{\omega}_{j1}, \ldots, \omega\widetilde{\omega}_{j,\ T-1}\}, for\ j = 0, 1, \ldots, J$ is obtained.

By referring to Equation (10), we can express a nonlinear function encompassing all $n(n-1)/2$ wavelet correlations at scale $\varkappa_j$, alongside a stable estimator of wavelet correlation obtained from the MODWT, as follows:

$$\widetilde{\text{Ʊ}}\mathfrak{X}(\varkappa_j) = \left(1 - \frac{1}{maxdiag\ \tilde{P}_j^{-1}}\right)^{\frac{1}{2}} = \frac{Corr(\widetilde{\omega}_{ijt},\widehat{\widetilde{\omega}}_{ijt})Cov(\widetilde{\omega}_{ijt},\widehat{\widetilde{\omega}}_{ijt})}{\left(Var(\widetilde{\omega}_{ijt})Var(\widehat{\widetilde{\omega}}_{ijt})\right)^{\frac{1}{2}}} \quad (4)$$

In this context, $\widetilde{\omega}_{ij}$ represents the regression that maximises $\hat{R}^2$ with the same set of regressors $\{\widetilde{\omega}_{kj}, k \neq i\}$. The variable w signifies the corresponding fitted values, while $L_j = (2^j - 1)(L - 1)$ denotes the number of wavelet coefficients influenced by the boundary conditions associated with a wavelet filter of length L and scale $\varkappa_j$. On the other hand, $\tilde{T} = T - L_j + 1$ represents the number of wavelet coefficients unaffected by the boundary conditions. Similarly, a reliable estimator of the WMCC can be computed as follows:

$$\widetilde{\text{Ʊ}}\mathfrak{X},\pi(\varkappa_j) = \frac{Corr(\widetilde{\omega}_{ijt},\ \widehat{\widetilde{\omega}}_{ijt+\pi})Cov(\widetilde{\omega}_{ijt},\ \widehat{\widetilde{\omega}}_{ijt+\pi})}{\left(Var(\widetilde{\omega}_{ijt})Var(\widehat{\widetilde{\omega}}_{ijt+\pi})\right)^{\frac{1}{2}}} \quad (5)$$

When determining the confidence interval (CI) for the WMC, Fernández-Macho (2012) employs a transformation denoted as arctan ϟ(r),. In order to simplify the process, the inverse hyperbolic tangent function, arctan ϟ(.), is utilised (Tweneboah, 2019). The confidence interval is derived under the assumption that the realisation of 𝔛 in the estimation of WMC and WMCC, as well as $\tilde{\mho}\ \mathfrak{X}(\varkappa_j)$ in equation (12), follows the same distribution, the $\tilde{\mathfrak{z}}_j \sim F\aleph(\mathfrak{z}_j, (T/2^j - 3)^{-1})$, where $\mathfrak{z}_j = arctan\ \text{ϟ}(\mho\mathfrak{X}(\varkappa_j)), \tilde{\mathfrak{z}}_j = arctan\ \text{ϟ}(\tilde{\mho}\ \mathfrak{X}(\varkappa_j))$, and $F\aleph$ symbolise the folded normal distribution. Consequently, an approximate confidence interval (1 - α) is denoted by the following expression:

$$CI(1-\acute{\alpha})(\mho\mathfrak{X}(\varkappa_j)) = tan\text{ϟ}\left[\tilde{\mathfrak{z}}_j - \frac{C_2}{\left(\frac{T}{2^j}-3\right)^{\frac{1}{2}}}; \tilde{\mathfrak{z}}_j + \frac{C_1}{\left(\frac{T}{2^j}-3\right)^{\frac{1}{2}}}\right] \quad (6)$$

where the $F\aleph$ critical values C_1, C_2 are: $\mho(C_1) + \mho(C_1 - 2\mathfrak{z}^0) = 1 - \alpha/2$ and $\mho(C_2) + \mho(C_1 - 2\mathfrak{z}^0) = 2 - \alpha/2$ with $\mho(.)$ represents the standard Gaussian probability distribution function, while $tanh(\mathfrak{z}^0) = \mho_{\mathfrak{x}}^0(\varkappa)$ denotes the value of a specific WMC formulated under a null hypothesis assuming the absence of correlation.

Baruník and Křehlík spillover and connectedness index

The study employs the BK-18 spillover connectedness index to model the transmission of volatility between the sample commodity, exchange rates, and equity markets, which was the study's second objective. The BK-18 model incorporates generalised forecast error variance decompositions (GFEVDs) as a means to quantify connectedness, inspired by the work of Diebold and Yilmaz (2012). It is constructed using the local covariance stationarity model of equations

and matrix of a VAR. The K-variate process is tinted as $\omega_t = (\omega_{1,t,\ldots,}\omega_{K,t})'$ at $t = 1, \ldots, T$ and further epitomise the $VAR_{(\rho)}$ as

$$\omega_t = \sum_{i=1}^{p} \Phi_i \omega_{t-1} + \varepsilon_t \tag{7}$$

In this context, the variables Φ_i and ε_t represent coefficient matrices, while $\prod$ denotes white noise with a covariance matrix that is likely non-diagonal. A regression analysis is conducted, as described in equation (7), where each variable in the system is regressed on its own ρ lags as well as the lags of all other variables. Consequently, the coefficient matrix Φ contains comprehensive information regarding the relationships between all variables within the system. Subject to convenience, we employ a $(K \times K)$ matrix $(\boldsymbol{I_K} - \emptyset_1 L - \cdots - \emptyset_p L^p)$ with identity $\boldsymbol{I_K}$. If the roots of the characteristic equation $|\theta(z)|$ are located beyond the boundaries of the unit circle, the VAR system exhibits a moving average component $MA\ (\infty)$

$$\omega_t = \psi(L)\varepsilon_t, \tag{8}$$

Considering $\psi(L)$ as an infinitely lagged polynomial, the GFEVD can be expressed as the contribution of the kth variable to the variance of the forecast error element j expressed as:

$$(\Omega_\text{ϟ})_{j,k} = \frac{\sigma_{kk}^{-1} \sum_{h=0}^{\text{ϟ}} (\,(\psi_h \prod)_{j,k})^2}{\sum_{h=0}^{\text{ϟ}} (\psi_h \prod_h{}')_{j,k}} \tag{9}$$

This is achievable due to the relationship between $h = 1, \ldots, \text{ϟ}$ and $\sigma_{kk} = (\prod_{kk})$. The measure of connectedness is contingent upon variance decompositions, which involve the transformation of ψ_h and represent the contributions of shocks

to the system. As the contributions within the row do not sum up to unity, the matrix $\Omega_{\text{ч}}$ is standardised in order to address this.

$$(\widetilde{\Omega}_{\text{ч}})_{\text{j,k}} = \frac{(\Omega_{\text{ч}})_{j,k}}{\sum_{k=1}^{\text{N}}(\Omega_{\text{ч}})_{j,k}} \tag{10}$$

The pairwise connectivity in equation (10) can be combined to determine a system's overall connectivity. This is the proportion of the variation in projections that is due to errors other than their own, according to Diebold and Yilmaz (2012). This is equivalent to the ratio of the total matrix product to the sum of the off-diagonal components as shown in eqn. (11).

$$\text{C}_{\text{ч}} = 100 * \frac{\sum_{j\neq k}(\widetilde{\Omega}_{\text{ч}})_{j,k}}{\sum \widetilde{\Omega}_{\text{ч}}} = 100 * \left(1 - \frac{\text{Tr}\{\widetilde{\Omega}_{\text{ч}}\}}{\sum \widetilde{\Omega}_{\text{ч}}}\right), \tag{11}$$

In this case, the operator Tr{ } denotes the tracing operation, and the denominator signifies the average value computed from all members within the matrix. Therefore, it becomes possible to evaluate bi-directional connectivity, encompassing the influence "to" and/or "from" market i towards all other markets denoted as k. Furthermore, the disparity between "to" and "from" spillovers is utilised to compute the "net" connectivity. Consequently, a market with a positive net spillover serves as a "net transmitter," while a market with a negative spillover function as a "net receiver" of shocks.

We present a spectral depiction of connectivity. By employing the Fourier transforms $\Psi_h$with $i = \sqrt{-1}$,, the coefficients of the frequency response function $\Psi(\text{e})^{-i\omega} = \sum_h e^{-i\omega}\Psi_h$ can be transformed, leading to the establishment of a spectral density $\omega_t$at a given frequency denoted as ω. This spectral density is obtained through the filtering of the series by means of an $MA(\infty)$ process.

$$S_{\omega(\omega)} = \sum_{h=-\infty}^{\infty} E(\mathfrak{G}'\mathfrak{G}_{t-h})e^{-\omega h} = \Psi\left(e^{-i\omega}\right)\prod\psi'\left(e^{+i\omega}\right) \quad (12)$$

In this context, $S_{\omega(\omega)}$ represents the power spectrum, providing a comprehensive depiction of the distribution of variance in Y_t across the frequency components denoted as ω. The spectrum of causation over $\omega \in (-\pi, \pi)$, as defined in equation (13), denotes the proportion of the ith variable that can be attributed to shocks originating from the kth variable at a specific frequency ω. Consequently,

$$(\mathcal{F}(\omega))_{j,k} = \frac{\sigma_{kk}^{-1}|\psi\left(e^{-i\omega}\right)\prod_{j,k}|^2}{\left(\psi(e^{-i\omega})\right)\prod\psi'(e^{+i\omega}))_{\mathrm{j,j}}}, \quad (13)$$

Consequently, it can be deduced that $(\mathcal{F}(\omega))_{\mathrm{j,k}}$ can be perceived as the causation within the frequency range of the denominator. In order to achieve a coherent decomposition of the GFEVD across frequencies, we assign a weight to $(\mathcal{F}(\omega))_{\mathrm{j,k}}$ based on the proportionate frequency share of the variance pertaining to the jth variable. This weight is defined as the weighting function.

$$\Gamma_j = \frac{(\psi\left(e^{-i\omega}\right)\prod\psi'\left(e^{+i\omega}\right))_{j,j}}{\frac{1}{2\pi}\int_{-\pi}^{\pi}(\psi(e^{-i\varkappa})\prod\psi'(e^{+i\varkappa}))_{j,j}d\varkappa} \quad (14)$$

Summating to real-valued numbers up to 2π and represents the index of the jth variable at a particular frequency. Connectivity must be measured across periods in practical financial applications. As a result, rather than measuring connectedness at single frequencies, it is more appropriate to do so across frequency bands. We take a formal representation of the frequency band $d, as\ d = (a, b): a, b \in (-\pi, \pi), a < b$, for which we define the GFEVDs as

$$(\Omega_d)_{j,k} = \frac{1}{2\pi}\int_a^b \Gamma_j(\omega)(\mathcal{F}(\omega))_{j,k}d\omega \quad (15)$$

Within the identical frequency band, d, it is possible to construct a scaled generalised variance decomposition.

$$(\widetilde{\Omega}_d)_{j,k} = {(\Omega_d)_{j,k}}\Big/{\sum_k(\Omega_\infty)_{j,k}}. \quad (16)$$

Subsequently, the within-frequency and frequency connectivity across d are represented by equations (17) and (18) respectively.

$$C_d^w = 100\left(1 - \frac{\mathrm{Tr}\{\widetilde{\Omega}_d\}}{\sum\widetilde{\Omega}_d}\right) \quad (17)$$

$$C_d^F = 100 * \left(\frac{\sum\widetilde{\Omega}_d}{\sum\widetilde{\Omega}_\infty} - \frac{\mathrm{Tr}\{\widetilde{\Omega}_d\}}{\sum\widetilde{\Omega}_\infty}\right) = C_d^w * \left(\frac{\sum\widetilde{\Omega}_d}{\sum\widetilde{\Omega}_\infty}\right) \quad (18)$$

It is imperative to acknowledge that C_d^w only indicates connectivity that takes place inside a specific frequency band and accounts for the series power on that frequency. As presented by Baruník and Křehlík (2018), C_d^F accomplishes the reverse and breaks down total connection into distinct components that add up to the initial connectedness metric. We used the frequency bands $\left(\pi + 0.0001, \frac{\pi}{4}, \frac{\pi}{16}, \frac{\pi}{64}, 0\right)$ which corresponds to short-term (intraweek), medium-term (week to a fortnight and to a month), and long-term (month to a quarter and beyond) and is in line with the existing literature (Bossman et al., 2022).

The BK-18 model, as delineated in equation 25, serves as a tool for scrutinising the concurrent level of risk connectedness among a spectrum of markets comprising sample equities (BSE, GSE, NSE, NASE, and JSE), agricultural commodities (cocoa, coffee, corn, and cotton), industrial metals

(aluminium, copper, nickel, and zinc), and exchange rates (BSP, GHS, KSH, NAD, and ZAR). It further highlights the potential for risk transmission across these markets over short, medium, and long-term time frames. To delve deeper into the mechanism of risk transmission, we employ both an integrated system (amalgamating all variables into a unified framework to unveil their responses to each other's fluctuations across diverse frequencies) and a sub-system (focusing on a country-specific level for both equity and exchange rate markets while keeping the commodity sample constant). The objective was to uncover the driving force behind commodity price fluctuations and their impact on both general equity and currency markets, as well as their country-specific manifestations.

Non-parametric causality test

The study employed the nonlinear causality test of Diks and Panchenko (2006) to examine the third objective, which emphasised the causal nexus between the sample exchange rates, commodity, and equity markets. The linear causality technique is utilised in the literature to examine the causal interactions between various financial assets. Notwithstanding its apparent value in locating causation, it suffers from a shortcoming in that it cannot incorporate a nonlinear causative relationship among the variables being probed (Diks & Panchenko, 2006; Ghosh & Chaudhuri, 2019). Ghosh and Chaudhuri (2019) went on to demonstrate that the sequential causality relationship has a multitude of drawbacks, such as its inability to compensate for structural breaks, destabilisation, and variability clustering, which all constitute inherent features of contemporary financial markets.

Multiple quasi-causation tests have been proposed in an attempt to mitigate these drawbacks, particularly Hiemstra and Jones (1994), which was found to distinguish itself since it best examined bivariate nonlinear causation between variables. The most apparent flaw in the preceding framework, which was subsequently adopted and scrutinised, was the over-rejection of the null hypothesis (Ghosh & Chaudhuri, 2019; Lundgren, Milicevic, Uddin, & Kang, 2018). To circumvent the aforementioned constraint posed by the Hiemstra and Jones model, Diks and Panchenko (2006) put forth a non-parametric adjacency variational causality test as an alternative solution. The nonlinear (non-parametric) causality test of Diks and Panchenko (DKP henceforth) takes the following pattern: Presume that $\mathcal{X}_t^{\lambda_\mathcal{X}} = (\mathcal{X}_{t-\lambda}\mathcal{X}+1, \ldots\ldots, \mathcal{X}_t)$ and $\mathcal{Y}_t^{\lambda_\mathcal{Y}} = (\mathcal{Y}_{t-\lambda}\,\mathcal{Y}+1, \ldots\ldots, \mathcal{Y}_t)$ are the adjournment vectors, where $\lambda\mathcal{X}, \lambda\mathcal{Y} \geq 1$. The null hypothesis that $\mathcal{X}_t^{\lambda\mathcal{X}}$ contains additional information about $\mathcal{Y}_{t+1}$is specified as:

$$\ddot{\mathcal{H}}_\vartheta = \mathcal{Y}_{t=1}\left|\left(\mathcal{X}_t^{\lambda\mathcal{X}}; \mathcal{Y}_t^{\lambda\mathcal{Y}}\right) \sim \mathcal{Y}_{t+1}\right|\mathcal{Y}_t^{\lambda\mathcal{Y}} \tag{19}$$

The null hypothesis tends to an invariant dispersion bound assertion of the $\lambda\mathcal{X} + \lambda\mathcal{Y} + 1$ dimensional vector,$\omega_t = (\mathcal{X}_t^{\lambda\mathcal{X}}, \mathcal{Y}_t^{\lambda\mathcal{X}}, \mathcal{Z}_t)$ where $\mathcal{Z}_t = \mathcal{Y}_{t+1}$. Flouting the horizon-induced index and assuming that $\lambda\mathcal{X} = \lambda\mathcal{Y} = 1$, the dispersion of $\mathcal{Z}$, with a consequent assertion that $(\mathcal{X}, \mathcal{Y}) = (\mathfrak{x}, \gamma)$, coincides with that of $\mathcal{Z}$, given $\mathcal{Y} = \gamma$. In other words, $\mathcal{X}$ and $\mathcal{Z}$ are separable and contingent on $\mathcal{Y} = \gamma$, for each static component of γ, so the shared likelihood density function $\mathcal{F}\mathcal{X}, \mathcal{Y}, \mathcal{Z}(\mathfrak{x}, \gamma, \mathfrak{z})$ and its marginals must mollify the following connexion:

$$\frac{\mathcal{F}\mathcal{X},\mathcal{Y},\mathcal{Z}(\mathfrak{x},\gamma,\mathfrak{z})}{\mathcal{F}_\mathcal{Y}(\gamma)} = \frac{\mathcal{F}_{\mathcal{X},\mathcal{Y}}(\mathfrak{x},\gamma)}{\mathcal{F}_\mathcal{Y}(\gamma)}\frac{\mathcal{F}_{\mathcal{X},\mathcal{Z}}(\gamma,\mathfrak{z})}{\mathcal{F}_\mathcal{Y}(\gamma)} \tag{20}$$

DKP further established that the regurgitated null premise infers:

$$\text{Ч} \equiv \mathfrak{E}[\mathcal{F}\text{Х}, \text{Y}, \text{Z}(\text{Х}, \text{Y}, \text{Z})\mathcal{F}\text{Y}(\text{Y}) - \mathcal{F}\text{Х}, \text{Y}(\text{Х}, \text{Y})\mathcal{F}\text{Y}, \text{Z}(\text{Y}, \text{Z})] = 0 \qquad (21)$$

where $\hat{\mathcal{F}}_{\text{ѡ}}(\text{ѡ}_i)$ is a local compactness estimator of an $\text{ԁѡ} - \text{variate}$ arbitrary trajectory ѡ at ѡ_i, distinct $\hat{\mathcal{F}}_{\text{ѡ}}(\text{ѡ}_i) = (2_{\varepsilon n})^{-\text{ԁ}}\text{ѡ}\ (n-1)^1 \sum_{jj} \neq {}_i\ \ddot{\text{I}}_{ij}^{\text{ѡ}}$, where, $\ddot{\text{I}}_{ij}^{\text{ѡ}} = \ddot{\text{I}}\left(\left|\left|\text{ѡ}_i - \ \text{ѡ}_j\right|\right| < \varepsilon_{\text{ѡ}n}\right)$, $\ddot{\text{I}}(.)$ the pointer function and $\varepsilon_{\text{ѡ}n}$ the spectrum factors, are contingent on the threshold length *n*. The statistical test which stands a weighted subset of Ч in (28), can be expressed simply as follows:

$$\int_n(\varepsilon_{\text{ѡ}n}) = \frac{n-1}{n(n-2)} \cdot \sum_i \begin{matrix}(\hat{\mathcal{F}}_{\text{Х,Z,Y}}(\text{Х}_i, \text{Z}_i, \text{Y}_i)\hat{\mathcal{F}}_{\text{Y}}(\text{Y}_i) \\ -\hat{\mathcal{F}}_{\text{Х,Y}}(\text{Х}_i, \text{Y}_i)\hat{\mathcal{F}}_{\text{Х,Y}}(\text{Y}_i, \text{Z}_i))\end{matrix} \qquad (22)$$

where $\int_n$ consists of a weighted average of local contributions $(\hat{\mathcal{F}}_{\text{Х,Z,Y}}(\text{Х}_i, \text{Z}_i, \text{Y}_i)\hat{\mathcal{F}}_{\text{Y}}(\text{Y}_i) - \hat{\mathcal{F}}_{\text{Х,Y}}(\text{Х}_i, \text{Y}_i)\hat{\mathcal{F}}_{\text{Х,Y}}(\text{Y}_i, \text{Z}_i))$, under the null hypothesis, appears to possess a likelihood of zero. DKP offers additional evidence to back up its contention. It is of the form that if $\varepsilon_{\text{ѡ}n} = \mathfrak{C}n^{-\text{ϐ}}(\mathfrak{C} > 0, \frac{1}{4} < \text{ϐ} < \frac{1}{3}$ for unity lag, then the test statistic in (29) satisfies the criterion given in (30):

$$\sqrt{n} = \frac{(\int_n(\varepsilon_{\text{ѡ}n}) - \text{Ч})}{\varsigma_n} \xrightarrow{\delta} N(0,1) \qquad (23)$$

Where $\xrightarrow{\delta}$ denotes convergence in distribution and ς_n is an estimator of the asymptotic variance of $\int_{\text{n}}(\cdot)$. The above stated null hypothesis in contrast with the alternative is stated as the absence of non-linear causal bearing among the target variables. In consequence, rejection or otherwise of the null hypothesis is contingent on the probability value (p-value). If the p-values of the test result is less than the significance level (ą = 0.01, 0.05, or 0.10), we reject the null hypothesis and conclude that there is a causal relationship between the studied variables. Otherwise, we fail to reject and dispute the existence of causal relationship.

Considering the diverse range of interactions observed among the variables under scrutiny, the DKP non-parametric causality test is utilised to evaluate the causal linkage that exists among them.

In spite of the predominance of the DKP causation test over the linear and parametric approaches, it is pertinent to grasp its constraints pertaining to bandwidth-based causality. The DKP test evaluates causation only in the constant-time realm, ignoring the shifting dynamics of market participants across time horizons. Pursuant to the previously discussed assertions and the assumptions of the contagion theory pertaining to disparities in investor conduct across disparate perspectives, we implement the variational mode of putrefaction (VMD) structure to capture the temporal and recurrence causal link between these variables.

Variational mode decomposition

The VMD algorithm was formulated by Dragomiretskiy and Zosso (2013) as a mechanism to optimise the fragmentation of a realistically valued signal being processed into an array of swap signals (modes) exhibiting particular rarity traits while concurrently reiterating the input. It further permits the non-recursive extraction of modes and concurrently estimates corresponding modes that would appropriately balance the errors between them (Isham, Leong, Lim, & Ahmad, 2018). The VMD approach as asserted by Isham et al. (2018) relies on three fundamental concepts, namely analytic signal, Wiener filtering, and Hilbert transform, in conjunction with frequency mixing and heterodyne demodulation.

According to Dragomiretskiy and Zosso (2013), the $\mathfrak{K}_{\mathfrak{s}h}$ mode $\mathfrak{U}_{\mathfrak{K}}(\mathfrak{s})$ is expressed as:

$$\mathfrak{A}_{\mathfrak{R}}(\mathfrak{s}) = \mathfrak{W}_{\mathfrak{R}}(\mathfrak{s})cos\big(\varphi_{\mathfrak{R}}(\mathfrak{s})\big), \tag{24}$$

Where $\varphi_{\mathfrak{R}}(\mathfrak{s})$ and $\mathfrak{W}_{\mathfrak{R}}(\mathfrak{s})$ and its constituent derivative $\mathfrak{Cp}_{\mathfrak{R}} = {}'\varphi_{\mathfrak{R}}$, respectively represent the instantaneous phase, amplitude, and scale. The VMD incorporates the Hilbert transition to formulate a coherent waveform and compute the proactive bandwidth spectrum for each distinct mode $\mathfrak{A}_{\mathfrak{R}}(\mathfrak{s})$. Using the Fourier spectrum transform's shifting property, the spectrum mode is further evolved towards the baseband. Concurrently, the bandwidth formulated by Gaussian fluidity Й^1. Practical optimisation involves minimising the entirety of all modulation function harmonic dimensions to a modest magnitude as:

$$\{\mathfrak{A}_{\mathfrak{R}}\},\{\mathfrak{Cp}_{\mathfrak{R}}\}\left\{\sum_{\mathfrak{R}=1}^{\mathfrak{R}}\left\|\vartheta_{\mathfrak{s}}\left[\left(\delta(\mathfrak{s})+\frac{\mathfrak{Ч}}{\pi\mathfrak{s}}\right)*\mathfrak{A}_{\mathfrak{R}}(\mathfrak{s})\right]\varrho^{-\mathfrak{Ч}\mathfrak{Cp}_{\mathfrak{R}}\mathfrak{s}}\right\|_2^2\right\},$$

$$\text{s.ъ.}\sum_{\mathfrak{R}=1}^{\mathfrak{R}}\mathfrak{A}_{\mathfrak{R}} = \mathcal{F}, \tag{25}$$

Where $\{\mathfrak{A}_{\mathfrak{R}}\}$ and $\{\mathfrak{Cp}_{\mathfrak{R}}\}$ symbolise the spectrum of the mode system and the reminiscent concentrated resonance ensemble, respectively, and $\mathfrak{R}$ reflects the mode detection. The Lagrangian multiplier and an exponential penal factor are incorporated to modify the initial restraint optimisation quandary into a seemingly unbridled situation as follows:

$$\mathcal{L}(\{\mathfrak{A}_{\mathfrak{R}}\},\{\mathfrak{Cp}_{\mathfrak{R}}\},\mathfrak{Я})$$

$$= \tilde{\alpha}\sum_{\mathfrak{R}=1}^{\mathfrak{R}}\left\|\vartheta_{\mathfrak{s}}\left[\left(\delta(\mathfrak{s})+\frac{\mathfrak{Ч}}{\pi\mathfrak{s}}\right)*\mathfrak{A}_{\mathfrak{R}}(\mathfrak{s})\right]\varrho^{-\mathfrak{Ч}\mathfrak{Cp}_{\mathfrak{R}}\mathfrak{s}}\right\|_2^2$$

$$+\left\|\mathcal{F}(\mathfrak{s})-\sum_{\mathfrak{R}=1}^{\mathfrak{R}}\mathfrak{A}_{\mathfrak{R}}(\mathfrak{s})\right\|_2^2+\mathfrak{Я}(\mathfrak{s}),\mathcal{F}(\mathfrak{s})\sum_{\mathfrak{R}=1}^{\mathfrak{R}}\mathfrak{A}_{\mathfrak{R}}(\mathfrak{s}), \tag{26}$$

Where $\tilde{\alpha}$ and ג reflect the corresponding penalty coefficient and the Lagrangian multiplier, respectively. VMD implements the aberrant orientation algorithm of modifiers to recursively compute the preceding expression. The initially generated signal is subsequently disintegrated into $\Re$ -IMF segments. We employ this model subject to its relevance in combating tailed variations and divulging disparities, its capacity to navigate with non-stationary and irregular series, and its potential to control signal errors by segregating the initial series into multiscale segments and establishing distinct integrating components, as highlighted by Dragomiretskiy and Zosso (2013) and maintained by studies (Woode et al., 2024a; Isham et al., 2018). Against the setting of this inquiry, VMFs relate to short, intermediate, and long-term timescales for investment horizons.

Reliability and Validity of Measurement

The study's methodology and data collection plan are repeatable, and its analysis will be based on data that is available to the general public. Among the trusted sources to be used in the data collection tool are EquityRT, Trading Economics, the Bloomberg Financial Database, Yahoo Finance, and the central banks of the various SSA countries. Data screening on the dataset was conducted with a priority on the stock prices of the selected commodity-dependent SSA countries, taking into account various vacations and other factors. Tests including those of stationarity, heteroscedasticity, and serial correlation on the variables were conducted at 5% significance level. The JB test was employed to assess the datasets' uniformity. These diagnostic tests were employed as a means to determine whether the genuine variance process differs those estimated since this is a possibility.

Ethical Considerations

The ethical aspect of sourcing verifiable facts and information is accorded due significance. Each individual data point employed in the present study was duly authorised for extraction from the requisite sources. Additionally, the avoidance of plagiarism was taken into account, ensuring that no intentional replication of another author's written work occurred without proper attribution. To facilitate this, reference software was utilised to diligently track and manage the references utilised. To ensure that inaccurate data was not included in the current inquiry, data from outside sources that had not undergone peer review was recognised and its accuracy confirmed. Furthermore, to enable proper analysis, statistical data were obtained from reliable sources. To ensure the objectivity and transparency of this study, the data used for it will be kept secured for three to five years.

Chapter Summary

The chapter discussed the procedure involved in conducting this by explaining the methodological procedure adopted. The chapter discussed explanatory and quantitative research approaches as applicable. Furthermore, the theoretical time series model was specified, from which empirical models were derived. Commodities, currencies, and equities were the main variables employed by the study, with emphasis given to commodity-dependent SSA countries. Moreover, this study used a multivariate wavelet model, Diks and Panchenko non-parametric causality model, and the Baruník and Křehlík (2018) connectedness model in analysing the study variables.

CHAPTER FOUR

RESULT AND DISCUSSIONS

Introduction

This chapter discusses the results obtained from the major objectives of the study. The first and second objectives were to respectively examine the interdependence structure between the sampled commodities and SSA stock returns and assess the extent of volatility transmissions from commodity and foreign currency markets into the equity markets of commodity-dependent SSA countries, while the third objective was to assess the impact of commodity and exchange rate volatility on the equities of commodity-dependent SSA countries.

Furthermore, in the context of this study, it is imperative to recognise that, to prevent any potential ambiguity in terminology, the preceding analysis will further truncate the names of the sampled equity and currency markets while concurrently employing proper designations to represent the respective countries in their entirety. In this vein, NSE, NASE, BSE, JSE, and GSE will respectively represent the equity markets of Kenya, Namibia, Botswana, South Africa, and Ghana. Conversely, the sequence of currency abbreviations will be as follows: Botswanan Pula (BSP), Ghanaian Cedi (GHS), Kenyan Shilling (KSH), Namibian Dollar (NAD), and South African Rand (ZAR).

Trend Analysis Between Commodity, Exchange Rates and Stock Market

The study in the first place assessed the trend between commodities, exchange rates, and stock returns to deepen understanding of the study variables. Figures 5, 6, 7, and 8 portray the movements of sampled markets.

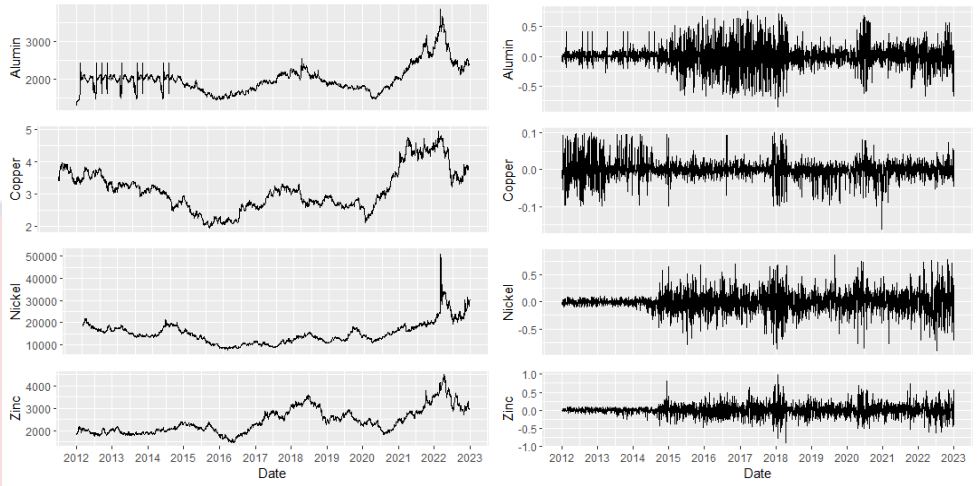

Figure 5. Time series of industrial metal price and returns

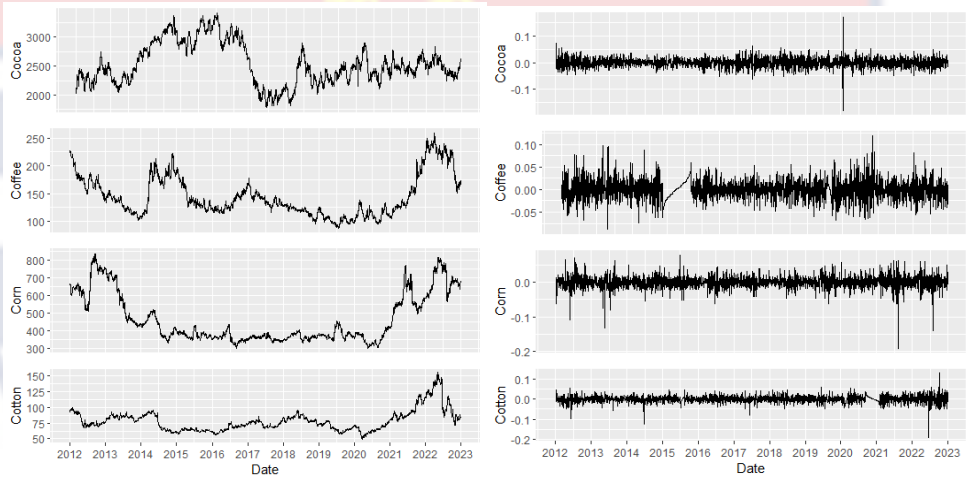

Figure 6. Time series of agricultural commodity price and returns series

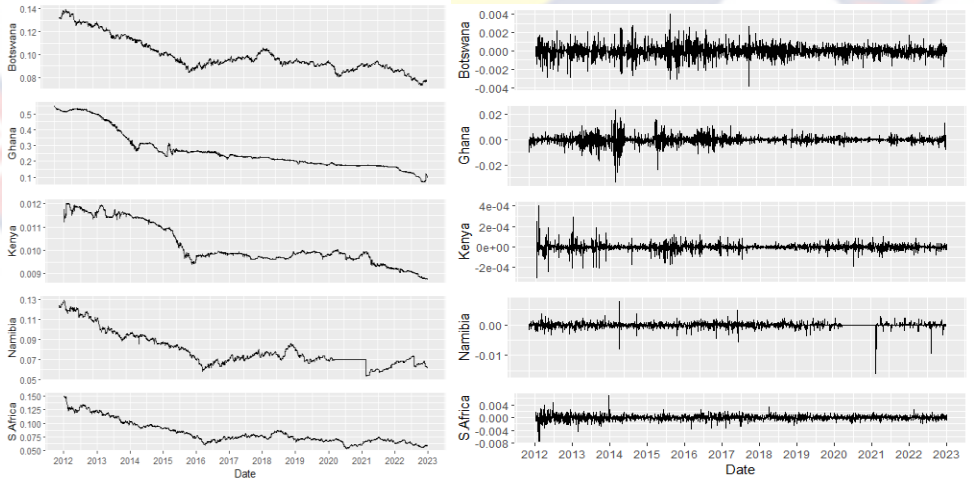

Figure 7. Time series of SSA exchange rates and returns

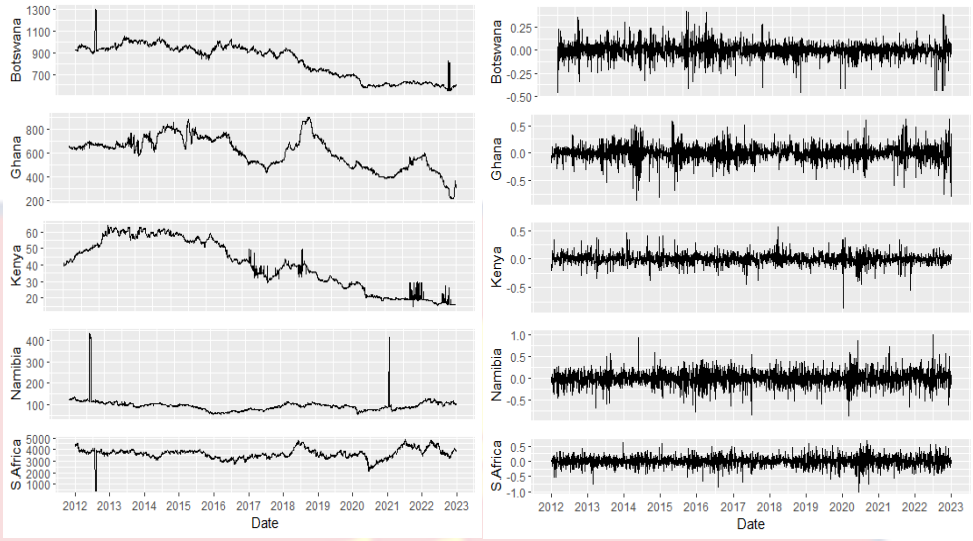

Figure 8. Time series of SSA stock price and returns series
Source: Woode (2023)

Figure 5 represent the price and returns series of industrial metal market. The pictorial view reflects that industrial metal prices have not been stable, with both upward and downward spirals. The earlier period was further marred by low prices. Figure 6 depicts the time-varying prices and log returns of agricultural commodity prices. Also, the fact that the fluctuations in the market for agricultural commodities were greater than those in the markets for industrial metals, foreign exchange rates, and SSA stocks during the sampling period demonstrates the speculative or volatile nature of agricultural commodities. Prior studies (Boako & Alagidede, 2016; Ogbulu, 2018; Oyelami & Yinusa, 2019; Rossi, 2012) all came to the same conclusion that the rate of return on stocks is often less volatile than that of commodities. Extant literature (Katusiime, 2018; Mollick & Sakaki, 2019) further revealed that this was the case even in the exchange rate market. This may partly be elucidated by the understanding that the prices of commodities, specifically those of aluminium and nickel, express the current equilibrium between supply and demand, which is subject to daily fluctuations.

The currency and equity series for the chosen SSA nations are shown in Figures 7 and 8, respectively. The increased depreciation of these currencies, which has been recorded in the literature, may be supported by a downward spiral in the exchange rate market over the sampled period. The stock return, however, exhibited both an upward and a downward spiral, with the JSE being the least stable among the selected countries and GSE remaining the most stable. Most of the SSA frontier and emerging economies experienced a recession after the period characterised as the aftermath of the worldwide pecuniary predicament abated in 2012 and 2013. The prices of stocks and metals became stable after these periods.

Furthermore, it can also be observed from the price series that in the early part of 2022, the series for industrial metal markets trended downward after an upward spike. On the other hand, the price series for stocks trends upward after a downward spike in the same period, while the return series for all the selected variables demonstrated stationarity over the sampled period. Regarding the realisation that the study is additionally designed to evaluate the bandwidth-dependent causative interaction among the variables under discussion, we additionally present a visualisation of the fragmented series in the appendix (Figures 9–11). The merely slight variations among the aforementioned visualisations compared to those expressed above are due to stationarity devoid of noise, particularly in short-term scenarios, which frequently surface in studies.

Preliminary Analysis

This study examines the interdependence structure and volatility transmission between commodity, currency, and equity markets in a sample of

commodity-dependent SSA countries. This section reveals the preliminary analysis of the sampled market. Table 2 summarises the results of the descriptive statistics.

Table 2: Results of Descriptive Statistics

Variables	Mean	SD	Skewness	Kurtosis	Jarque-Bera
Industrial metals					
Aluminium	0.0001	0.2023	-0.0798	2.1123	512.03***
Copper	-0.0001	0.0260	-0.0677	4.2429	2054.30***
Nickel	0.0001	0.1879	-0.0683	2.9662	1005.50***
Zinc	0.0001	0.1606	0.1835	3.1212	1126.20***
Agricultural commodities					
Cocoa	-0.0001	0.1707	0.2213	2.4071	683.33***
Coffee	-0.0001	0.0207	0.3540	1.8763	458.89***
Corn	-0.0001	0.1609	-0.1060	2.2107	562.74***
Cotton	0.0000	0.0161	-0.7656	11.802	16134***
Exchange rates					
Botswana Pula	0.0000	0.0006	-0.0888	4.5491	2362.40***
Ghanaian Cedi	-0.0002	0.0030	-0.6542	16.716	32021***
Kenyan Shilling	0.0000	0.0000	0.1276	28.584	93065***
Namibian Dollar	0.0000	0.0008	-4.5876	96.095	1061176***
South African Rand	0.0000	0.0007	-0.5031	11.998	16512***
Sub-Saharan African stocks					
BSE	0.0000	0.0790	-0.4336	5.7080	3798.60***
GSE	0.0000	0.1376	-0.3186	4.3154	2169.10***
NSE	-0.0001	0.0867	-0.3499	7.8147	7013.9***
NASE	0.0001	0.1659	-0.1065	2.7826	890.56***
JSE	0.0003	0.1584	-0.2707	3.3532	665.12***

Notes: Jarque-Bera denotes the normality test, which is χ^2distributed asymptotically. *** denotes significance at the 1% level.

Source: Woode (2023)

From Table 2, the majority of selected metallic commodities, exchange rates, and SSA equities exhibited positive middling quotidian proceeds except for metals (copper), agricultural (cocoa, coffee, and corn), GHS, and NSE, which had negative middling proceeds. The highest (lowest) and middling proceeds were recorded by the JSE (GHS) markets, respectively. But astoundingly, the highest standard deviation was recorded in the metal (aluminium and nickel) market, followed by the agricultural (cocoa) market, despite a comparatively lower return than those of the JSE.

The KSH, on the other hand, recorded both the lowest mean and volatility among the selected variables. The risk metrics for all sampled variables is higher than their mean, indicating a higher level of risk in these markets except for the KSH, which exhibited a lack of volatility and return. Most of the variables exhibit skewness to the left, with a few others being right-skewed, showing an asymmetric distribution. The skewness values reveal closer asymmetry, while the kurtosis values show leptokurtic behaviour in the markets. The Jarque-Bera test also offers definite evidence that the distribution of the sampled markets is not normally distributed given the statistically significant the p-values.

Unit Root Test

This section reviews the classical univariate unit root tests, which stands as a requirement for financial time series analysis. A unit root implies the inclusion of a stochastic trend component in the series, making it unpredictable and challenging to model accurately. Its presence signifies a deviation from stationarity, necessitating transformations to the dataset. The absence of a unit root signals stationarity, indicating predictable behaviour over time. Kočenda and Černý (2015) emphasise the relevance of conducting unit root tests, asserting that non-stationarity can yield spurious results and erroneous conclusions, whereas its absence facilitates robust hypothesis testing and accurate parameter estimation in econometric models. The results of the unit root test (ADF and PP) with and without trends for both the original and decomposed series are shown in Appendix Table 13. It was possible to determine the ideal latency for the ADF by using the Akaike Information Criterion (AIC). The bandwidth for the PP was chosen to be the Bartlett kernel. The

full sample approximations highlight that both the ADF and PP tests reject the unit root null hypothesis for all the selected variables at a 1% significance level after the first logarithmic differencing and, in essence, confirm the series as stationary.

Autocorrelation Effects

This section highlights the results of the autocorrelation (LBQ) among the datasets. The test is crucial in time series analysis as it helps detect whether there is a systematic pattern of dependence among observations, which can impact the validity of statistical analyses and model predictions. Such identification enhances statistical inferences and forecasts that are reliable and accurate, as well as identifying any patterns or dependencies in the data that violate the assumption of independence in a quest to employ a model that suits such limitations. This violation, if not addressed, can lead to biassed parameter estimates, inflated standard errors, and incorrect inferences in statistical analyses. Appendix Table 14, highlight the results of the LBQ test with the null premise of no serial correlation for both the original and decomposed series.

From the Appendix Table 14, it was revealed that, except for cocoa, cotton, and NAD, the results demonstrate that autocorrelation is present, which confirms the rejection of the null hypothesis. The presence of autocorrelation in the return series and the possible variation motivate the need for adopting a model with analogous tenacity and capacity. This stimulates the utilisation of the multivariate wavelet and the BK-18 spillover and connectedness index in modelling the interdependencies and volatility transmission among the chosen variables as well as the persistence of this precariousness. The bearing of the aforesaid model in

apprehending systemic connectedness, precariousness, shock transmissions, and the contagion effect within markets and over-frequencies has been recognised in studies (Bossman et al., 2022; Owusu Junior et al., 2020; Woode et al., 2024b).

Interdependence between Commodities and Sub-Saharan African Stock

This section emphasised the first objective of the study, which is to assess the interdependence framework between commodities and equities in commodity-dependent SSA countries. These domains of interest were evaluated utilising the WMC and WMCC methodologies. We combined the sampled commodities and stocks into a single pool, analysed the interdependence structure between them, and further analysed the pairwise interdependencies. The objective is to reveal how SSA stocks perform in an investment portfolio with commodities and to assess the diversification prospect of these assets over a stint. Table 3 provides a comprehensive summary of the coefficient interdependencies derived from the graphs pertaining to the WMC and WMCC, as further illustrated in Figures 12 and 13 included in the appendix B.

Table 3: Interdependencies Between Commodities and Stocks

Frequency	WMC	WMCC	Leader (Lag)	Coefficient
Intraday	0.4483	0.1580	Cocoa	0
Daily	0.2168	0.2904	Copper	3
Intraweekly	0.1582	0.3375	Corn	4
Weekly	0.4301	0.4278	Corn	-27
Fortnightly	0.5536	0.5579	Aluminium	1
Monthly	0.6343	0.6883	Corn	-2
Quarterly	0.8146	0.8641	Corn	-3

Note: WMC and WMCC are equivalent to wavelet multiple correlation and cross-correlation respectively

Source: Woode (2023)

The WMC and WMCC results as summarised in Table 3 are epitomised visually, with the WMC visual evidence further precisely signifying the magnitude of the interdependencies. The WMCC plots also show the time lag at which the sturdiest or most precise wavelet correlation coefficient is localised. This is indicated by the vertical black dashed lines in the visual plot. In addition, the comprehension of the dimensions in the preservation of a five-day-per-week data cadence wavelet-like metrics translate to the segments of, respectively, “1-2 days” (daily scales), “2–4 days” (intraweekly scales), “4–8 days” (weekly scale), “8–16 days” (fortnightly scale), “16–32” days (monthly scale), and “32–64 days” (monthly to quarterly scale).

The WMC ascertains the short-, medium-, and long-term interactions between commodities (agricultural and metal) and sampled equities in the SSA markets. On average, the cumulative WMC was found to be increasing except for the intraweekly (fortnightly) scales, which recorded a comparatively advanced level of integration above that of their respective succeeding (preceding) scales. The convergence metrics were lowest (highest) for the fortnightly (monthly to quarterly) time horizon, with an integration level of up to 15% (81%). Thus, the highest degree of integration (monthly to quarterly scale) suggests a variational explanatory capacity of approximately 81% for the remaining variables and can account for the extent of the variation in one variable's monthly to quarterly returns, culminating in a spectrum of interdependencies.

The dependency structure was determined to be moderately compatible, with an augmented degree of an upward spiral in the respective coefficients except

for the intraweek to weekly scale, where the latter exhibited a higher degree of integration than the former and largely represents the level of inconsistency. During the shift from the monthly to quarterly scale, the spiral was comparatively higher than all preceding interactions and then further increased by approximately 20%. Our analysis demonstrates that there is comparatively fragile interdependence between SSA stock and commodities (agricultural and metals) except for the monthly to quarterly scales.

In accordance with the validation of the MPT and the IPM regarding risk diversification through the integration of equities and commodities, the modest positive correlation between commodities and SSA stocks demonstrates the existence of such advantageous attributes, particularly within the intraweekly to fortnightly time frame. Moreover, it elucidates the presence of both hedging and safe-haven characteristics within these asset classes, as defined by Baur and Lucey (2010). Thus, the findings of the study indicate that international investors could diversify their investment perils by combining agricultural commodities (cocoa, coffee, corn and cotton), industrial metals (aluminium, copper, nickel and zinc), and SSA equities (BSE, GSE, NSE, NASE, and JSE) in a single portfolio especially in the short to medium term. Thus, the risk element inherent in the selected assets remain the weakest across the aforesaid timeframe and investors could take advantage of such luxury.

The aforementioned findings provide additional validation for the initial hypothesis of limited interdependencies among commodities and equities in commodity-dependent countries in SSA, which was derived from the fundamental

principles of MPT. The observed weak interdependencies among the analysed asset classes further affirm the relevance of the second tenets of MPT regarding investor sensitivity towards unwarranted risks. Moreover, the results from the short and medium terms failed to lend credence to the final propositions of portfolio theory concerning the symmetrical nature of investor information. Accordingly, the presence of a combination of weak and moderate integration across time and horizon reveals the existence of asymmetric systemic information in the short and medium terms. It suggests that in the absence of accurate and equitable information, investors could benefit from portfolio diversification by shifting their wealth from highly correlated assets and markets to ones with a low level of correlation.

On the other hand, the strong integration found between these asset classes in the long term (spanning fortnightly to quarterly intervals) is evidence that, in contrast to the earlier hypotheses, there are no incentives for portfolio diversification during such periods. Furthermore, the presence of a combination of somewhat strong integration in the long term across markets and horizons serves as evidence for the existence and significance of systemic information. It suggests that investors could only benefit from portfolio diversification through low integrated assets in the short and medium term, but such luxury is depleted in the long term due to symmetric information and market efficiency. It further underscores investor rationality, considering the contemporary landscape where information dissemination has evolved from a multitude of fragmented sources into a unified entity that spreads at an unexpectedly accelerated pace.

Globally, these findings partially corroborate the findings of studies (Siddiqui & Roy, 2019; Sokhanvar & Bouri, 2023), both of which found that commodity prices could be utilised to anticipate the equity direction, subject to the high degree of interdependence between these markets, and further confirm the findings of Sadiq et al. (2022) in the Asian context. In a corresponding scenario, our discoveries for dependence in the immediate to intermediate timeframe invalidate those of the previously referenced studies attributable to the constrained convergence metrics spanning these dimensions. Hence, the feeble link observed during the short to medium periods contradicts the claims made by the above empirical studies regarding the existence of strong interdependencies.

In the SSA paradigm, the results of this study partially validate those of studies (Mongale & Eita, 2014; Oyelami & Yinusa, 2019), which unveil the nexus between African stocks (Nigerian and South African) and global commodity classes. The results partially lend credence to the assertion made by Mongale and Eita (2014) that rising commodity prices are linked to improved stock market performance in the enduring term. In line with the findings of the commodity-investing proponents and partially embedded with prior studies (Addison et al., 2016; de Boyrie & Pavlova, 2018), who confirmed the above propositions, the results partially confirm (disprove) the hypothesis of a low overall link between equities and commodities, especially in the short (long) term. Nevertheless, the outcomes from the WMC were inconclusive in terms of identifying the safe haven potential, as it lacked the ability to ascertain the assets' resilience to risk. Therefore, further investigation was carried out using the WMCC to explore this aspect.

The outcomes obtained from the WMCC, as illustrated in Appendix Figure 13, are further synthesised and presented in Table 3. From the visualisation, we observe that the WMCC of the preselected commodity markets (agricultural and metals) and SSA stocks eventuate at distinct frequencies, with leads and lags of up to 30 days. We identify the agricultural and metal commodities and stocks that have the highest correlation in reference to a concatenation of the remaining assets across all wavelet scales. The potential leading and lagging variables must be tested with both positive and negative shocks. At each scale, positive lag localisations represent the lagging variable, and negative lag localisations represent the leading variable. There is no lead or lag at the zero-lag of localisation (dashed) lines. Consequently, when a dashed line appears next to a listed variable in the heatmap, it indicates a lead (delirious lag) or lag (favourable lag), unless the dashed line is on the zero-lag, in which case it denotes neither a lead nor a lag.

Consequently, WMCCs have tremendous economic relevance since they distinguish the most persuasive variable at a given wavelet spectrum that acts as a leading (i.e., the first to respond to shocks) or lagging (the last to respond to shocks) variable. Corn possesses the lagging prospect by 4 lags at the intraweekly scales and further possesses the leading potentials respectively by 2, 3, and 27 lags at the weekly, monthly, and quarterly scales, while aluminium possesses the prospect to trail by 1 lag at the fortnightly scale. This indicates that amid uncertain market shocks, the aluminium market is the last to be affected and could serve as a safe haven instrument. The leading potential of corn at the aforementioned scales as well as that of copper at the weekly scale reveals that in the event of external shocks, the

corn and copper markets remain the most vulnerable assets to be affected in such holdings, a trait investor must acknowledge given their relevance to portfolio diversification and also in providing relevant mitigation across such scales.

Nevertheless, corn's lagging capacity on the weekly to fortnightly scale signifies the opposite. Surprisingly, the cocoa market was the only asset among the equity-commodity couplings that was deemed daunting due to the absence of tracking error (zero lag) at the intraweekly scales. Additionally, considering that cocoa proved susceptible to lead (lag) at zero scales, the aforementioned potential remains indeterminate in light of the antecedent explication from the lead (lag) perspective (Tweneboah, 2019). The results further revealed that African equities and commodities (agricultural and metals) are somewhat intricately and constantly entwined in both the WMC and the WMCC.

It is imperative to recognise that the economic significance of the WMCC analysis aligns with the second proposition of MPT and the IPM model, which emphasise risk. Therefore, the mere observation of a combination of weak and moderate levels of integration in the preceding analysis is insufficient to confirm the presence of diversification, as prudent investors consider factors beyond returns. In accordance with the second principle of portfolio theory, rational investors will evaluate both the risk and reward inherent in an investment vehicle before making a decision. This illustrates that the presence of a weak correlation between asset classes in an international portfolio does not offer adequate signal to support the benefits of diversification (Woode et al., 2024a).

Given the aforementioned considerations, we can further contend that investors who derive insights from this study must additionally take into account the results of the WMCC as a supplementary measure to those of the WMC if they are to adhere to rationality principles and account for inherent risk when diversifying their portfolio. The WMCC results, as previously elucidated, entail the following risks: Consequently, under normal circumstances (in the absence of an economic crisis), the aforementioned assertions hold about potential portfolio diversification among the sampled asset classes. However, such advantages may diminish in the face of turbulence.

Interdependence between Commodities and SSA Stocks: Bivariate Analysis

The initial objective of the study was to examine the dynamic interdependence structure between commodities and equities using WMC and WMCC and complement these findings with the Barunik and Křehlík bivariate interconnectedness index to further investigate the interdependencies at the pairwise level, subject to the pairwise nature of most investment holdings and slight inconsistencies in our multivariate integration results from the WMC model. This was implemented to further confirm or refute the earlier conclusions reached and also for portfolio diversification purposes. Also, this will permit us to exemplify the prospect of bilateral composites to rebalance these asset classes and further validate the level of coherence within these asset markets via disclosure, an essential investor guide. The results of the bivariate interdependence framework between commodities and equities are summarised in Appendix Table 14.

From Appendix Table 15, the results of the bivariate analysis exhibit comparative disparities but somewhat corroborate those of the intermediate-to-enduring convergence from the WMC. These results signal that some market combinations could diverge. The results further affirm the assertions of the commodity investing proponents, given the weak correlation between the sampled markets, especially in the immediate and intermediate terms. In addition, there was a combination of both positive and negative interactions between these pairings, indicating that, despite the weak interactions at the highest frequencies, some assets act as both a hedge and a safe haven, according to Baur and Lucey (2010).

For instance, in the immediate and intermediate term, the majority of the commodity-equity pairings exhibited a negative level of connectedness, indicating that, in normal periods, investors could employ such asset combinations in their portfolios as weak hedging instruments, while those with positive interconnectedness metrics could function as weak diversifiers. Conversely, during periods of turbulence, as previously illustrated, those combinations exhibiting negative coefficients may function as feeble havens of safety, attributable to their relatively lower level of interconnectedness. The long term was rather marred by a higher level of interdependency given the substantial coefficients between the equity-commodity pairings. The results at the lowest frequency rather exhibited strong coefficients, with some exceeding unity, while the only exception remains the pairings between commodities (cotton, nickel, and zinc) and SSA equities (GSE and NSE). For instance, the negative significant holding coefficients of SSA equities (BSE, GSE, NSE, NASE, and JSE) and commodities (cocoa and corn) and

likewise those of aluminium and equities (GSE, NSE, and JSE) in the long-term implies that in normal periods, investors could utilise these asset combinations as strong hedges, while in precarious periods, these holdings could function as strong safe havens (Baur & Lucey, 2010; Boyrie & Pavlova, 2018; Woode et al., 2024b).

The positive (negative) significant (insignificant) coefficients for the pairwise commodity-equity holdings further signify the long-term diversification (weak hedge) prospects for these asset classes in normal periods, while the negative insignificant coefficients indicate the weak haven prospects. The long-term findings corroborate those of the WMC, while the strong connectedness between corn and SSA equities validates the leading (and lagging) prospects as established from the WMCC results. Astoundingly, the NSE exhibited both the highest and lowest level of integration with commodities. Particularly, the highest level of connectedness was observed from the NSE-corn holdings in the long term, while the least was exhibited between the NSE-Zinc, with both pairings being negative.

In summary, considering the concepts of safe havens and hedges proposed by Baur and Lucey (2010), it can be inferred that the bivariate pairings with negative (positive) coefficients in the short term may serve as feeble safe havens (hedges). These findings are somewhat consistent with our results in the WMC in the medium term, where a relatively higher level of interconnectedness was observed among all asset classes interacting within a unified market. The partially divergent outcomes from these different approaches suggest that the diversification potential of commodity-stock pairings is limited to the bivariate case and not the

multivariate case, wherein the individual assets contribute significantly to a heightened level of integration within the system or the overall market.

Volatility Transmission in Commodity, Exchange Rate and the Stock Market

This section was assigned the task of scrutinising the second facet of the investigation. The objective was to ascertain if volatility in commodity and exchange rate markets is transmitted to the stock markets of the selected SSA economies and vice versa. The study utilises the Barunik and Křehlík spillage indicators to accomplish this objective. We implement the aforesaid objective by considering how the volatilities in the selected commodities transmit into the exchange rates and stock markets on a country level and overall. This gave us a total of six different collections, with the uniqueness in the sub-system being the exchange rate and stock returns of peculiar SSA countries in each portfolio subject to country-wide analysis.

Furthermore, it is pertinent to acknowledge that "Absolute_From" tracks transmissions from distinct markets towards the market (ɟ), whereas "Absolute_To" covers transmissions from the market (ɟ) to other segments, particularly the market (ƙ). "To_Within" captures transmissions from the market (ɟ) to neighbouring financial markets, which incorporate those related to ɟ's novelties in markets (ƙ), whereas "From_Within" captures transmissions from other markets (ƙ) towards market (ɟ), which comprise those corresponding to markets (ƙ's) novelties in market ɟ. Furthermore, it is relevant to acknowledge that "Net" represents the resultant shock transmissions (receipts) of a peculiar market. An adverse (negative) net coefficient signals a shock-receiving market participant, while a favourable

(positive) net coefficient implies that the respective participant is a transmitter of shocks to other markets (neighbouring economies). The principal contributions of exchanges are highlighted in vibrant accents per regularity band.

Furthermore, given the aforementioned suppositions, Barunik and Křehlík (2018) further contended that short-term components typically correspond to erratic trading behaviours, such as herding effects and investor sentiments, whereas long-term components generally allude to enduring patterns, such as fluctuations in economic fundamentals. Thus, periods characterised by heightened connectedness at higher frequencies are indicative of financial markets swiftly processing information, whereby a shock to one asset predominantly impacts short-term cyclic behaviour. This pattern of behaviour can be attributed to fundamental shifts in investors' expectations, which exert a lasting influence on systemic risk. These expectations subsequently propagate to neighbouring assets within portfolios.

Conversely, if the interconnectedness stems from the opposing segment of the cross-spectral density, specifically lower frequencies, it implies that shocks are being transmitted over extended durations. In a systemic context where asset prices are influenced by diverse factors, including participant behaviour characterised by distinct recurring components, seismic disturbances with heterogeneous responses foster connections of varying degrees of persistence, thereby giving rise to multiple sources of interconnectedness and systemic risk. The results of the time-varying frequency connectedness and spillage for the overall markets are summarised in Table 4, while those for the country-specific markets are further highlighted in Tables 5–9.

Table 4: Spillover Connectedness for Overall Commodities, Exchange Rates, and Equity Markets

Panel A										
Variables	Alumin.	Copper	Nickel	Zinc	Cocoa	Coffee	Corn	Cotton	BSP	GHS
Spillover band: 3.14 to 0.79; corresponds to intraweek or short-term (1 to 4 days)										
Industrial metals										
Aluminium	0.01	0.00	0.00	0.00	0.01	0.01	0.05	0.00	0.00	0.04
Copper	0.01	0.00	0.00	0.00	0.00	0.01	0.03	0.02	0.00	0.02
Nickel	0.02	0.03	5.62	0.00	0.03	0.00	0.03	0.00	0.06	0.02
Zinc	0.00	0.01	0.00	0.16	0.02	0.00	0.00	0.04	0.00	0.01
Agricultural commodities										
Cocoa	0.00	0.01	0.01	0.00	0.07	0.01	0.08	0.00	0.03	0.08
Coffee	0.04	0.03	0.00	0.00	0.02	0.33	0.01	0.00	0.00	0.02
Corn	0.00	0.01	0.01	0.00	0.06	0.01	0.09	0.00	0.04	0.07
Cotton	0.05	0.05	0.00	0.00	0.01	0.00	0.00	1.21	0.01	0.00
SSA currency market										
Botswana Pula	0.00	0.01	0.01	0.00	0.08	0.00	0.09	0.00	0.07	0.09
Ghanaian Cedi	0.01	0.00	0.01	0.00	0.03	0.01	0.05	0.00	0.01	0.05
Kenyan Shilling	0.00	0.01	0.01	0.00	0.13	0.00	0.09	0.00	0.07	0.11
Namibian Dollar	0.00	0.08	0.01	0.00	0.12	0.00	0.09	0.00	0.07	0.11
South African Rand	0.00	0.08	0.01	0.00	0.12	0.00	0.08	0.00	0.07	0.11
SSA equity market										
BSE	0.03	0.01	0.01	0.00	0.00	0.00	0.02	0.01	0.01	0.00
GSE	0.07	0.00	0.01	0.00	0.02	0.00	0.01	0.01	0.06	0.01
NSE	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00
NASE	0.03	0.01	0.00	0.00	0.03	0.00	0.01	0.05	0.01	0.02
JSE	0.06	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01
TO_ABS	0.02	0.03	0.01	0.01	0.04	0.00	0.04	0.01	0.02	0.04
TO_WTH	2.56	3.81	0.65	0.12	4.45	0.41	4.13	0.93	2.76	4.47
NET	**-0.005**	**0.016**	**-0.014**	**-0.009**	**0.011**	**-0.012**	**0.007**	**0.001**	**-0.02**	**0.017**

Table 4, continued

Spillover band: 0.79 to 0.10; corresponds to intermediate-term thus week to a month (4 to 32 days)										
Industrial metals										
Aluminium	0.14	0.29	0.01	0.02	0.14	0.09	0.47	0.03	0.05	0.37
Copper	0.10	0.25	0.04	0.01	0.02	0.09	0.29	0.17	0.00	0.14
Nickel	0.08	0.04	31.04	0.04	0.27	0.01	0.24	0.00	0.52	0.19
Zinc	0.01	0.10	0.10	1.41	0.26	0.01	0.01	0.38	0.02	0.12
Agricultural commodities										
Cocoa	0.23	0.56	0.05	0.01	0.64	0.06	0.71	0.01	0.30	0.74
Coffee	0.09	0.28	0.18	0.00	0.18	2.78	0.12	0.00	0.01	0.18
Corn	0.24	0.51	0.05	0.01	0.55	0.05	0.77	0.02	0.36	0.69
Cotton	0.01	0.02	0.04	0.08	0.14	0.02	0.00	10.17	0.06	0.04
SSA currency market										
Botswana Pula	0.25	0.60	0.10	0.01	0.78	0.03	0.84	0.02	0.60	0.81
Ghanaian Cedi	0.17	0.50	0.06	0.01	0.33	0.08	0.48	0.01	0.08	0.50
Kenyan Shilling	0.26	0.79	0.12	0.00	1.20	0.02	0.81	0.01	0.68	1.04
Namibian Dollar	0.24	0.73	0.10	0.01	1.14	0.03	0.80	0.03	0.68	1.01
South African Rand	0.22	0.73	0.10	0.00	1.17	0.02	0.77	0.02	0.67	1.03
SSA equity market										
BSE	0.03	0.09	0.05	0.01	0.11	0.00	0.19	0.09	0.14	0.06
GSE	0.00	0.01	0.08	0.00	0.18	0.04	0.07	0.08	0.46	0.05
NSE	0.02	0.03	0.05	0.05	0.00	0.00	0.08	0.10	0.01	0.01
NASE	0.07	0.14	0.01	0.01	0.35	0.01	0.07	0.47	0.09	0.24
JSE	0.10	0.11	0.00	0.00	0.03	0.02	0.09	0.01	0.00	0.06
TO_ABS	0.12	0.31	0.06	0.02	0.38	0.03	0.33	0.08	0.23	0.38
TO_WTH	1.69	4.43	0.93	0.23	5.50	0.45	4.83	1.16	3.32	5.44
NET	**-0.044**	**0.150**	**-0.109**	**-0.103**	**0.123**	**-0.121**	**0.069**	**0.014**	**-0.13**	**0.183**

Table 4, continued

Spillover band: 0.10 to 0.00; corresponds to enduring-term thus, month and beyond (32 days to infinite days)										
Industrial metals										
Aluminium	1.94	3.54	6.40	0.07	4.53	1.48	4.10	10.76	4.87	5.37
Copper	1.88	3.38	5.89	0.05	4.29	1.66	4.03	10.96	4.77	5.22
Nickel	2.79	3.77	16.00	0.30	6.24	0.26	4.69	3.96	7.04	5.84
Zinc	2.60	4.04	6.19	9.39	5.92	0.33	4.47	6.49	5.89	5.99
Agricultural commodities										
Cocoa	2.35	4.18	6.76	0.12	5.19	1.02	4.77	8.66	5.59	6.26
Coffee	2.80	3.29	5.60	0.38	6.62	8.50	4.06	7.81	7.26	4.83
Corn	2.53	4.34	6.60	0.13	5.51	0.87	5.04	7.77	5.99	6.56
Cotton	2.66	2.54	4.24	3.06	6.61	0.99	3.90	18.59	7.19	4.46
SSA currency market										
Botswana Pula	2.58	4.40	6.65	0.13	5.60	0.77	5.08	7.72	6.15	6.60
Ghanaian Cedi	1.99	3.62	6.35	0.10	4.54	1.38	4.25	10.65	4.98	5.45
Kenyan Shilling	2.39	4.17	6.77	0.11	5.16	0.75	4.71	9.14	5.75	6.15
Namibian Dollar	2.74	4.49	6.50	0.14	5.98	0.65	5.30	7.06	6.61	6.80
South African Rand	2.48	4.28	6.71	0.11	5.38	0.74	4.86	8.57	5.97	6.37
SSA equity market										
BSE	3.69	4.49	5.18	0.21	8.75	0.24	5.89	3.41	9.65	7.19
GSE	3.96	3.80	3.49	0.30	9.66	0.56	5.81	4.96	10.80	6.62
NSE	1.90	3.33	5.60	0.50	4.16	0.47	3.75	5.54	4.49	5.11
NASE	3.05	3.39	3.20	2.46	8.34	2.56	4.72	1.41	8.17	6.08
JSE	2.95	3.09	5.44	0.24	7.21	0.07	4.24	9.75	8.00	5.05
TO_ABS	2.52	3.60	5.42	0.47	5.81	0.82	4.37	6.92	6.28	5.58
TO_WTH	2.70	3.86	5.81	0.50	6.22	0.88	4.68	7.42	6.73	5.99
NET	**-2.746**	**-1.578**	**1.568**	**-4.297**	**0.754**	**-3.807**	**-0.66**	**3.002**	**1.315**	**0.505**

Table 4, continued: Panel B

Variables	KSH	NAD	ZAR	BSE	GSE	NSE	NASE	JSE	FRM_ABS[a]	FRM_WTH[b]
Spillover band: 3.14 to 0.79; corresponds to intraweek or short-term (1 to 4 days)										
Industrial metals										
Aluminium	0.06	0.00	0.01	0.00	0.07	0.00	0.01	0.00	0.02	2.02
Copper	0.03	0.00	0.00	0.00	0.15	0.00	0.04	0.00	0.02	2.03
Nickel	0.10	0.01	0.02	0.00	0.01	0.00	0.00	0.04	0.02	2.19
Zinc	0.00	0.02	0.01	0.00	0.01	0.00	0.04	0.02	0.01	1.10
Agricultural commodities										
Cocoa	0.12	0.00	0.01	0.00	0.07	0.01	0.00	0.00	0.03	3.20
Coffee	0.01	0.00	0.00	0.00	0.14	0.02	0.01	0.01	0.02	1.78
Corn	0.15	0.01	0.01	0.01	0.07	0.00	0.01	0.00	0.03	3.35
Cotton	0.00	0.00	0.01	0.07	0.00	0.01	0.00	0.00	0.01	0.82
SSA currency market										
Botswana Pula	0.19	0.01	0.01	0.05	0.05	0.00	0.01	0.01	0.04	4.56
Ghanaian Cedi	0.06	0.00	0.00	0.00	0.12	0.00	0.01	0.00	0.02	2.44
Kenyan Shilling	0.19	0.00	0.01	0.06	0.04	0.01	0.00	0.00	0.04	4.07
Namibian Dollar	0.18	0.01	0.01	0.03	0.04	0.01	0.00	0.00	**0.04**	**4.88**
South African Rand	0.17	0.00	0.01	0.05	0.03	0.01	0.00	0.00	0.04	4.80
SSA equity market										
BSE	0.05	0.06	0.06	0.00	0.01	0.00	0.01	0.02	0.02	1.75
GSE	0.05	0.01	0.00	0.34	0.08	0.01	0.03	0.02	0.03	3.65
NSE	0.01	0.00	0.00	0.00	0.08	0.34	0.00	0.00	0.01	0.92
NASE	0.02	0.00	0.00	0.08	0.00	0.01	0.04	0.04	0.02	1.81
JSE	0.01	0.00	0.00	0.11	0.16	0.02	0.00	0.00	0.02	2.20
TO_ABS	0.07	0.01	0.01	0.05	0.06	0.01	0.01	0.01	**0.42**	
TO_WTH	7.75	0.90	0.98	5.17	6.65	0.75	1.17	0.99		**47.57**
NET	**0.032**	**-0.04**	**-0.03**	**0.030**	**0.026**	**-0.01**	**-0.01**	**-0.01**		

Table 4, continued

Spillover band: 0.79 to 0.10; corresponds to intermediate-term thus week to a month (4 to 32 days)										
Industrial metals										
Aluminium	0.59	0.05	0.08	0.02	0.58	0.02	0.08	0.02	0.16	2.33
Copper	0.26	0.01	0.01	0.04	1.28	0.00	0.33	0.03	0.16	2.26
Nickel	0.88	0.17	0.22	0.09	0.12	0.02	0.00	0.23	0.17	2.50
Zinc	0.05	0.17	0.14	0.11	0.08	0.02	0.38	0.17	0.12	1.71
Agricultural commodities										
Cocoa	1.15	0.05	0.07	0.06	0.58	0.06	0.03	0.01	0.26	3.73
Coffee	0.11	0.03	0.02	0.04	1.16	0.19	0.09	0.05	0.15	2.20
Corn	1.37	0.10	0.12	0.06	0.53	0.05	0.07	0.03	0.27	3.84
Cotton	0.01	0.03	0.06	0.55	0.01	0.09	0.03	0.01	0.07	0.96
SSA currency market										
Botswana Pula	1.73	0.11	0.12	0.44	0.43	0.04	0.11	0.05	0.36	5.17
Ghanaian Cedi	0.59	0.01	0.01	0.05	1.02	0.05	0.05	0.01	0.19	2.80
Kenyan Shilling	1.78	0.06	0.08	0.60	0.30	0.08	0.01	0.00	0.34	4.88
Namibian Dollar	1.74	0.09	0.12	0.34	0.27	0.10	0.00	0.00	**0.41**	**5.89**
South African Rand	1.66	0.07	0.11	0.50	0.20	0.09	0.00	0.00	0.40	5.83
SSA equity market										
BSE	0.53	0.56	0.64	0.14	0.09	0.02	0.18	0.23	0.17	2.42
GSE	0.45	0.05	0.02	2.96	0.68	0.05	0.31	0.18	0.28	4.00
NSE	0.10	0.03	0.01	0.06	0.71	2.87	0.04	0.02	0.07	1.06
NASE	0.19	0.02	0.03	0.85	0.01	0.11	0.31	0.33	0.17	2.42
JSE	0.13	0.00	0.01	0.94	1.38	0.16	0.02	0.04	0.17	2.45
TO_ABS	0.64	0.08	0.10	0.43	0.49	0.06	0.10	0.08	**3.91**	
TO_WTH	9.23	1.22	1.40	6.18	7.02	0.92	1.38	1.10		**56.44**
NET	**0.301**	**-0.32**	**-0.31**	**0.261**	**0.209**	**-0.01**	**-0.07**	**-0.09**		

Table 4, continued

Spillover band: 0.10 to 0.00; corresponds to enduring-term thus, month and beyond (32 days to infinite days)										
Industrial metals										
Aluminium	15.26	1.31	1.73	18.65	10.61	0.55	4.53	0.97	**5.26**	**5.64**
Copper	14.54	1.41	1.82	18.52	11.04	0.70	5.20	1.18	5.18	5.55
Nickel	12.67	1.67	2.02	13.72	2.59	0.05	1.06	0.67	3.85	4.13
Zinc	14.57	1.30	1.74	17.10	5.11	1.23	2.40	0.39	4.76	5.11
Agricultural commodities										
Cocoa	16.86	1.31	1.69	19.05	7.90	0.30	3.23	0.90	5.05	5.42
Coffee	11.25	2.17	2.70	7.15	13.08	0.10	3.40	0.84	4.63	4.96
Corn	16.97	1.37	1.75	19.09	6.82	0.26	2.93	1.00	5.03	5.39
Cotton	7.58	2.49	3.28	9.99	8.35	0.76	2.28	0.20	3.92	4.21
SSA currency market										
Botswana Pula	17.46	1.39	1.76	18.66	6.64	0.22	2.75	0.95	4.96	5.32
Ghanaian Cedi	15.81	1.37	1.78	18.11	10.50	0.52	4.44	0.99	5.08	5.44
Kenyan Shilling	17.95	1.35	1.68	18.06	7.81	0.26	3.19	0.91	4.35	4.67
Namibian Dollar	17.24	1.50	1.89	1856	5.74	0.18	2.40	0.96	5.18	5.55
South African Rand	17.73	1.38	1.73	18.34	7.17	0.23	2.97	0.94	5.23	5.61
SSA equity market										
BSE	13.01	2.45	3.07	17.84	2.53	0.05	1.08	0.92	3.99	4.28
GSE	8.90	3.38	4.28	11.59	6.39	0.13	1.51	0.78	4.47	4.80
NSE	11.48	1.00	1.15	14.43	9.85	20.02	1.17	1.57	4.20	4.50
NASE	6.83	2.27	3.22	16.84	1.25	0.25	14.29	1.36	4.19	4.49
JSE	10.89	2.54	3.24	7.72	13.97	1.34	1.95	3.66	4.87	5.22
TO_ABS	12.73	1.68	2.16	14.75	7.28	0.40	2.58	0.86	**84.22**	
TO_WTH	13.64	1.80	2.31	15.82	7.80	0.42	2.77	0.93		**90.29**
NET	**8.372**	**-3.51**	**-3.08**	**10.76**	**2.802**	**-3.80**	**-1.61**	**-4.01**		

Source: Woode (2023)

Table 5: Spillover Connectedness Among Commodities, Exchange Rates, and Botswana Stock Exchange

Variables	BSE	BSP	Aluminium	Copper	Nickel	Zinc	Cocoa	Coffee	Corn	Cotton	FROM_ABS[a]	FROM_WTH[b]
Spillover band: 3.14 to 0.79; corresponds to intraweek or short-term (1 to 4 days)												
BSE	0.02	0.73	0.37	0.29	0.01	0.02	0.16	0.03	0.61	0.00	**0.22**	10.28
BSP	0.03	0.73	0.37	0.29	0.01	0.02	0.16	0.03	0.61	0.00	0.15	7.02
Aluminium	0.03	0.43	0.23	0.17	0.01	0.02	0.10	0.04	0.36	0.00	0.12	5.37
Copper	0.03	0.77	0.38	0.31	0.01	0.02	0.16	0.03	0.64	0.00	0.20	9.47
Nickel	0.03	0.73	0.37	0.29	0.06	0.02	0.16	0.03	0.61	0.00	0.22	10.38
Zinc	0.03	0.68	0.34	0.27	0.01	0.00	0.15	0.03	0.56	0.00	0.21	9.58
Cocoa	0.03	0.72	0.36	0.29	0.01	0.02	0.15	0.03	0.60	0.00	0.21	9.54
Coffee	0.03	0.73	0.37	0.29	0.01	0.02	0.16	0.06	0.61	0.00	**0.22**	10.31
Corn	0.03	0.73	0.37	0.29	0.01	0.02	0.16	0.03	0.61	0.00	0.16	7.59
Cotton	0.03	0.73	0.37	0.29	0.01	0.02	0.16	0.03	0.60	0.00	**0.22**	**10.40**
TO_ABS[a]	0.03	0.63	0.33	0.25	0.01	0.01	0.14	0.03	0.52	0.00	**1.94**	
TO_WTH[b]	1.24	29.05	11.48	15.22	0.54	0.65	6.27	1.42	24.05	0.00		**89.94**
Net	**-0.20**	**0.48**	**0.21**	**0.04**	**-0.22**	**-0.19**	**-0.07**	**-0.19**	**0.34**	**-0.22**		
Spillover band: 0.79 to 0.10; corresponds to intermediate-term thus week to a month (4 to 32 days)												
BSE	0.17	5.93	2.98	2.35	0.11	0.13	1.27	0.27	4.93	0.00	1.80	10.28
BSP	0.24	5.94	2.98	2.36	0.11	0.13	1.27	0.27	4.92	0.00	1.23	7.03
Aluminium	0.27	3.54	1.86	1.41	0.09	0.12	0.79	0.33	2.90	0.01	0.95	5.42
Copper	0.23	6.23	3.10	2.49	0.11	0.12	1.33	0.26	5.16	0.00	1.65	9.46
Nickel	0.24	5.95	2.98	2.37	0.31	0.12	1.27	0.27	4.93	0.00	1.81	10.38
Zinc	0.24	5.50	2.73	2.18	0.07	0.04	1.18	0.26	4.53	0.01	1.67	9.55
Cocoa	0.24	5.85	2.93	2.32	0.11	0.13	1.24	0.28	4.84	0.00	1.67	9.55
Coffee	0.23	5.96	3.00	2.37	0.12	0.13	1.29	0.49	4.95	0.00	1.81	10.33
Corn	0.24	5.93	2.97	2.36	0.11	0.13	1.27	0.27	4.91	0.00	1.33	7.59
Cotton	0.25	5.93	2.97	2.36	0.11	0.12	1.28	0.27	4.91	0.03	**1.82**	**10.41**
TO_ABS[a]	0.22	5.08	2.66	2.01	0.09	0.11	1.10	0.25	4.21	0.00	**15.73**	

Table 5, continued

TO_WTH[b]	1.25	29.07	15.23	11.49	0.53	0.65	6.28	1.42	24.07	0.01		**90.00**
Net	**-1.58**	**3.85**	**1.72**	**0.36**	**-1.72**	**-1.56**	**-0.57**	**-1.56**	**2.88**	**-1.82**		
Spillover band: 0.10 to 0.00; corresponds to enduring-term thus month and beyond (32 days to infinite days)												
BSE	1.16	25.96	12.98	10.32	0.45	0.54	5.56	1.15	21.47	0.00	7.85	9.76
BSP	1.04	25.90	13.01	10.32	0.47	0.56	5.58	1.19	21.46	0.00	5.36	6.67
Aluminium	2.30	22.98	16.32	11.60	0.61	1.40	7.85	3.51	20.07	0.64	7.10	8.83
Copper	0.95	26.05	12.67	10.13	0.44	0.49	5.37	1.03	21.48	0.01	6.85	8.52
Nickel	1.04	25.86	12.97	10.29	0.37	0.56	5.56	1.19	21.42	0.00	7.89	9.82
Zinc	1.98	24.72	12.52	9.95	0.59	3.55	5.33	1.17	20.56	0.82	7.76	9.66
Cocoa	1.06	25.87	3.11	10.38	0.47	0.58	5.66	1.25	21.47	0.00	7.42	9.23
Coffee	1.02	25.87	12.89	10.25	0.44	0.53	5.53	1.26	21.38	0.01	7.79	9.70
Corn	1.05	25.89	13.02	10.33	0.47	0.57	5.59	1.20	21.46	0.00	5.81	7.23
Cotton	1.10	25.86	12.97	10.30	0.46	0.60	5.54	1.16	21.40	0.14	**7.94**	**9.88**
TO_ABS[a]	1.15	22.91	11.61	9.37	0.44	0.58	5.19	1.29	19.07	0.15	**71.77**	
TO_WTH[b]	1.44	28.50	14.45	11.66	0.55	0.72	6.46	1.60	23.73	0.19		**89.30**
Net	**-6.69**	**17.54**	**4.52**	**2.53**	**-7.45**	**-7.183**	**-2.23**	**-6.51**	**13.26**	**-7.79**		

Source: Woode (2023)

Table 6: Spillover Connectedness Among Commodities, Exchange Rates, and Ghana Stock Exchange

Variables	GSE	GHS	Aluminium	Copper	Nickel	Zinc	Cocoa	Coffee	Corn	Cotton	FROM_ABS[a]	FROM_WTH[b]
Spillover band: 3.14 to 0.79; corresponds to intraweek or short-term (1 to 4 days)												
GSE	0.00	0.28	0.23	0.12	0.01	0.05	0.44	0.05	0.17	0.00	**0.14**	**9.24**
GHS	0.01	0.26	0.25	0.09	0.01	0.06	0.44	0.05	0.18	0.00	0.11	7.37
Aluminium	0.01	0.26	0.22	0.11	0.01	0.05	0.41	0.06	0.15	0.00	0.11	7.25
Copper	0.01	0.27	0.22	0.11	0.01	0.05	0.42	0.06	0.15	0.00	0.12	8.01
Nickel	0.02	0.20	0.15	0.10	2.37	0.03	0.30	0.05	0.09	0.00	0.09	6.26
Zinc	0.01	0.10	0.09	0.05	0.00	0.61	0.16	0.02	0.05	0.00	0.05	3.32
Cocoa	0.02	0.25	0.21	0.11	0.01	0.04	0.14	0.06	0.40	0.00	0.08	5.73
Coffee	0.02	0.20	0.15	0.09	0.01	0.02	0.30	0.34	0.10	0.00	0.09	6.16
Corn	0.01	0.26	0.22	0.11	0.01	0.05	0.15	0.05	0.41	0.00	0.11	7.55
Cotton	0.01	0.25	0.21	0.12	0.01	0.04	0.40	0.05	0.13	0.11	0.12	8.22
TO_ABS[a]	0.01	0.21	0.17	0.09	0.01	0.04	0.33	0.04	0.12	0.00	**1.02**	
TO_WTH[b]	0.93	14.02	11.60	6.10	0.76	2.59	22.12	2.98	7.95	0.06		**69.12**
Net	**-0.12**	**0.10**	**0.06**	**-0.03**	**-0.08**	**-0.01**	**0.24**	**-0.05**	**0.05**	**-0.12**		
Spillover band: 0.79 to 0.10; corresponds to intermediate-term thus week to a month (4 to 32 days)												
GSE	0.00	2.38	1.91	1.01	0.10	0.43	3.71	0.43	1.40	0.02	**1.14**	**9.77**
GHS	0.08	2.17	2.05	0.75	0.12	0.51	3.65	0.45	1.48	0.03	0.91	7.78
Aluminium	0.12	2.20	1.82	0.94	0.12	0.38	3.44	0.46	1.27	0.00	0.89	7.66
Copper	0.11	2.21	1.83	0.94	0.12	0.39	3.47	0.46	1.27	0.00	0.99	8.46
Nickel	0.15	1.61	1.24	0.78	12.77	0.17	2.45	0.34	0.79	0.00	0.75	6.46
Zinc	0.12	0.85	0.73	0.41	0.27	5.23	1.34	0.17	0.45	0.09	0.44	3.80
Cocoa	0.15	2.12	1.74	0.93	0.12	0.34	1.18	0.46	3.30	0.00	0.71	6.05
Coffee	0.20	1.69	1.29	0.80	0.18	0.21	2.49	2.83	0.87	0.00	0.77	6.62
Corn	0.12	2.14	1.80	0.90	0.12	0.39	1.22	0.45	3.39	0.01	0.93	7.98
Cotton	0.07	2.07	1.71	0.97	0.11	0.36	3.29	0.46	1.11	0.92	1.02	8.70
TO_ABS[a]	0.11	1.73	1.43	0.75	0.13	0.32	2.72	0.6	0.98	0.02	**8.55**	

Table 6, continued

TO_WTH[b]	0.98	14.80	12.25	6.42	1.09	2.72	23.34	3.11	8.42	0.14		**73.26**
Net	**-1.03**	**0.82**	**0.54**	**-0.24**	**-0.63**	**-0.13**	**2.02**	**-0.41**	**0.05**	**-1.00**		
Spillover band: 0.10 to 0.00; corresponds to enduring-term thus month and beyond (32 days to infinite days)												
GSE	1.39	17.42	14.85	6.56	0.81	3.57	27.83	2.86	27.83	0.46	**8.58**	**9.88**
GHS	1.54	16.62	16.91	5.40	0.76	3.37	27.14	2.37	27.14	0.33	7.08	8.15
Aluminium	0.77	17.80	15.41	7.39	0.90	3.25	28.11	3.39	28.11	0.09	7.25	8.35
Copper	0.67	17.80	15.40	7.42	0.87	3.26	28.20	3.35	28.20	0.11	8.05	9.26
Nickel	1.12	14.34	11.57	6.59	6.91	2.34	22.07	3.59	22.07	0.06	6.95	8.00
Zinc	1.19	7.27	5.21	2.81	3.14	38.70	10.65	1.18	10.65	14.75	5.05	5.82
Cocoa	1.01	18.04	15.24	7.79	0.93	2.97	10.53	3.61	28.23	0.04	6.02	6.93
Coffee	1.11	15.75	12.06	7.94	1.59	2.09	23.77	15.85	23.77	0.11	7.23	8.33
Corn	0.85	17.81	15.59	7.26	0.88	3.14	11.08	3.31	28.19	0.09	7.71	8.88
Cotton	0.73	17.15	14.02	7.75	0.91	3.58	26.92	3.56	26.92	3.55	8.41	9.68
TO_ABS[a]	0.90	14.34	12.09	5.95	1.08	2.76	22.29	2.72	22.29	1.61	**72.33**	
TO_WTH[b]	1.04	16.51	13.92	6.85	1.24	3.18	25.66	3.13	9.91	1.85		**83.29**
Net	**-7.68**	**7.26**	**4.83**	**-2.10**	**-5.87**	**-2.30**	**16.63**	**-4.51**	**0.90**	**-6.80**		

Source: Woode (2023)

Table 7: Spillover Connectedness Among Commodities, Exchange Rates, and the Nairobi Stock Exchange

Variables	NSE	KSH	Aluminium	Copper	Nickel	Zinc	Cocoa	Coffee	Corn	Cotton	FROM_ABS[a]	FROM_WTH[b]
Spillover band: 3.14 to 0.79; corresponds to intraweek or short-term (1 to 4 days)												
NSE	0.08	0.74	0.28	0.12	0.00	0.03	0.19	0.55	0.03	0.02	0.20	10.03
KSH	0.01	0.77	0.29	0.12	0.01	0.05	0.20	0.57	0.03	0.01	0.13	6.65
Aluminium	0.01	0.75	0.28	0.11	0.01	0.05	0.19	0.55	0.03	0.01	0.17	8.78
Copper	0.01	0.80	0.30	0.13	0.01	0.05	0.21	0.60	0.03	0.01	0.20	10.42
Nickel	0.01	0.78	0.29	0.12	0.07	0.05	0.20	0.57	0.03	0.01	**0.21**	**10.59**
Zinc	0.00	0.48	0.18	0.07	0.00	0.53	0.12	0.35	0.01	0.00	0.12	6.28
Cocoa	0.01	0.76	0.29	0.12	0.01	0.05	0.19	0.56	0.03	0.01	0.18	9.38
Coffee	0.01	0.77	0.29	0.12	0.01	0.05	0.20	0.57	0.65	0.01	0.15	7.66
Corn	0.00	0.23	0.09	0.04	0.00	0.01	0.07	0.65	0.03	0.01	0.06	3.20
Cotton	0.01	0.75	0.28	0.12	0.01	0.05	0.20	0.56	0.03	0.01	0.20	10.25
TO_ABS[a]	0.01	0.61	0.23	0.09	0.01	0.04	0.16	0.45	0.03	0.01	**1.63**	
TO_WTH[b]	0.45	31.06	11.76	4.72	0.30	2.00	8.12	22.92	1.41	0.51		**83.25**
Net	**-0.19**	**0.49**	**0.06**	**-0.12**	**-0.20**	**-0.08**	**-0.03**	**0.30**	**-0.04**	**-0.19**		
Spillover band: 0.79 to 0.10; corresponds to intermediate-term thus week to a month (4 to 32 days)												
NSE	0.63	5.99	2.25	0.93	0.06	0.28	1.56	4.46	0.25	0.15	1.59	9.96
KSH	0.10	6.31	2.38	0.97	0.07	0.41	1.65	4.66	0.27	0.10	1.06	6.63
Aluminium	0.10	6.14	2.30	0.92	0.07	0.41	1.56	4.46	0.27	0.08	1.40	8.76
Copper	0.10	6.53	2.48	1.03	0.06	0.41	1.74	4.89	0.27	0.11	1.66	10.37
Nickel	0.10	6.33	2.38	0.97	0.35	0.40	1.65	4.67	0.27	0.10	**1.69**	**10.53**
Zinc	0.02	3.90	1.50	0.57	0.20	4.51	0.96	2.85	0.11	0.05	1.02	6.35
Cocoa	0.10	6.21	2.33	0.94	0.07	0.41	1.58	4.55	0.27	0.09	1.50	9.35
Coffee	0.10	6.30	2.37	0.96	0.07	0.41	1.64	4.64	5.44	0.10	1.22	7.63
Corn	0.01	2.01	0.74	0.31	0.17	0.09	0.57	5.44	1.49	0.07	0.54	3.40
Cotton	0.08	6.15	2.32	0.95	0.06	0.38	1.63	4.54	0.27	0.07	1.64	10.23
TO_ABS[a]	0.07	4.96	1.88	0.75	0.08	0.32	1.30	3.66	0.23	0.08	**13.32**	

Table 7, continued

TO_WTH[b]	0.45	30.96	11.72	4.70	0.52	1.98	8.09	22.85	1.41	0.53		**83.21**
Net	**-1.52**	**3.89**	**0.47**	**-0.91**	**-1.60**	**-0.70**	**-0.20**	**2.44**	**-0.32**	**-1.55**		
Spillover band: 0.10 to 0.00; corresponds to enduring-term thus month and beyond (32 days to infinite days)												
NSE	7.48	27.54	10.44	4.27	0.36	1.54	7.09	20.30	1.29	1.29	7.39	9.01
KSH	0.49	30.21	11.42	4.66	0.32	1.94	7.90	22.30	0.46	0.46	5.08	6.19
Aluminium	0.51	30.37	11.84	4.86	0.36	2.05	7.87	22.12	0.38	0.38	6.98	8.51
Copper	0.46	30.11	11.04	4.47	0.28	1.82	7.88	22.39	0.52	0.52	7.57	9.23
Nickel	0.49	30.07	11.36	4.64	0.26	1.94	7.88	22.23	0.47	0.47	**8.04**	**9.80**
Zinc	3.97	17.22	5.81	2.26	1.97	26.57	4.06	11.73	9.46	9.46	5.70	6.95
Cocoa	0.50	30.26	11.59	4.75	0.34	1.98	7.94	22.28	0.44	0.44	7.35	8.96
Coffee	0.49	30.20	11.46	4.68	0.33	1.96	7.91	22.29	0.61	0.46	5.88	7.17
Corn	1.27	8.46	3.09	1.29	5.08	0.35	2.33	59.01	6.34	0.61	2.88	3.51
Cotton	0.40	29.76	11.24	4.59	0.33	2.34	7.74	21.96	1.91	1.91	7.96	9.71
TO_ABS[a]	0.86	23.40	8.74	3.60	0.94	1.59	6.07	17.17	1.41	1.41	**64.84**	
TO_WTH[b]	1.05	28.52	10.66	4.39	1.14	1.94	7.40	20.92	1.72	1.72		**79.04**
Net	**-6.53**	**18.32**	**1.76**	**-3.97**	**-7.10**	**-4.11**	**-1.28**	**11.29**	**-1.81**	**-6.56**		

Source: Woode (2022)

Table 8: Spillover Connectedness Among Commodities, Exchange Rates, and Namibian Stock Exchange

Variables	NASE	NAD	Aluminium	Copper	Nickel	Zinc	Cocoa	Coffee	Corn	Cotton	FROM_ABS[a]	FROM_WTH[b]
Spillover band: 3.14 to 0.79; corresponds to intraweek or short-term (1 to 4 days)												
NASE	0.16	0.42	0.23	0.45	0.00	0.02	0.23	0.02	0.10	0.05	0.15	8.85
NAD	0.13	0.40	0.23	0.43	0.00	0.02	0.23	0.02	0.10	0.05	0.12	6.96
Aluminium	0.13	0.47	0.25	0.49	0.00	0.02	0.25	0.02	0.11	0.04	0.15	8.89
Copper	0.13	0.25	0.15	0.28	0.00	0.01	0.16	0.01	0.11	0.05	0.08	4.85
Nickel	0.12	0.40	0.22	0.42	0.38	0.02	0.22	0.02	0.10	0.04	0.16	9.00
Zinc	0.12	0.44	0.24	0.46	0.00	0.09	0.23	0.02	0.10	0.04	0.17	9.65
Cocoa	0.12	0.53	0.28	0.55	0.00	0.02	0.28	0.02	0.13	0.04	**0.17**	**9.86**
Coffee	0.13	0.43	0.24	0.46	0.00	0.02	0.24	0.06	0.11	0.04	0.17	9.70
Corn	0.13	0.45	0.25	0.11	0.00	0.02	0.24	0.02	0.47	0.04	0.16	9.42
Cotton	0.13	0.40	0.22	0.43	0.00	0.02	0.21	0.02	0.10	0.39	0.15	8.89
TO_ABS[a]	0.11	0.38	0.21	0.42	0.00	0.02	0.20	0.01	0.09	0.04	**1.48**	
TO_WTH[b]	6.60	21.99	11.99	24.24	0.10	1.06	11.67	0.83	5.28	2.32		**86.09**
Net	**-0.04**	**0.26**	**0.05**	**0.33**	**-0.15**	**-0.15**	**0.03**	**-0.15**	**-0.07**	**-0.11**		
Spillover band: 0.79 to 0.10; corresponds to intermediate-term thus week to a month (4 to 32 days)												
NASE	0.16	3.47	1.93	3.71	0.02	0.16	1.93	0.14	0.85	0.38	1.26	8.92
NAD	0.13	3.32	1.88	3.58	0.02	0.16	1.86	0.13	0.82	0.38	0.99	7.03
Aluminium	0.13	3.85	2.10	4.05	0.02	0.19	2.06	0.14	0.91	0.37	1.26	8.95
Copper	0.13	2.05	1.29	2.36	0.01	0.11	1.31	0.12	0.89	0.41	0.70	4.93
Nickel	0.12	3.29	1.80	3.50	2.02	0.14	1.80	0.12	0.80	0.36	1.28	9.08
Zinc	0.12	3.64	2.00	3.83	0.04	0.73	1.93	0.13	0.86	0.32	1.37	9.73
Cocoa	0.12	4.35	2.33	4.54	0.02	0.20	2.34	0.14	1.03	0.34	**1.40**	**9.91**
Coffee	0.13	3.57	1.98	3.80	0.03	0.18	1.96	0.49	0.87	0.35	1.38	9.81
Corn	0.13	3.69	2.02	0.89	0.02	0.18	2.00	0.13	3.91	0.37	1.34	9.49
Cotton	0.13	3.30	1.82	3.50	0.02	0.20	1.75	0.14	0.78	3.14	1.26	8.93
TO_ABS[a]	0.11	3.12	1.70	3.44	0.02	0.15	1.66	0.12	0.75	0.33	**12.24**	

Table 8, continued

TO_WTH[b]	6.60	22.13	12.08	24.40	0.13	1.08	11.77	0.83	5.31	2.34		**86.76**
Net	**-0.31**	**2.13**	**0.44**	**2.75**	**-1.26**	**-1.22**	**0.26**	**-1.27**	**-0.59**	**-0.93**		
Spillover band: 0.10 to 0.00; corresponds to enduring-term thus month and beyond (32 days to infinite days)												
NASE	6.48	21.59	11.99	22.97	0.11	1.11	11.85	0.88	5.24	2.22	7.80	9.26
NAD	6.85	21.43	12.11	23.00	0.10	1.05	12.04	0.82	5.35	2.42	6.37	7.57
Aluminium	5.65	22.66	11.62	23.29	0.09	1.08	11.49	0.75	4.91	1.95	7.19	8.54
Copper	10.25	17.50	12.93	21.90	0.16	0.99	13.48	1.35	5.04	4.35	6.77	8.04
Nickel	6.67	20.70	16.64	22.24	1.06	1.02	11.62	0.80	5.13	2.38	8.22	9.76
Zinc	6.13	21.60	11.49	22.25	0.23	2.59	11.17	0.86	4.83	2.63	8.12	9.65
Cocoa	4.88	23.41	11.28	23.18	0.08	1.10	10.93	0.68	4.57	1.61	7.08	8.41
Coffee	5.76	21.81	11.86	22.88	0.17	1.31	11.61	1.62	5.11	1.81	**8.23**	**9.78**
Corn	6.04	22.30	11.82	5.04	0.09	1.06	11.65	0.74	23.19	2.06	7.90	9.38
Cotton	5.54	19.44	10.67	20.57	0.25	2.52	10.51	1.34	4.63	6.88	7.55	8.97
TO_ABS[a]	5.78	19.10	10.58	20.36	0.13	1.12	10.54	0.82	4.64	2.14	**75.22**	
TO_WTH[b]	6.87	22.69	12.57	24.18	0.15	1.34	12.52	0.98	5.51	2.55		**89.36**
Net	**-2.02**	**12.73**	**3.39**	**13.59**	**-8.09**	**-7.00**	**3.46**	**-7.41**	**-3.26**	**-5.40**		

Source: Woode (2023)

Table 9: Spillover Connectedness for Commodities, Exchange Rates, and the Johannesburg Stock Exchange

Variables	JSE	ZAR	Aluminium	Copper	Nickel	Zinc	Cocoa	Coffee	Corn	Cotton	FROM_ABS[a]	FROM_WTH[b]
Spillover band: 3.14 to 0.79; corresponds to intraweek or short-term (1 to 4 days)												
JSE	0.06	0.92	0.36	0.19	0.00	0.03	0.18	0.01	0.63	0.00	0.23	9.83
ZAR	0.06	0.91	0.36	0.19	0.00	0.03	0.18	0.01	0.63	0.00	0.15	6.14
Aluminium	0.07	0.94	0.37	0.20	0.00	0.03	0.18	0.01	0.65	0.00	0.21	8.77
Copper	0.06	0.92	0.36	0.19	0.00	0.03	0.18	0.01	0.63	0.00	0.22	9.26
Nickel	0.06	0.91	0.36	0.19	0.01	0.03	0.18	0.01	0.63	0.00	**0.24**	**10.00**
Zinc	0.05	0.90	0.36	0.19	0.00	0.02	0.18	0.01	0.62	0.00	0.23	9.80
Cocoa	0.05	0.89	0.35	0.18	0.00	0.03	0.17	0.01	0.61	0.00	0.21	9.02
Coffee	0.06	0.91	0.36	0.19	0.00	0.03	0.18	0.01	0.63	0.00	0.23	9.92
Corn	0.06	0.91	0.36	0.19	0.00	0.03	0.18	0.01	0.63	0.00	0.17	7.31
Cotton	0.06	0.91	0.36	0.19	0.00	0.03	0.18	0.01	0.62	0.00	0.24	9.95
TO_ABS[a]	0.05	0.82	0.32	0.17	0.00	0.03	0.16	0.01	0.57	0.00	**2.13**	
TO_WTH[b]	2.16	34.69	13.59	7.17	0.07	1.19	6.75	0.40	23.93	0.05		**90.01**
Net	**-0.18**	**0.68**	**0.11**	**-0.05**	**-0.24**	**-0.20**	**-0.05**	**-0.23**	**0.39**	**-0.23**		
Spillover band: 0.79 to 0.10; corresponds to intermediate-term thus week to a month (4 to 32 days)												
JSE	0.51	7.42	2.91	1.53	0.02	0.26	1.43	0.09	5.11	0.01	1.88	9.83
ZAR	0.45	7.35	2.90	1.52	0.02	0.25	1.43	0.09	5.07	0.01	1.17	6.15
Aluminium	0.54	7.57	2.98	1.58	0.01	0.24	1.48	0.06	5.25	0.01	1.67	8.77
Copper	0.46	7.41	2.92	1.54	0.01	0.25	1.44	0.08	5.11	0.01	1.77	9.26
Nickel	0.45	7.37	2.90	1.53	0.06	0.25	1.43	0.08	5.08	0.01	**1.91**	**10.00**
Zinc	0.44	7.31	2.87	1.52	0.01	0.16	1.42	0.09	5.04	0.01	1.87	9.80
Cocoa	0.42	7.20	2.83	1.48	0.02	0.26	1.37	0.10	4.94	0.01	1.72	9.03
Coffee	0.46	7.34	2.89	1.52	0.01	0.25	1.42	0.04	5.06	0.01	1.89	9.92
Corn	0.45	7.33	2.89	1.52	0.02	0.26	1.42	0.09	5.05	0.01	1.40	7.31
Cotton	0.46	7.33	2.88	1.52	0.01	0.25	1.43	0.08	5.05	0.01	1.90	9.96
TO_ABS[a]	0.41	6.63	2.60	1.37	0.01	0.23	1.29	0.08	4.57	0.01	**17.20**	

Table 9, continued

TO_WTH[b]	2.16	34.69	13.60	7.18	0.07	1.19	6.75	0.40	23.93	0.05		**90.02**
Net	**-1.47**	**5.45**	**0.92**	**-0.40**	**-1.90**	**-1.64**	**-0.44**	**-1.82**	**3.18**	**-1.89**		
Spillover band: 0.10 to 0.00; corresponds to enduring-term thus; month and beyond (32 days to infinite days)												
JSE	1.63	30.32	11.86	6.22	0.07	1.11	5.84	0.40	20.81	0.06	7.67	9.77
ZAR	1.84	30.24	11.92	6.28	0.06	1.05	5.88	0.36	20.87	0.05	4.83	6.15
Aluminium	2.60	30.23	11.44	6.01	0.04	0.87	5.67	0.21	20.73	0.04	6.64	8.45
Copper	1.92	30.26	11.85	6.23	0.06	1.02	5.84	0.32	20.84	0.04	7.22	9.19
Nickel	1.87	30.22	11.91	6.27	0.05	1.04	5.87	0.35	20.85	0.05	**7.84**	**9.99**
Zinc	1.84	30.13	11.92	6.29	0.08	1.30	5.89	0.38	20.86	0.10	7.75	9.87
Cocoa	1.63	30.17	12.15	6.43	0.08	1.12	6.01	0.48	20.95	0.07	7.31	9.30
Coffee	2.02	30.15	11.91	6.26	0.07	1.02	5.85	0.55	20.80	0.04	7.81	9.95
Corn	1.81	30.21	11.96	6.31	0.07	1.06	5.90	0.38	20.88	0.05	5.77	7.35
Cotton	1.83	30.21	11.90	6.25	0.06	1.11	5.85	0.34	20.82	0.24	7.84	9.98
TO_ABS[a]	1.74	27.19	10.74	5.63	0.06	0.94	5.26	0.32	18.75	0.05	**70.68**	
TO_WTH[b]	2.21	34.62	13.67	7.17	0.08	1.20	6.70	0.41	23.88	0.06		**90.00**
Net	**-5.92**	**22.36**	**4.10**	**-1.58**	**-7.78**	**-6.81**	**-2.05**	**-7.49**	**12.98**	**-7.79**		

Source: Woode (2023)

The results from Table 4 exhibit a progressive escalation of volatility propagation within the system. Consequently, the systemic dissemination of risk pertaining to the overall market transitioned from 47.57% during the immediate period to 56.44% in the intermediate term, whereas the long-term period displayed the highest degree of transmission, reaching a substantial value of 90.29%. This suggests that the transmission of risk transpiring over extended time horizons (ranging from 32 days to an indeterminate length) represents the predominant element among the three frequency bands, constituting the majority of the total spillovers.

The values presented in rows symbolise the fraction of variability in the predicted error for all the sampled variables, while the column-wise values show the proportion of variance in projected errors in one variable that is accounted for by another. The vast majority of short-term market-wise risk transmissions appeared to be insignificant, with only a few intrinsic risk transmissions being comparatively significant. In particular, the nickel, cotton, NSE, coffee, zinc, GHS, and GSE markets possessed a slight transmission of approximately 5.62%, 1.21%, 0.34%, 0.33%, 0.19%, and 0.11%, respectively. The short-term intrinsic spillover effect supports the distinct claims made by prior studies (Bossman et al., 2022; Owusu Junior et al., 2020) that risk originating from one segment of the market not only migrates into another but periodically endures in the emanating market.

Moreover, in the short-term analysis, it was revealed that aluminium (-0.005), nickel (-0.014), zinc (-0.009), coffee (-0.012), BSP (-0.02), NAD (-0.04), ZAR (-0.03), NSE (-0.01), NASE (-0.01), and JSE (-0.01) were all recipients of net

shocks within the system, while other variables such as copper (0.016), cocoa (0.011), corn (0.007), cotton (0.001), GHS (0.017), KSH (0.032), BSE (0.030), and GSE (0.026) acted as transmitters of shocks. Consequently, those markets identified as recipients of net shocks are the most susceptible within the system, particularly in the short term. Therefore, within a portfolio encompassing the sampled assets, it is imperative to regard these markets as high-risk assets due to their vulnerability to external shocks. Conversely, those markets characterised as net risk transmitters represent potential assets capable of absorbing shocks stemming from external events.

Similarly, the outcomes of the intermediate-term analysis (spanning from 0.79 to 0.10) exhibited slightly superior results compared to the short-term. Within the system, a combination of significant and insignificant pairwise volatility transmissions occurred, resulting in an overall systemic volatility of 56.44%. Notably, the nickel, cotton, and coffee markets were individually impacted by their own risks to the extent of 31.04%, 10.17%, and 2.78%, respectively. For example, the medium-term persistence in the nickel market escalated from 5.62% to 31.04%, signifying a significant change. Furthermore, the list of risk transmitters and recipients in the short term retains their respective positions in the medium term; the disparity lies in the magnitude of transmission. Similarly, the currency market of Namibia (NAD) emerges as the primary transmitter and receiver of shocks in the medium term.

In a comparative analysis, the long-term examination yielded characteristics reminiscent of contagion, marked by a multitude of bidirectional transmissions

within the system. When scrutinised, the long-term can be defined as a period of heightened risk transmission, evident through the combination of volatility transmission and persistence observed in nearly all sampled markets, save for a few exceptions. Based on the aforementioned findings, the concept of contagion can be further elucidated as the inter-market dissemination of shocks, resulting in a broader and more interconnected crisis or disruption within the system. Given the extent of interconnectedness observed, particularly in the long term, the only plausible interpretation is that explained above. In the long term, the sampled market exhibits a level of interconnectedness to an extent where the notion of a safe haven (hedge) becomes implausible amid turbulence (normal) market conditions.

Among the pairwise combinations, the highest level of risk transmission was observed in the fusion of the BSE market, exhibiting an intensified level of both risk transmission and absorption. Conversely, the combination involving the zinc market recorded the lowest pairwise transmission of volatility within the system, with the least transmission observed between zinc and nickel. Overall, the extent of transmission observed in the long term reinforces the notion of contagion, characterised by multiple levels of bidirectional transmission.

In a similar vein, aluminium (5.64) emerged as the foremost transmitter and recipient of total shocks within the system, while nickel (4.13), conversely, emerged as the least receiver of overall shocks. Furthermore, the list of entities that predominantly receive shocks within the system includes aluminium (-2.476), copper (-1.578), zinc (-4.297), coffee (-3.807), corn (-0.66), NAD (-3.51), ZAR (-3.08), NSE (-3.80), NASE (-1.61), and JSE (-4.01), while the remaining markets,

including nickel (1.568), cocoa (0.754), cotton (3.002), BSP (1.315), GHS (0.505), KSH (8.372), BSE (10.76), and GSE (2.802) function as disseminators of shocks. Zinc stood out as the primary recipient of net shocks from the system, while BSE emerged as the primary transmitter of net shocks within the system. Interestingly, the list of net shock transmitters and receivers underwent slight alterations in the long term, with copper and corn relinquishing their respective roles as shock transmitters, while nickel and BSP gained impetus in assuming the mantle of shock transmitters within the system.

Remarkably, the most advanced SSA equity markets included in the sample, namely JSE and NASE, along with their corresponding currencies, ZAR and NAD, served as net recipients within the system. These intriguing findings can be attributed to their elevated level of exposure, owing to the expanded scope of their market, which encompasses domestic and foreign risk and is driven by investor participation and the strength of their currencies. The plausibility of these findings is contingent upon the frequency of repatriations from these markets, especially the JSE, by foreign investors in the short term, as earlier highlighted (JSE, 2022). Consequently, such activities are likely to generate adverse volatility effects on these markets in the form of demand and supply shocks, exacerbated by prevailing uncertainty. To elucidate the top-performing SSA country within the sampled markets and comprehend the performance of individual equity markets concerning other relevant variables, we devised a system resembling a portfolio for each country. This approach enabled us to more accurately identify the actual sources and recipients of volatility shocks within each country.

Table 5 presents a concise overview of how risks spread within the specific sub-market of Botswana over various timeframes. In contrast to the findings in the overall market under examination in Table 4, the outcomes within the Botswana context demonstrate a blend of both forward and backward escalation in the propagation of market volatility within the sub-system. Consequently, the dissemination of systemic risk pertaining to the overall market has transitioned from 89.94% during the immediate period to 90% in the intermediate term. The long-term period, on the other hand, exhibited the lowest degree of overall connectedness in terms of transmission yet had a significant value of 89.30%. This suggests a nearly equal transmission of risk from the short to the long term. Despite these findings, the most noteworthy disparity among these distinct timeframes lies in the bilateral transmission, wherein there was a progressive propagation of risk across the entire market, with the extended time horizons (spanning from 32 days to an unspecified length) serving as the dominant element among the three frequency bands and constituting the majority of the total spillovers.

The vast majority of short-term market-wise risk transmissions appeared to be insignificant, with only a few intrinsic risk transmissions being comparatively significant. Comparatively, there was an insignificant transmission of risk from all the sampled markets into the respective markets of nickel, zinc, coffee, cotton, and BSE. Nevertheless, there was a slightly significant transmission of risk from other markets into the respective markets of BSP, aluminium, and corn. The highest pairwise transmission (0.77%) was recorded between copper and BSP, with copper acting as the transmitter.

Moreover, in the short-term analysis, cotton (10.40%) served as the highest receiver of shocks from other markets in the system, including shocks originating from its own market, while it emerged together with BSE and coffee as the highest receiver (0.22%) of shocks only from other markets in the system without those originating from their respective markets. On the other hand, BSP (29.05%) emerged as the prime transmitter of overall shocks, both inherent and towards other markets in the Botswanan sub-system, while cotton (0.00%) served as the least transmitter of the same. It was further revealed that BSE (-0.195), nickel (-0.221), zinc (-0.193), cocoa (-0.071), coffee (-0.192), and cotton (-0.224) were all recipients of net shocks within the Botswanan system, while the remaining markets, including BSP (0.475), aluminium (0.212), copper (0.043), and corn (0.335), acted as net transmitters of shocks.

Similarly, the outcomes of the intermediate-term analysis exhibited slightly superior results compared to the short-term. Within the system, a combination of significant and insignificant pairwise volatility transmissions occurred, resulting in the comparatively highest (90%) systemic volatility transmissions. Notably, the BSP (5.94%), cotton (4.91%), and copper (2.49%) markets were respectively impacted by shocks originating from their own markets. This further supports the earlier assertions on volatility persistence.

Moreover, similar to the short-term pairwise risk transmission, the BSP, aluminium, copper, cocoa, and corn markets exhibited the most significant pairwise transmission when they respectively acted as harbours of transmission for all the sampled markets. The magnitude of transmission in the intermediate term is

relatively significant compared to the short term, while the direction of internal transmission appears to be consistent. Furthermore, cotton (10.41%) retained its role as the highest recipient of systemic risk, including those originating from its market, yet this does not place BSE (10.28%), nickel (10.38%), or coffee (10.33%) far off the list of recipients of systemic risk. On the other hand, BSP (29.07%) and cotton (0.00%) maintained their respective highest and lowest overall transmission capacities into the system, including those transmitted into their markets.

In a comparative analysis, the long-term examination yielded multitudes of bidirectional transmissions within the system, except for zinc and cotton. Nevertheless, the cotton and zinc markets, respectively, transmitted significant risk into all other markets except for the nickel (0.59%) and cotton (0.82%) markets in the case of zinc and nickel (0.46%) and zinc (0.60%) in the case of cotton. When scrutinised, the long-term can be defined as a period of heightened pairwise risk transmission, evident through the combination of volatility transmission and persistence observed in nearly all sampled markets, except for the few mentioned exceptions.

Additionally, among the pairwise combinations, the highest level of risk transmission was observed in the fusion of the BSP market, exhibiting an intensified level of both risk transmission and absorption within the system, with the exception being its transmissions into the cotton (0.00%), nickel (0.47%), and zinc (0.56%) markets. Conversely, there was a significant transmission of risk from all the sampled markets into BSP, including those evident as unidirectional risk transmitters. Additionally, the combination involving the cotton market recorded

the lowest pairwise transmission of volatility within the system, with the least transmission (0.00%) recorded between the pairwise transmissions from BSE, BSP, nickel, cocoa, and corn into the cotton market. Overall, the extent of transmission observed in the long term partially reinforces the notion of contagion, characterised by multiple levels of bidirectional transmission with a few exceptions.

In a similar vein, cotton maintained its respective roles as both the foremost recipient (9.88%) and the least transmitter (0.19%) of shocks into the system, including those originating from its own market, while BSP, conversely, emerged both as the highest transmitter (28.50%) and the least recipient (6.67%) of the overall shocks in the system, which includes shocks transmitted into its own markets. Similarly, cotton (-7.79) stood out as the primary recipient of net shocks from the system, while the BSP (17.54) emerged as the primary transmitter of net shocks within the system, closely followed by the corn market (13.36). Similarly, the list of net shock transmitters and receivers within the system maintained their respective positions in direction but with varying magnitudes.

Furthermore, it is rather overwhelming to acknowledge that the BSP and commodities (aluminium, copper, and corn) emerged as transmitters of shocks, considering the substantial reliance of the Botswanan economy on the aforementioned. According to prior studies (Bolokwe & Sedimo, 2021; Workman, 2022), a substantial proportion of Botswana's total exports comprise metallic products, while the mineral sectors occupy approximately 80% of the country’s equity market capitalisation. Thus, considering such heavy dependence, one could agree with the rationale behind these assets’ shock-transmitting capacity. This also

implies that shocks originating from these markets are likely to impact the equity market, which is in line with the shock transmission assertions of the fractal market hypothesis (Moradi et al., 2021) and those of the predictive capacity as emphasised in the APT (Ouma & Muriu, 2014; Sokhanvar & Bouri, 2023; Siddiqui & Roy, 2019).

The currency market, on the other hand, emerged as the highest net transmitter of risk, while unsurprisingly, cotton simultaneously emerged as the highest net receiver of the same. Despite these developments, there was a weak overall pairwise transmission of risk within the Botswanan sub-system, especially over the short term, which can be attributed to the relatively weak sensitivity to external shocks and information in the short term, as earlier established, despite the augmented level of information transmission.

Table 6 provides a succinct overview of how risks propagate within the specific sub-market of Ghana across different timeframes. Analogous to the broader markets under examination, the findings demonstrate a gradual intensification of volatility dissemination within the system. Consequently, the systemic diffusion of risk concerning the overall market evolved from 69.12% during the immediate timeframe to 73.26% in the intermediate term, while the long-term duration exhibited the highest level of transmission, attaining a substantial magnitude of 83.29%. This implies that the transference of risk occurring over extended scopes represents the dominant factor among the three frequency bands.

The majority of short-term pairwise risk transmissions were deemed inconsequential, with only a handful of inherent risk transmissions exhibiting

relative significance. However, there was a slightly notable transmission of risk from other markets to the respective markets of GHS, aluminium, cocoa, and corn. The highest pairwise transmission (0.44%) occurred between GSE, GHS, and cocoa, with cocoa assuming the role of the recipient for shocks. Furthermore, GSE (9.24%) emerged as the primary recipient of shocks from other markets within the system, encompassing shocks originating from its own market. Additionally, GSE (0.14%) also stood out as the highest recipient of shocks solely from all other markets in the system, excluding those originating from its own market.

Conversely, cocoa (22.1%) assumed the role of the predominant transmitter of overall shocks, both originating within the Ghanaian sub-system and directed towards other markets. In contrast, cotton (0.06%) exhibited the least transmission of such shocks. It was further observed that GSE (-0.12), copper (-0.03), coffee (-0.05), cotton (-0.12), nickel (-0.08), and zinc (-0.01) all experienced net inflows of shocks within the Ghanaian system, while the remaining markets, namely GHS (0.10), aluminium (0.06), cocoa (0.24), and corn (0.05), acted as net transmitters of shocks. Also, the cocoa market displayed the highest magnitude of net risk transmission, whereas GSE concurrently exhibited the highest net risk reception. However, despite these dynamics, the Ghanaian sub-system demonstrated a feeble overall pairwise transmission of risk over the short term.

Similarly, the findings of the intermediate-term analysis presented marginally more favourable outcomes in comparison to the short-term analysis. Within the system, a blend of significant and insignificant pairwise volatility transmissions took place, resulting in relatively higher levels of systemic volatility

transmissions (73.26%). Notably, the nickel (12.77%), zinc (5.23%), corn (3.39%), coffee (2.83%), and GHS (2.17%) markets experienced the impact of shocks originating from their respective markets.

Furthermore, akin to the short-term pairwise risk transmission, the GHS, aluminium, cocoa, and corn markets demonstrated the most notable pairwise transmissions when they served as conduits for transmitting risk from all the sampled markets. Also, the GSE continues to uphold its position as the most significant recipient of systemic risk, encompassing both internal and external sources, with a magnitude of 9.77%. Conversely, cocoa (23.34%) maintains its prominent role as the highest overall transmitter of risk, while cotton (0.14%) retains its position as the lowest transmitter across the system, inclusive of transmissions within their respective markets. Notably, the list of net-risk transmitters and recipients remains consistent between the short-term and medium-term analyses, with the disparity embedded in the magnitude of transmission. Similarly, cocoa (2.02) retains its status as the primary net transmitter of risk, while GSE (-1.03) also maintains its position as the primary net receiver of shocks within the system.

In a comparative analysis, the long-term assessment revealed numerous instances of bidirectional transmissions within the system, except for the cotton and nickel markets. Consequently, the cotton and nickel markets transmitted significant shocks to all other markets, except for cotton (0.06%) in the case of nickel and the GSE (0.73%) in the case of cotton. Upon close examination, the long-term period can be characterised as a phase of heightened pairwise risk transmission, as

evidenced by the combined presence of volatility transmission and persistence in nearly all sampled markets, except for the aforementioned markets. Also, among the various pairwise combinations, the cocoa and the GHS markets demonstrated the highest level of risk transmission, displaying an intensified degree of both risk transmission and absorption within the system.

In contrast, there was a notable transmission of risk from all the sampled markets into both the corn and the GHS markets, encompassing instances where the transmission occurred unidirectionally. Additionally, the blend involving the market of cotton (0.04%) exhibited the lowest pairwise transmission of volatility within the system, with the minimum transmission rate observed in the transmission from cocoa to the cotton market. Similar to the intermediate-term findings, zinc (38.7%), corn (28.19%), GHS (16.62%), coffee (15.85%), aluminium (15.41%), cocoa (10.53%), and copper (7.42%) were respectively influenced by shocks originating within their own markets.

In a similar vein, GSE maintained its respective roles as both the foremost recipient of total shocks (9.88%) and the least transmitter shocks (1.04%) into the system, including those originating from its own market, while cocoa (25.66%), conversely, emerged both as the highest transmitter of shocks and the least recipient of same in the system, which includes shocks transmitted into its own markets. Similarly, the list of net shock transmitters and receivers within the system maintained their respective positions not only in direction but with diverse magnitudes. For instance, GSE (-7.68), cotton (-6.80), nickel (-5.87), coffee (-4.51), zinc (-2.30), and copper (-2.10) were all recipients of net shocks within the

Ghanaian sub-system, while the remaining markets, including cocoa (16.63), GHS (7.26), aluminium (4.83), and corn (0.90), acted as net transmitters of shocks.

Furthermore, it is intriguing to acknowledge that GHS and commodities (aluminium, cocoa, and corn) emerged as transmitters of shocks, considering the substantial reliance of the Ghanaian economy on the aforementioned. Based on recent data provided by the global export hub by Workman (2022), Ghana's merchandise achieved an approximate value of US$12.75 billion in 2021. Among these commodities, the top ten consisted primarily of industrial and precious metals, amounting to $3.73 billion, and cocoa beans, paste, and butter, totalling $2.8 billion. The division of these prominent exports into metal and cocoa, constituting 29.1% and 22%, respectively, accounted for a cumulative 51.1% of the overall export earnings, as was additionally disclosed. These reports were further validated by the merchandise trade flow report from the Bank of Ghana. According to the Bank of Ghana (2022), the export of cocoa and metallic products in the aforementioned year accounted for $2.23 billion and $6.61 billion, respectively.

Furthermore, according to the World Integrated Trade Solutions (2022), an extension of the World Bank's trade and tariff hub, maize constituted a noteworthy export for Ghana. Specifically, in 2021, a total of 250,000 kilograms of maize were exported to countries within the SSA region, including Niger, Sierra Leone, and the Congo Republic. Contrarily, as highlighted by Ramji, Wairimu, Mwita, and Mwanyasi (2021), the cumulative impact of the nation's foreign and domestic capital, alongside its domestic equity markets, yields a substantial contribution amounting to approximately 19.24% and 8.03% of the country's GDP, respectively,

accompanied by a rising market capitalisation of $12.68 billion. Notably, the equity market in Ghana demonstrates a notable concentration of firms primarily associated with the mining and agricultural sectors. Consequently, alterations in the operations and activities of these particular sectors exert a consequential influence on the broader equity market.

Likewise, given the nation's substantial reliance on such commodities and the concurrent dependence of various listed firms within the equity markets on imports, particularly those operating in the food and beverage sector such as Samba Ghana, Guinness Ghana Breweries, Hords, and Unilever Ghana Limited, among others, one can concur with the reasoning behind the risk and shock propagation potential of the local currency and the aforementioned commodities. This also implies that shocks originating from these markets are likely to reverberate within the equity market, aligning with the assertions regarding shock transmissions.

Table 7 provides a succinct overview of how risks propagate within the specific sub-market of Kenya across different timeframes. Comparable to the wider scope of markets analysed, the results illustrate a diminishing escalation of volatility propagation within the system. As a result, the systemic dispersion of risk pertaining to the overall market decreased from 83.25% during the immediate period to 83.21% in the intermediate term, with the long-term duration displaying the lowest level of transmission, reaching a significant magnitude of 79.04%.

Notwithstanding, the majority of short-term interrelated risk transmissions were deemed insignificant, with only a few instances of inherent risk transmissions displaying relative significance. However, there was a slightly noteworthy

transmission of risk from other markets to the respective markets of KSH, aluminium, copper, cocoa, and coffee. Furthermore, nickel (10.59%) emerged as the primary recipient of shocks from other markets within the system, encompassing shocks originating from its market. Conversely, KSH (31.06%) assumed the role of the predominant transmitter of overall shocks, both originating within the sub-system and directed towards other markets. In contrast, nickel (0.30%) exhibited the least transmission of such shocks. Additionally, it was observed that nickel (-0.20), NSE (-0.19), cotton (-0.19), copper (-0.12), zinc (-0.08), corn (-0.04), and cocoa (-0.03) all experienced net inflows of shocks within the Kenyan system, while the remaining markets, namely KSH (0.49), coffee (0.30), and aluminium (0.06), acted as net transmitters of shocks.

Similarly, the outcomes of the intermediate-term analysis yielded marginally more favourable results when compared to the short-term analysis. Within the overall system, a combination of consequential and inconsequential pairwise transmissions of volatility occurred, leading to relatively elevated levels of systemic volatility transmissions (83.21%). Notably, the KSH (6.31%), coffee (4.64%), and zinc (4.51%) markets were impacted by shocks originating from their respective markets. Additionally, similar to the short-term pairwise risk transmission, the KSH, aluminium, copper, cocoa, and coffee markets demonstrated prominent pairwise transmissions as they served as conduits for transmitting risk from all the sampled markets. Consequently, the magnitude of transmission during the intermediate term assumes greater significance compared to the short term.

Furthermore, nickel (10.53%) continues to assert its significance as the preeminent recipient of systemic risk, encompassing both internal and external origins. Following closely are copper (10.37%), cotton (10.23%), and NSE (9.96%) as the subsequent recipients within this triumvirate. In contrast, KSH (30.96%) maintains its prominent role as the foremost overall transmitter of risk, while NSE (0.45%) retains its position as the lowest transmitter across the system, encompassing transmissions within their respective markets. Notably, the list of net-risk transmitters and recipients remains consistent between the short-term and medium-term analyses, with the discrepancy manifesting in the magnitude of transmission. Similarly, KSH (3.89) upholds its status as the primary net transmitter of risk, while nickel (-1.60) also preserves its position as the principal net receiver of shocks within the system.

In a comparative analysis, the long-term evaluation revealed numerous instances of reciprocal transmissions within the system, except for the corn and nickel markets. Consequently, the nickel and corn markets disseminated substantial shocks to all other markets, except for the NSE (0.49%), corn (0.47%), and cotton (0.47%) in the case of nickel, and cotton (0.61%) and zinc (0.35%) in the case of corn. Except for the aforementioned markets, nearly all sampled markets exhibit concurrent volatility transmission and persistence, which indicates that the long-term period is a phase of increased pairwise risk transmission. Among the various pairwise combinations, the KSH and the coffee market exhibited the highest level of risk transmission, showcasing an intensified degree of both risk transmission and

absorption within the system. However, it is important to note that their transmissions into the cotton and zinc markets deviated from this pattern.

Additionally, the highest level of risk transmission was observed in the fusion of the NSE market, with the exception being its transmission into the zinc markets (0.36%). In contrast, there was a notable transmission of risk from all the sampled markets into the aluminium, cocoa, coffee, copper, and KSH markets. Additionally, the combination involving the market of copper and nickel (0.28%) exhibited the lowest pairwise transmission of volatility within the system. Similar to the intermediate-term findings, KSH (30.21%), zinc (26.57%), coffee (22.29%), and aluminium (11.84%) were respectively influenced by shocks originating within their own markets.

Similarly, nickel (9.80%) and corn (3.51%) emerged as the primary and least receivers of perturbations in the system, encompassing shocks originating from both their respective markets and external sources. Conversely, KSH (28.82%) and NSE (1.05%) emerged as the most significant and least influential transmitters of overall risk into the system, which includes the propagation of shocks into their respective markets. Moreover, the hierarchy of net shock transmitters and recipients within the system remained consistent in terms of direction, albeit with varying degrees of magnitude. Notably, nickel (-7.10), cotton (-6.56), NSE (-6.53), zinc (-4.11), copper (-3.97), corn (-1.81), and cocoa (-1.28) were all recipients of net shocks within the Kenyan sub-system, while KSH (18.32), coffee (11.29), and aluminium (1.76) served as net transmitters of shocks.

Moreover, it is rather formidable to acknowledge the emergence of KSH, coffee, and aluminium as significant transmitters of perturbations within the Kenyan sub-system. Insight from recent data presented by Workman (2022) through the global export hub revealed that Kenya's merchandise export recorded a substantial value of approximately US$7.4 billion in 2022, representing an increase from its previous value of $6.74 billion in 2021. Notably, among the prominent commodities driving these values were tea and coffee, contributing a combined worth of $1.7 billion, and metals, with a value of $230 million. The classification of these key exports into the beverage and metal sectors, accounting for 23.4% and 3.11%, respectively, collectively constituted 26.51% of the overall export earnings, as reported. Furthermore, considering the nation's significant dependence on such commodities, coupled with the recent devaluation of the local currency by 7.5% and 16.4% in 2021 and 2022, respectively, one can further comprehend the risk-transmitting capacity inherent in these markets. Consequently, shocks originating from these markets are likely to reverberate within the equity market, aligning with the assertions regarding shock transmission outlined in the fractal market hypothesis (Moradi et al., 2021).

Table 8 provides a concise overview of how risks propagate within the specific sub-market of Namibia across various timeframes. Similar to the broader markets under investigation, the findings demonstrate a gradual amplification of volatility diffusion within the system. Consequently, the systemic dispersion of risk relative to the overall market evolved from 86.09% in the short term to 89.36% in the long-term. These results suggest that the transfer of risk over the long term plays

a predominant role among the three frequency bands, encompassing the majority of the overall spillages.

The majority of risk transmissions occurring in the short term between pairs of markets were considered insignificant, with only a limited number of intrinsic risk transmissions demonstrating relative importance. However, cocoa (9.86%) assumed the highest role as a recipient of shocks from other markets within the system, including shocks originating from its respective market. Similarly, cocoa, along with coffee and zinc, emerged as the primary recipients of shocks (0.17%) solely from other markets within the system, excluding those originating from their respective markets. On the contrary, copper (24.24%) emerged as the predominant transmitter of overall shocks, both intrinsic and directed towards other markets within the Namibian sub-system, while nickel (0.10%) assumed a minimal role as a transmitter of such shocks. Additionally, it was revealed that nickel (-0.15), zinc (-0.15), cotton (-0.11), coffee (-0.07), and NASE (-0.04) were all recipients of net shocks within the system, while copper (0.33), NAD (0.26), aluminium (0.05), and cocoa (0.03) acted as net transmitters of shocks.

Likewise, the outcomes of the intermediate-term analysis revealed marginally more positive results when compared to the short-term analysis. Notably, the markets of corn (3.91%), NAD (3.32%), cotton (3.14%), and copper (2.36%) experienced the impact of intrinsic shocks. Furthermore, cocoa (9.91%) continues to maintain its prominent position as the most significant recipient of systemic risk, encompassing both internal and external sources. On the contrary, copper (24.40%) and nickel (0.13%) uphold their respective positions as the highest

and lowest overall transmitters of risk into the system, including transmissions into their respective markets. Similarly, copper (2.75) maintains its status as the primary net transmitter of risk, while coffee (-1.27) emerges as the primary net receiver of shocks within the system.

Through a comparative analysis, the long-term evaluation revealed numerous instances of bidirectional transmissions within the system, except for the coffee and nickel markets. Consequently, the nickel and coffee markets exhibited significant shock transmissions to all other markets, except for the nickel market (0.17%) in the case of coffee. Furthermore, among the various pairwise combinations, the aluminium, copper, and NAD markets showcased the highest level of risk transmission, demonstrating an intensified degree of both risk transmission and absorption within the system.

In contrast, the combination involving the nickel market exhibited the most minimal pairwise transmission of volatility within the system, with the lowest transmission (0.08%) documented in the case of cocoa transmitting shocks into the nickel market. Corresponding to the intermediate-term findings, corn (23.19%), copper (21.90%), NAD (21.43%), and aluminium (11.62%) were respectively influenced by shocks originating within their respective markets. Similarly, coffee (9.78%) and NAD (7.57%) emerged as the primary and least recipients of shocks within the system, including those originating from their respective markets. Conversely, copper (24.18%) and nickel (0.15%) emerged as the highest and least transmitters of overall shocks into the system.

Additionally, the list of net shock transmitters and receivers within the system maintained their respective positions in route but with diverse magnitudes. For instance, nickel (-8.09), coffee (-7.41), zinc (-7.00), cotton (-5.40), corn (-3.26), and NASE (-2.02) were all recipients of net shocks within the Namibian sub-system, while the remaining markets, including copper (13.59), NAD (12.73), cocoa (3.46), and aluminium (3.39), acted as net transmitters of shocks.

Nevertheless, according to the findings of Saville and Gopaidas (2021), the combined influence of Namibia's foreign and domestic equity capital, exerts a noteworthy impact, constituting approximately 953% and 17% of the country's GDP, respectively, with a market capitalisation of $138.37 billion that continues to rise. The disparities between domestic and foreign capital, alongside the heavy reliance on foreign capital for equity market development, provide insights into the underlying factors contributing to the heightened levels of currency depreciation and its consequential systemic shock propagation capacity. This situation can be attributed to the imperative need for consistent repatriation and the substantial dependence on commodities, considering that a significant portion of Namibia's public companies are either wholly or partially owned by foreign entities, most of which are engaged in mining activities. Notably, prominent listed firms such as Anglo American Plc, B2Gold Corporation, Bannerman Resource, Barloworld, Deep Yellow, and Forsys Metals Limited, among others, make substantial contributions to Namibia's GDP while primarily focusing on the exploration of various metals such as copper, uranium, gold, and more. This further explains the

long-term shock transmission from commodity and currency markets into the equity market, especially during periods of possible repatriation.

Table 9 offers a concise overview of the manner in which risks propagate within the specific sub-market of South Africa across different timeframes. The results elucidate a combination of nuanced upward and downward escalations in the dissemination of volatility within the system. Consequently, the systemic diffusion of risk pertaining to the sub-market progressed from 90.01% in the immediate timeframe to 90.0% in the prolonged term. This signifies that the variations in the overall interconnectedness of risk transmission over the short, intermediate, and long terms were relatively minor.

The vast majority of transient pairwise risk transmissions were deemed inconsequential, with only a limited number of intrinsic risk transmissions demonstrating relative significance. However, the most substantial pairwise transmission (0.94%) occurred between aluminium and ZAR, with ZAR assuming the role of the recipient for exogenous shocks. Furthermore, in the short-term analysis, nickel (10.0%) emerged as the preeminent recipient of exogenous shocks from other markets within the system, encompassing shocks originating from its own market while also serving as the primary recipient (0.24%) of such shocks from other markets in the system excluding its own. Conversely, the ZAR (34.69%) emerged as the foremost transmitter of overall shocks, encompassing both endogenous shocks and those directed towards other markets within the subsystem, closely trailed by corn (22.93%) and aluminium (13.59%), whereas cotton (0.05%) emerged as the least transmitter of such shocks. It was further revealed that nickel

(-0.24), coffee (-0.23), cotton (-0.23), zinc (-0.20), the JSE (-0.18), cocoa (-0.05), and copper (-0.05) all acted as recipients of net shocks within the system, while the remaining markets, including ZAR (0.68), corn (0.39), and aluminium (0.11), acted as net transmitters of shocks.

Likewise, the outcomes of the intermediate-term analysis revealed slightly more favourable results when compared to the short-term analysis. Notably, ZAR (7.35%), corn (5.05%), and aluminium (2.98%) were subject to the impact of endogenous shocks. Furthermore, resembling the earlier observed pairwise risk transmission, the markets of ZAR, aluminium, copper, cocoa, and corn exhibited the most significant pairwise transmissions as conduits for transmitting risk from all the sampled markets. As a result, the magnitude of transmission during the intermediate term assumes greater significance in comparison to the short term.

Furthermore, nickel (10.0%) continues to occupy its position as the foremost recipient of systemic risk, encompassing both internal and external sources. Following closely are cotton (9.96%), coffee (9.92%), JSE (9.83), and zinc (9.80%) as subsequent recipients within this triad. Conversely, ZAR (34.69%) and cotton (0.05%) maintain their respective highest and lowest capacities for overall risk transmission into the system, including transmission into their respective markets. Similarly, ZAR (5.45) retains its status as the primary net transmitter of risk, while copper (-1.90) emerges as the primary net receiver of shocks within the system.

In a comparative analysis, the long-term assessment unveiled numerous instances of bidirectional transmissions within the system, with the exception of the

coffee, cotton, and zinc markets. Consequently, the coffee, cotton, and zinc markets exerted significant shocks to all other markets, except for the nickel and cotton markets in the case of coffee, the nickel and coffee markets in the case of cotton, and the coffee, cotton, and nickel markets in the case of zinc. Upon meticulous scrutiny, the long-term period can be characterised as a phase of heightened pairwise risk transmission, exemplified by the simultaneous presence of volatility transmission and persistence in almost all sampled markets. Furthermore, among the various pairwise combinations, the ZAR, corn, and aluminium markets exhibited the highest level of risk transmission, showcasing an intensified degree of both risk transmission and absorption within the system.

On the contrary, the combination involving the cotton and nickel markets recorded the lowest pairwise transmission of volatility within the system, with the minimal transmission (0.04%) observed between the pairwise transmissions of aluminium and nickel, as well as between aluminium, copper, coffee, and cotton, with nickel and cotton serving as the recipients of shocks in these transmissions. Analogous to the findings in the intermediate-term analysis, ZAR (30.24%), corn (20.88%), and aluminium (11.44%) were individually influenced by shocks originating within their respective markets. Likewise, nickel (9.99%) and ZAR (6.15%) emerged as the primary and least recipients of shocks within the system, encompassing shocks from their respective markets, while ZAR (34.62%) and cotton (0.06%) were, conversely, identified as the highest and lowest transmitters of overall shocks into the system, including their inherent shocks.

Furthermore, the list of net shock transmitters and receivers within the system retained their respective positions, not just in terms of direction but also with varying magnitudes. For instance, cotton (-7.79), nickel (-7.78), coffee (-7.49), zinc (-6.81), JSE (-5.23), cocoa (-2.05), and copper (-1.58) were all designated as recipients of net shocks within the South African sub-system. Conversely, the remaining markets, including ZAR (22.36), corn (12.98), and aluminium (4.10), functioned as net transmitters of shocks.

Furthermore, as indicated by the findings elucidated by Saville and Gopaidas (2021), the South African equity market showcases a collective capitalisation surpassing one trillion dollars, encompassing a vast array of 372 actively listed firms. Moreover, the amalgamation of JSE's foreign and domestic capital, alongside its domestic equity markets, exerts a momentous influence, constituting approximately 260% and 136% of the nation's GDP, respectively. Despite the relatively higher domestic capitalisation, a substantial disparity of over 120% between the contributions of domestic and foreign capital to the GDP underscores the significance of foreign capital within the country. Nonetheless, the profound reliance on foreign capital for the development of the equity market provides valuable insights into the underlying factors driving the heightened levels of currency depreciation and the subsequent propagation of systemic shocks. This circumstance can be attributed to the imperative necessity for consistent repatriation and the relatively elevated dependency on commodities.

Notwithstanding the comparatively substantial advancement of the South African economy and its equity market, the noteworthy contributions it makes to

the global export of commodities should not be disregarded. To illustrate, according to the reports presented by Workman (2022), the total value of South Africa's exports in 2022 amounted to approximately $121 billion, with metals constituting more than 25% of this sum. Moreover, it was further revealed that despite a significant decline of 21.3% in corn production compared to previous years, the nation made a momentous contribution to a total global corn production of 15.5 million metric tonnes, signifying its substantial share of over 50% in sub-regional exports.

Conversely, reports from the United Nations Conference on Trade and Development (UNCTAD, 2022) have disclosed that South Africa remains the leading exporter of metallic and non-metallic commodities within the SSA region as of 2021. Additionally, according to Saville and Gopaidas (2021), South Africa and Namibia, respectively, hold the top positions as the first and third most advanced equity markets in SSA in terms of market capitalisation. It is crucial to emphasise that such prosperity also carries potential risks originating from both the currency and commodity markets, given the extensive exposures involved. Furthermore, it is unsurprising that a significant proportion of the commodities (such as copper, cocoa, corn, and cotton), currencies (GHS and KSH), and equities (BSE and GSE) emerged as transmitters of shocks, considering the substantial reliance of the sampled SSA countries on these commodities and the roles played by certain currencies. For instance, the economies under scrutiny heavily depend on the aforementioned commodities, with some countries generating approximately half of their export earnings from such commodities. Notably, aluminium, cocoa,

copper, and corn feature prominently among the highest-exporting commodities of the sampled markets, implying that shocks originating from these markets are likely to impact the equity market.

Likewise, the equity market of South Africa will probably encounter systemic shocks within the sub-region due to the predominant presence of South African capital in the listed firms of several surveyed countries or their establishment of branches in South Africa. To illustrate, enterprises such as Choppies Enterprise Limited (pertaining to agriculture), Minergy and Anglo-American PLC (involved in mining), and CA Sales Holdings Limited (related to manufacturing), among others, enlisted on the BSE, are either fully or partially under the ownership of South African companies. Similarly, entities like AngloGold Ashanti and MTN Ghana Limited, among others, listed on the GSE possess partial ownership by South African investments, thereby rendering the JSE vulnerable to risks originating from said markets.

On a global scale, our findings regarding multiple lists of bidirectional risk causality between commodity and equity markets align with those of Vardar et al. (2018), who employed a similar model to examine risk transmissions from commodities (metals and energy) and equities (US, UK, France, Germany, Asia, and South Africa) and identified bi-directional transmission of shocks and volatility effects between stock and commodity returns. Similarly, our results pertaining to bidirectional volatility transmission among the sampled markets support the findings of separate studies on bidirectional transmission and causality of volatility across the globe (Mollick & Sakaki, 2019), Eastern Europe (Hegerty, 2018), and

Asia (Maitra & Dawar, 2019; Siddiqui & Roy, 2019). These results further substantiate the notion that global phenomena are not restricted by geographical boundaries but rather evolve.

Moreover, within the SSA context, our findings align with those of previous studies (Agya et al., 2022; Katusiime, 2018; Ogbulu, 2018; Zankawah & Stewart, 2020), which respectively investigated risk and volatility transmission in the commodity, exchange rate, and equity markets of Uganda, Ghana, and Nigeria. These studies collectively identified a combination of unidirectional (Ogbulu, 2018) and significant bidirectional (Agya et al., 2022; Zankawah & Stewart, 2020) volatility transmission among the sampled markets. Furthermore, the presence of weak but noteworthy volatility transmissions observed in the medium term between commodities and currencies further supports the findings of Katusiime (2018), who examined the spillover implications involving the volatility of commodities such as oil and food prices and the exchange rate between the local currency and the US dollar and revealed a modest yet dynamically fluctuating transmission of volatility.

From a theoretical standpoint, the findings of this study provide support for the assertions put forth by contagion theory (pure contagion), which emphasises the dissemination of shocks across markets via mechanisms beyond basic transmission channels, setting off a chain of subsequent spillages while adhering to the shift contagion in the long term given the heightened transmissions across the period. Moreover, our study provides further evidence that risk transmission is indeed possible within the sampled market, particularly in the long term, as established by studies (Ahnert & Bertsch, 2022; Seth & Panda, 2018; Trevino, 2020).

Moreover, the absence of regional currencies and the region's heavy reliance on the US dollar for regional transactions support the notion of the recent accelerated depreciation of local currencies within the sub-region. Furthermore, it is worth noting that a significant portion of equity market firms are predominantly owned by foreign investors. This fact contributes to the ongoing depreciation of the domestic currency, as it highlights the continuous repatriation needs and the consistent transmission of currency shocks into the equity market.

Globally, the findings can be attributed to the recent volatility in global commodity prices, influenced by factors such as global demand, supply disruptions, geopolitical tensions, and economic conditions spanning from 2012 to 2022. Furthermore, significant monetary policy decisions made by central banks worldwide, such as the US Federal Reserve's tapering of quantitative easing (2013–2014) and the European Central Bank's implementation of quantitative easing (2015–2018), also contributed to volatilities in SSA countries. Moreover, the global pandemic that persisted from 2020 to 2022 exerted a substantial influence on economies and financial markets on a global scale. Also, investor sentiment underwent rapid shifts driven by diverse factors, including geopolitical events, economic indicators, and market dynamics. Prominent occurrences that influenced sentiment encompassed the pandemic's impact, trade tensions between the United States and China, the precipitous decline in the industrial metal market. Furthermore, fiscal reforms and austerity measures implemented as responses to economic challenges, and regulatory reforms within financial markets all contributed to the transformative dynamics observed.

However, it should be noted that natural disasters transpire in an intermittent manner, and their repercussions on commodities and economies are subject to variation. Noteworthy incidents that transpired during the specified timeframe encompassed severe droughts experienced in specific regions, as exemplified by the drought that afflicted Southern Africa between 2015 and 2016, while the recent report on climate from the World Bank in 2021 indicated that about 75% of drought in the region hits countries such as South Africa and Kenya, with drought also hitting some sections. Moreover, the imposition of tariffs and negotiations regarding trade agreements unfolded throughout the period under examination. Notable occurrences include the implementation of agreements such as the African Continental Free Trade Area (AfCFTA), which commenced in 2021.

In conclusion, it was established both in the overall and sub-system that all the respective currency markets and the majority of the sampled commodities metals (aluminium and copper) as well as all the agricultural commodities except for cotton acted as significant shock transmitters into the system while all the sampled equity markets served as net shock receivers across all time horizons. This further confirms the assertions that the commodity and currency market mostly drive equities as was established in the APT (Roll & Ross, 1984), further established by studies (Jacobsen et al., 2019; Sokhanvar & Bouri, 2023; Siddiqui & Roy, 2019). Also, the risk and shock transmission abilities of the aforementioned markets into those of equities further corroborate those of the pure contagion theory (Ahnert & Bertsch, 2022; Hurd, 2016; Moradi et al., 2021; Seth & Panda, 2018; Trevino, 2020).

Impact of Commodity Prices and Exchange Rate Volatility on Stock

This section was assigned the task of scrutinising the third facet of the investigation. Thus, to augment the results from the BK-18 spillover estimates and in light of the absence of a statistically significant coefficient derived from the aforementioned model, we intend to further investigate the causal relationship between the variables under scrutiny using the Diks and Panchenko non-parametric causality tests. Specifically, in the context of the exchange rate-equity market nexus, this analysis is essential to elucidate whether the dependence structure between these two asset classes aligns with the assertions of the APT or diverges from them. Such knowledge will be invaluable for policymakers and national governments in shaping their policy formulations. For instance, if it is established that a stable equity market can effectively stabilise currency markets, governments can strategically employ the equity market as a tool to promote stability in local currencies. Therefore, our investigation seeks to address the fundamental question of whether a causal link exists among global commodities, foreign exchange rates, and the equity markets of the sampled countries in SSA.

Furthermore, considering the recent excessive native currency fluctuations within the SSA setting, the heightened global commodity prices amidst pandemics and polarisations, the outcomes derived from the BK-18 risk transmission analysis, and the assertions of the APT and those of the extant literature on the current subject, our anticipation leans towards the existence of a unidirectional causality flowing from the commodity and exchange rate markets towards the equity markets of the sampled SSA countries. Despite the above assertions, the conventional non-

parametric causality test, in contrast, allows for bidirectional analysis. Thus, $\mathfrak{X}|\Upsilon$ represent variable X causes variable Y and $\Upsilon|\mathfrak{X}$ demonstrates that variable Y causes variable X. In this study, variable X, which corresponds to the commodity and exchange rate markets, serves as the hypothesised predictor, while variable Y represents the equity market and serves as the predicted variable. The model's null hypothesis, suggesting no causal relationship, is assessed based on the calculated t-statistics and probability value. A threshold of 2.0 is employed for the t-statistics, while a significance level of 5% is used for the p-value to determine whether to reject or fail to reject the null hypothesis. We reject the null hypothesis with a simultaneous t-statistic above the threshold of 2 and an alpha value of less than 5%.

Additionally, in the case where both null hypotheses for the joint test are rejected, a bidirectional causal relationship between X and Y is substantiated. Likewise, if one of the null hypotheses is rejected while the other is not, a unidirectional causal relationship is established. Conversely, if neither null hypothesis is rejected, it implies the absence of any causal relationship. Hence, the absence of evidence of causality, unidirectional evidence of causality, and bidirectional evidence of causality correspond to independence, dependence, and interdependence, respectively. The results for the full sample and fragmented series are respectively summarised in Tables 10 and 11.

Table 10: Results of the Non-parametric Causality Among Commodities, Exchange Rates, and SSA Equities

Panel A	BSE		GSE		NSE		NASE		JSE	
Industrial metals	𝒳|𝒴	𝒴|𝒳	𝒳|𝒴	𝒴|𝒳	𝒳|𝒴	𝒴|𝒳	𝒳|𝒴	𝒴|𝒳	𝒳|𝒴	𝒴|𝒳
Aluminium	1.931	-0.281	3.374***	1.007	-1.719	-0.243	3.669***	0.446	3.754***	0.069
ṕ-value	(0.0267)	(0.6105)	(0.0004)	(0.1570)	(0.9572)	(0.5960)	(0.0001)	(0.3278)	(0.0000)	(0.4726)
Copper	0.475	0.362	2.647***	0.741	1.746	-2.636	3.679***	-0.293	3.126***	-0.449
ṕ-value	(0.3175)	(0.3175)	(0.0041)	(0.2295)	(0.0404)	(0.9958)	(0.0001)	(0.6152)	(0.0009)	(0.6732)
Nickel	1.883	0.582	1.762	0.541	1.057	-1.837	1.331	1.363	-2.010	0.436
ṕ-value	(0.0298)	(0.7199)	(0.0391)	(0.2944)	(0.1452)	(0.9669)	(0.0917)	(0.0865)	(0.9778)	(0.3314)
Zinc	-1.031	0.247	-0.629	0.571	1.059	0.429	1.929	1.392	-0.734	1.024
ṕ-value	(0.8487)	(0.4025)	(0.7353)	(0.2839)	(0.1448)	(0.3339)	(0.0269)	(0.0820)	(0.7686)	(0.1530)
Agricultural commodities										
Cocoa	0.511	0.249	3.364***	1.899	1.303	0.039	3.138***	-0.339	4.161***	0.184
ṕ-value	(0.3046)	(0.4017)	(0.0004)	(0.0288)	(0.0963)	(0.4843)	(0.0009)	(0.6325)	(0.0000)	(0.4268)
Coffee	1.565	0.558	-0.011	-0.463	0.635	0.552	1.609	1.618	3.572***	3.979***
ṕ-value	(0.0588)	(0.2884)	(0.5045)	(0.6783)	(0.7374)	(0.2903)	(0.0538)	(0.0528)	(0.0002)	(0.0000)
Corn	1.672	-0.071	3.845***	1.956	0.738	-0.265	3.303***	1.364	4.071***	1.857
ṕ-value	(0.9527)	(0.5282)	(0.0001)	(0.0252)	(0.7699)	(0.6044)	(0.0005)	(0.0862)	(0.0000)	(0.0317)
Cotton	0.061	-0.324	-2.140	0.372	1.473	0.781	2.222**	1.137	1.282	0.038
ṕ-value	(0.4756)	(0.6271)	(0.9838)	(0.3548)	(0.0704)	(0.2175)	(0.0132)	(0.1277)	(0.1000)	(0.4849)
Exchange rates	BSP|BSE		GHS|GSE		KSH|NSE		NAD|NASE		ZAR|JSE	
t-test	3.050***	0.040	4.746***	2.170**	2.280**	0.839	3.447***	-0.265	3.864***	0.854
ṕ-value	(0.0012)	(0.4840)	(0.0000)	(0.0150)	(0.0113)	(0.2007)	(0.0003)	(0.6044)	(0.0001)	(0.1967)

Note: ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Source: Woode (2023)

Table 11: Time-varying Non-parametric Causality Among Commodities, Exchange Rates, and SSA Equities

Panel B	BSE		GSE		NSE		NASE		JSE	
Markets	𝒳|𝒴	𝒴|𝒳	𝒳|𝒴	𝒴|𝒳	𝒳|𝒴	𝒴|𝒳	𝒳|𝒴	𝒴|𝒳	𝒳|𝒴	𝒴|𝒳
					Short-term					
Industrial metals										
Aluminium	2.118**	0.181	2.227**	1.944	1.425	-1.004	1.540	-0.011	0.166	2.361***
ṕ-value	(0.0171)	(0.4283)	(0.0130)	(0.0260)	(0.0770)	(0.8423)	(0.0618)	(0.5044)	(0.4341)	(0.0091)
Copper	0.863	0.052	2.179**	0.162	2.162**	-0.035	3.475***	1.068	1.111	2.380***
ṕ-value	(0.1940)	(0.4791)	(0.0147)	(0.4356)	(0.0153)	(0.5141)	(0.0003)	(0.1427)	(0.1334)	(0.0087)
Nickel	-1.290	-0.338	1.388	-1.159	-0.421	0.174	2.385***	-0.804	-0.405	2.783***
ṕ-value	(0.9015)	(0.6322)	(0.0826)	(0.8767)	(0.6632)	(0.4311)	(0.0085)	(0.7893)	(0.6572)	(0.0027)
Zinc	0.360	-0.031	2.108**	1.073	1.143	0.151	3.397***	1.896	2.554***	2.932***
ṕ-value	(0.3594)	(0.5122)	(0.0175)	(0.1416)	(0.1264)	(0.4400)	(0.0003)	(0.0290)	(0.0053)	(0.0017)
Agricultural commodities										
Cocoa	1.433	1.733	2.045**	0.350	1.810	0.923	2.569***	1.886	1.291	0.176
ṕ-value	(0.0760)	(0.0416)	(0.0204)	(0.3630)	(0.0352)	(0.1781)	(0.0051)	(0.0297)	(0.0984)	(0.4301)
Coffee	2.137**	1.347	0.916	-0.239	0.881	0.177	2.097**	1.847	1.411	1.780
ṕ-value	(0.0163)	(0.0889)	(0.1799)	(0.5944)	(0.1891)	(0.4296)	(0.0180)	(0.0324)	(0.0791)	(0.0375)
Corn	-0.767	-0.290	2.185**	-0.104	1.854	-0.592	1.293	-0.402	0.627	2.092**
ṕ-value	(0.7786)	(0.6140)	(0.0144)	(0.5415)	(0.0319)	(0.7232)	(0.0980)	0.6560	(0.2654)	(0.0182)
Cotton	2.225**	0.955	1.014	0.262	1.690	0.519	2.228**	0.100	1.397	0.828
ṕ-value	(0.0131)	(0.1699)	(0.8448)	(0.3965)	(0.0455)	(0.3019)	(0.0120)	(0.4601)	(0.0811)	(0.2039)
Exchange rates	BSP|BSE		GHS|GSE		KSH|NSE		NAD|NASE		ZAR|JSE	
t-test	-1.269	0.126	2.936***	1.181	0.735	0.589	0.463	2.097**	2.792***	0.325
ṕ-value	(0.8978)	(0.4499)	(0.0017)	(0.1188)	(0.2312)	(0.2778)	(0.3216)	(0.0180)	(0.0026)	(0.6274)

Table 11, continued

Industrial metals					**Intermediate-term**					
Aluminium	2.170**	2.013**	2.405***	1.707	-0.648	-1.203	2.832***	1.497	2.305**	2.576***
ṕ-value	(0.0150)	(0.0221)	(0.0081)	(0.0439)	(0.7415)	(0.8856)	(0.0023)	(0.0672)	(0.0106)	(0.0050)
Copper	2.190**	0.457	2.044**	1.045	2.184**	0.527	2.171**	0.290	2.131**	0.201
ṕ-value	(0.0143)	(0.3239)	(0.0205)	(0.1480)	(0.0145)	(0.2992)	(0.0150)	(0.3861)	(0.0166)	(0.4202)
Nickel	2.380***	0.263	2.086**	0.313	2.263**	1.141	2.403***	1.110	3.142***	(0.451)
ṕ-value	(0.0087)	(0.3962)	(0.0185)	(0.3772)	(0.0118)	(0.1270)	(0.0081)	(0.1334)	(0.0008)	(0.3258)
Zinc	1.227	-0.757	-0.450	0.767	2.104**	0.632	1.780	0.130	3.225***	0.389
ṕ-value	(0.1100)	(0.7754)	(0.6735)	(0.2216)	(0.0177)	(0.2636)	(0.0376)	(0.4482)	(0.0006)	(0.3487)
Agricultural commodities										
Cocoa	2.475***	0.847	2.155**	-0.762	0.482	0.523	2.332***	1.482	1.307	0.538
ṕ-value	(0.0067)	(0.1985)	(0.0156)	(0.7769)	(0.3149)	(0.3004)	(0.0098)	(0.0692)	(0.0956)	(0.2952)
Coffee	0.954	-0.102	2.111**	0.566	2.373***	2.580***	2.519***	1.979	3.303***	2.704***
ṕ-value	(0.1701)	(0.5408)	(0.0174)	(0.7144)	(0.0088)	(0.0050)	(0.0059)	(0.0239)	(0.0005)	(0.0034)
Corn	2.041**	1.529	2.310***	1.349	2.480***	0.875	2.084**	1.261	2.308**	1.413
ṕ-value	(0.0206)	(0.0632)	(0.0104)	(0.0887)	(0.0066)	(0.1909)	(0.0186)	(0.1037)	(0.0105)	(0.0788)
Cotton	-2.281	1.001	1.047	1.077	2.067**	2.220**	0.713	0.717	1.205	0.193
ṕ-value	(0.9887)	(0.1583)	(0.1476)	(0.1408)	(0.0194)	(0.0132)	(0.2380)	(0.2366)	(0.1140)	(0.4236)
Exchange rates	BSP|BSE		GHS|GSE		KSH|NSE		NAD|NASE		ZAR|JSE	
t-test	5.032***	3.965***	3.163***	1.020	1.942	0.916	4.330***	-0.525	5.036***	1.431
ṕ-value	(0.0000)	(0.0000)	(0.0008)	(0.1538)	(0.0261)	(0.1797)	(0.0000)	(0.7001)	(0.0000)	(0.0762)

Table 11, continued

Industrial metals					**Long term**					
Aluminium	2.208**	1.273	2.846***	2.060**	4.157***	2.404***	2.186**	1.293	3.979***	0.193
ṕ-value	(0.0136)	(0.1016)	(0.0022)	(0.0197)	(0.0000)	(0.0081)	(0.0144)	(0.0980)	(0.0000)	(0.4234)
Copper	0.846	0.921	3.433***	0.793	2.883***	-0.418	2.695***	2.209**	2.575***	1.397
ṕ-value	(0.1987)	(0.1786)	(0.0003)	(0.2138)	(0.0020)	(0.6621)	(0.0035)	(0.0136)	(0.0050)	(0.0812)
Nickel	1.888	-1.109	3.310***	0.473	3.751***	1.456	1.902	0.446	4.155***	1.473
ṕ-value	(0.0296)	(0.8663)	(0.0005)	(0.3181)	(0.0001)	(0.0727)	(0.0286)	(0.3277)	(0.0000)	(0.0704)
Zinc	2.256**	0.313	0.734	-0.217	2.452***	0.943	2.232**	1.162	3.675***	1.309
ṕ-value	(0.0120)	(0.3772)	(0.2315)	(0.5859)	(0.0071)	(0.1728)	(0.0128)	(0.1227)	(0.0001)	(0.0953)
Agricultural commodities										
Cocoa	0.377	0.097	2.644***	0.303	2.563***	1.463	2.262**	1.095	2.359***	2.267**
ṕ-value	(0.3523)	(0.4615)	(0.0041)	(0.3808)	(0.0052)	(0.0717)	(0.0119)	(0.1367)	(0.0092)	(0.0117)
Coffee	2.151**	-0.224	1.437	1.394	2.588***	2.667***	2.334***	1.273	3.100***	3.403***
ṕ-value	(0.0158)	(0.5887)	(0.0754)	(0.0817)	(0.0048)	(0.0038)	(0.0098)	(0.1015)	(0.0009)	(0.0003)
Corn	2.244**	1.642	3.569***	0.959	2.637***	1.224	2.072**	0.328	2.446***	1.788
ṕ-value	(0.0124)	(0.0503)	(0.0002)	(0.1689)	(0.0042)	(0.1104)	(0.0191)	(0.3713)	(0.0072)	(0.0369)
Cotton	-0.423	-0.422	2.850***	0.566	2.213**	2.150**	2.325**	1.934	4.117***	0.650
ṕ-value	(0.6638)	(0.6635)	(0.0022)	(0.2856)	(0.0134)	(0.0158)	(0.0100)	(0.0266)	(0.0000)	(0.2579)
Exchange rates	BSP|BSE		GHS|GSE		KSH|NSE		NAD|NASE		ZAR|JSE	
t-test	3.199***	2.138**	6.077***	1.169	3.060***	2.141**	2.227**	1.188	3.652***	0.620
ṕ-value	(0.0007)	(0.0163)	(0.0000)	(0.1213)	(0.0011)	(0.0161)	(0.0129)	(0.1175)	(0.0001)	(0.2677)

Note: The test is bidirectional; 𝕏|ϒ represent variable X Granger-causes variable Y, and ϒ|𝕏 demonstrates that variable Y Granger-causes variable X. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Source: Woode (2023)

The results from Table 10 demonstrate that, with the exception of BSE, all the sampled equities exhibit a significant reliance on industrial metals such as aluminium and copper. Consequently, fluctuations in commodity markets have a substantial impact on the aforementioned equities. Conversely, it was observed that the sampled equity markets maintained independence from the remaining industrial metal market. Thus, changes in the latter did not exert a driving force on equity movements throughout the examined period. These outcomes are particularly intriguing due to the presence of numerous firms within BSE involved in the production of the aforementioned metals, while South Africa plays a significant role in the global production and exportation of industrial metals such as nickel and zinc.

Moreover, akin to the findings regarding dependence on the industrial metal market, the agricultural commodity market also displayed a combination of reliance and independence. Notably, BSE exhibited independence from all the surveyed agricultural commodities, while the other equity markets, namely GSE (3.36|1.89), NASE (3.14|-0.34), and JSE (4.16|0.18), showed interdependence on cocoa. Surprisingly, only the JSE (3.57|3.98) demonstrated interdependence with the coffee market, with the NSE curiously lacking such a connection. This observation raises intriguing questions, particularly in light of the contributions of Kenya to global coffee production, as previously established. Furthermore, the corn market significantly influenced GSE (3.85|1.96), NASE (3.30|1.36), and JSE (4.07|1.86), whereas NASE (2.22|1.14) was the sole market driven by cotton. The results

pertaining to the agricultural markets present a mixture of substantial and negligible dependence, diverging from those observed in the metal market.

Furthermore, the magnitude of interdependence between commodities and the equity market was most pronounced in the case of corn and JSE equities, which is not surprising considering the significant contributions of the South African economy to global and regional corn production. However, it is intriguing to note that BSE remains independent of all the sampled commodities, despite its substantial interconnectedness and spillover effects with the majority of the mentioned markets. It is worth noting that existing literature has established that risk propagation and connectivity do not necessarily imply causality (Kumar, 2019; Musawa & Mwaanga, 2017; Oyelami & Yinusa, 2019).

Moreover, the observed causal relationship between the sampled currencies and equity markets was particularly intriguing. In line with the earlier findings on the interdependencies between commodities and equity, we discovered a significant unidirectional causal relationship between all equity and exchange rate markets, except for GSE and GHS, where the causality was found to be bidirectional. This indicates that both the currency and equity markets are influenced by each other's dynamics, establishing their interdependence. Notably, the exchange rate market of Ghana exhibited the highest level of causality towards GSE, suggesting a substantial impact of exchange rate movements on Ghana's equities, as affirmed by Queku et al. (2022). Furthermore, subject to the tenets of the contagion theory and acknowledging the diverse behaviour of market participants, we proceed to explore the dynamic causal relationship between the aforementioned markets.

From Table 11, it was revealed that the time-varying analysis exhibit a combination of enhanced and fluctuating characteristics compared to the static analysis, with the majority of the causal relationships determined as non-significant in the static analysis, further establishing an enhanced status across the short, intermediate, and long-term periods. To illustrate, in the short term, there existed a unidirectional causal relationship flowing from the respective markets of aluminium (2.12|0.19), coffee (2.14|1.35), and cotton (2.23|0.96) into the BSE markets.

Furthermore, a unidirectional causal relationship was observed between all the sampled commodities and equity markets, except for NSE (1.94|-1.00) and NASE (1.54|-0.01) in the case of aluminium, BSE (0.86|0.05) in the case of copper, BSE (-1.29|-0.34), GSE (1.39|-1.16), and NSE (-0.42|0.17) in the case of nickel, BSE (0.36|-0.03) and NSE (1.14|0.15) in the case of zinc, BSE (1.43|1.73), NSE (1.81|0.92), and JSE (1.29|0.18) in the case of cocoa and BSE (-0.77|-0.29), NSE (-0.10|1.85), and NASE (1.29|-0.40) in the case of corn. Moreover, the findings from the currency markets revealed a unidirectional causal relationship with equities exclusively in Ghana (2.94|1.18) and South Africa (2.79|0.33), while NASE (0.46|2.09), on the other hand, causes changes in NAD.

Furthermore, the results from the intermediate-term analysis unveiled a unidirectional causal relationship flowing from the aluminium, coffee, copper, corn, nickel, and currency markets into the majority of the sampled equity markets. Notably, bidirectional causality was observed between BSE (2.17|2.01) and JSE (2.31|2.58) in the case of aluminium and between NSE (2.37|2.58) and JSE

(3.30|2.70) in the case of coffee. Conversely, a significant unidirectional causal relationship was identified between cocoa and equity markets, with the exception of NSE (0.48|0.52) and JSE (1.31|0.54), where the relationship was insignificant. Similarly, the relationship between all the sampled equity markets and zinc was found to be insignificant, except for the NSE (2.10|0.63) and JSE (3.23|0.39). Moreover, a bidirectional causal relationship existed between cotton and NSE (2.07|2.22), while the causal relationship between the aforementioned commodity and the remaining equities did not meet the established threshold for significance.

Comparatively, the long-term analysis presented a remarkable degree of causality, characterised by a combination of unidirectional and bidirectional causal relationships among the sampled markets. Notably, there were significant dual causal relationships observed between various markets such as aluminium, BSP, cocoa, coffee, copper, cotton, and KSH, with BSE (3.20|2.14) and NSE (3.06|2.14) in the case of BSP and KSH, GSE (2.85|2.06) and NSE (4.16|2.40) in the case of aluminium, NASE (2.69|2.21) in the case of copper, NSE (2.21|2.15) cotton, JSE (2.36|2.27) in the case of cocoa, and NSE (2.59|2.67) and JSE (3.10|3.40) in the case of coffee. However, the remaining causal relationships were found to be unidirectional, with the sampled commodities acting as the predictor.

Conversely, the causal link between the BSE and cocoa (0.38|0.09), copper (0.85|), cotton (-0.42|-0.42), and nickel (1.89|-1.11), as well as the relationships between GSE and coffee (1.44|-1.11) and zinc (0.73|1.39) and between NASE and nickel (1.46|1.90), were deemed insignificant based on the established threshold.

The prevalent causal relationships observed in the extended period further support the findings of long-term volatility transmission in the BK-18 analysis.

The existence of variations in the causal relationship between the sampled markets across different time periods and the diverse outcomes obtained from the pairwise causalities provide theoretical support for the fundamental tenets of the heterogeneous behaviour of market participants, as validated by studies (Elshqirat, 2019; Nordin et al., 2014). Furthermore, the predictive capability of commodity and exchange rates on the equity market in the SSA context confirms the assertions made studies (Siddiqui & Roy, 2019; Sokhanvar & Bouri, 2023), as previously established. This finding also aligns with the research of Mollick and Sakaki (2019), highlighting the superior predictive abilities of commodities and exchange rates compared to other classical variables.

Furthermore, the unidirectional causality evidence discovered in this investigation, both in the static and time-varying dimensions, aligns with the conclusions drawn from previous studies within the SSA framework. Noteworthy among these studies are the works (Lesotho, Motlaleng, & Ntsosa, 2016; Mongale & Eita, 2014; Ogbulu, 2018; Oyelami & Yinusa, 2019; Zankawah & Stewart, 2020), among others, which explored the impacts of commodities and exchange rates on financial markets. Additionally, empirical support for the unidirectional causal nexus between the sampled markets has been offered by prior studies (Queku et al., 2022; Agya et al., 2022). These studies, in conjunction with our findings, further validate the significant causal connection between commodity and currency markets. The evidence found in the literature can be rationalised by considering the

persistent depreciation of local currencies against major global currencies, alongside volatile commodity prices, which adversely affect the profitability of manufacturing firms and consequently impact investor returns, thereby influencing foreign investment as well.

In summary, we validate the hypothesis put forth in this study, which posits a noteworthy unidirectional influence of commodity and exchange rate volatility on the equity market, with only a few exceptions. Therefore, our non-parametric causality test outcomes demonstrate that the volatilities observed in both industrial metals and agricultural commodities have a significant impact on BSE, GSE, NSE, NASE, and JSE. These effects are observed at significance levels of 1% and 5% for different markets. However, the majority of the results reveal a unidirectional relationship. Considering the earlier assertions regarding policy implementation, we can deduce that the governments of the sampled SSA countries should focus on developing their respective equity markets to effectively withstand shocks originating from currency and commodity markets, considering the driving capacity of the latter on the former.

Chapter Summary

Chapter 4 of the study presented empirical evidence on the individual objectives of the research endeavour. With the first objective, a limited level of interconnection was observed between the sampled commodities and the SSA equities, particularly in the short and medium terms. However, in the long term, a robust correlation was established, contrasting the existence of the aforementioned. Concerning the second objective, significant bidirectional volatility transmission

was identified from both commodity and exchange rate markets to the equity market, as well as in the reverse direction, particularly in the long term. In contrast, the transmissions were comparatively weak and moderate in the short and medium terms, respectively. Additionally, it was discovered that none of the sampled equity markets functioned as net shock transmitters.

The third objective complemented the second objective by revealing a significant influence of the sampled commodity and selected exchange rate markets on the equity market, with a majority instances of unidirectional and a few bidirectional causalities. Consequently, it can be inferred that despite the growing integration of global markets, the SSA market retains diversification benefits and displays reduced investor sensitivity, resulting in a weakened transmission of risk in the short and medium terms. It was also determined that commodity and exchange rate markets exert an impact on the SSA equities.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This chapter offers a comprehensive outline of the study, encompassing its findings and supplementary policy submissions. The summary section presents a synopsis of the study's problem and purpose, the research hypothesis, methodology, and findings. Subsequently, the conclusion section presents the outcome of the findings within the context of the established hypothesis. Considering the significance of the study, the recommendations section furnishes essential policy direction for implementation to pertinent stakeholders. Ultimately, the chapter concludes by proposing avenues for prospective research.

Summary

The convergence of financial markets gives rise to complexities in the dynamics of returns and volatility. However, the transmission of risk across markets (commodities, foreign exchange, and equities) occurs when the flow of information is neither immediate nor complete. This phenomenon also implies that a market's exaggerated response to negative sentiment spreads to other markets, irrespective of the underlying economic conditions (Maitra & Dawar, 2019). To substantiate the above assertions, the IMF (2023) disclosed an escalated currency devaluation in SSA, wherein certain nations surpassed the regional benchmark of 20%, and this occurred against the backdrop of surges in global commodity prices, the aftermath of global pandemic shocks, market downturns, and political polarisation.

Amidst such occurrences, it becomes essential to acknowledge the potential transmission of risks from commodity and currency markets into the equity market in SSA. This acknowledgement stems from the close link between stock market performance and economic advancement. However, the development of these markets, relies heavily on various factors, with particular emphasis on commodity price movements. This notwithstanding, the substantial dependence of numerous indigenous firms on imports consequently leading to the vulnerability of domestic currencies as a result of disruptive shocks stemming from excessive demand for foreign currency. The aforementioned scenario has prompted numerous studies within the sub-region even before the recent chaos, primarily focusing on commodities such as treasured metals and crude oil. However, it is worth noting that the SSA economy, as well as its equity markets, encompasses commodities beyond the aforementioned, with the list including the industrial metal and agricultural commodities. Surprisingly, few studies emphasised the vulnerability of equity markets to shocks originating from the agricultural commodity market, despite the region's exposure to commodity price shocks and an import deficit of over 50%, as reported by UNCTAD (2022). In light of the aforementioned arguments and the increasing interactions between African economies and the global market, one could argue that there exists a significant gap requiring substantial attention for informed decision-making within the sub-region.

The study examined the interdependencies of the commodities and equity markets in the SSA region, evaluated the level of risk transmission among commodities, exchange rates, and equities in a sample of markets within SSA, and

additionally examined the impact of volatility in commodities and exchange rates on equities in the chosen SSA markets. These objectives were substantiated by pertinent theoretical and empirical studies. The study was grounded in modern portfolio theory, arbitrage pricing theory, and contagion theory.

The study was predicated on the post-positivism research paradigm and employed a quantitative approach. Moreover, an explanatory research design was adopted, which facilitated the estimation of various models. Furthermore, the study incorporated a selection of eight commodity markets, evenly distributed between industrial metals and agricultural commodities, along with five equity and currency markets within the SSA region and benchmarked against the US dollar. This particular sample was driven by data availability, commodity reliance, and the study's scope, among other factors. To achieve the study's objectives, three distinct models and estimation techniques were adopted, with each model targeting a specific objective. The first objective was accomplished through the utilisation of multivariate wavelet analysis, while the second objective was implemented by employing Barunik and Křehlík connectedness and spillover index. The third objective was further pursued using the Diks and Panchenko causality test.

The findings of the study partially validated the first hypothesis, indicating the presence of weak interdependencies between commodity and equity markets in the short and medium time. However, this assertion was refuted in the long term due to the presence of robust integration among the markets under examination. The study's findings confirmed the existence of interdependencies in the transmission of risk across commodities, exchange rates, and the equity market,

further validating the second hypothesis. Specifically, this hypothesis was confirmed over an extended duration, highlighting the existence of bidirectional volatility transmissions among the markets examined. Nevertheless, the results regarding the short and medium timeframes indicated a limited degree of transmission among the sampled markets, albeit with a few exceptions.

The findings provided additional support to the third hypothesis, albeit partially, by revealing the presence of both significant and insignificant causal links between commodities, exchange rates, and equities. These results were further elevated by the time-varying causal relationship. For instance, the results pertaining to intermediate and long-term periods demonstrated the existence of both unidirectional and bidirectional causal links among the markets under scrutiny. Notably, the currency market exerted noteworthy impacts on the selected equity markets across all periods, with only minor exceptions.

Conclusion

In line with the results from the first objective, we conclude that there is a weak level of integration between commodities and equities. This implies that these markets do not move in perfect synchronisation and therefore provide opportunities for portfolio diversification. Investors can potentially benefit from diversifying their investments across these asset classes to enhance returns and mitigate risk. Considering the bidirectional transmission of risk among commodity, exchange rate, and SSA stock markets, particularly in the long term we conclude that changes in commodity prices and exchange rates can influence the volatility of SSA stock markets, especially in the long term.

Also, the fact that all sampled SSA equities served as net receivers of shocks both in the overall and sub-market analyses demonstrates how exposed these markets are to external shocks and the need for risk management strategies that consider the potential spillover effects among these markets. We also conclude that commodity prices and exchange rates have a causal impact on SSA equities which further indicates that changes (both favourable and unfavourable) in commodity prices and exchange rates can lead to fluctuations in SSA equity markets. In summary, the study emphasises the potential benefits of portfolio diversification, the interconnectedness of risk, and the causal relationships between commodity and exchange rate shocks on SSA equities. These findings can inform policymakers, investors, and market participants to make informed decisions, develop appropriate risk management strategies, and promote market stability and resilience.

Recommendations

Based on the study's key findings, the following recommendations are suggested for policymakers, including government authorities, stock market regulators, central banks, and other stakeholders including investors.

Firstly, considering the identified weak integration between commodities and equities and the feeble risk transmission among the sampled markets in the short and medium term, a possible diversification prospect for investors in the region is recommended. This suggests that diversifying investments across different asset classes can help mitigate risk and enhance returns. Regulators of equity markets, together with the ministry in charge of trade and industry in the sampled SSA countries, are expected to collaborate and promote awareness of this

luxury in an attempt to enhance foreign investment for equity market development. It is also imperative for the governments of the sampled economies to create a collaborative environment to enhance citizens' engagement in intra-regional portfolio diversification with commodities and equities within the region rather than investing beyond these regional blocks. Also, implementing investor-based policies such as intra-regional tax havens on returns and capital gains and domestic currency identification among the sampled economies could further incentivise investors in their investment mantle, reducing the burden on the exchange rate market, especially in the short and medium term. Also, long-term policies should focus on implementing robust risk management frameworks to mitigate the impact of market fluctuations.

Additionally, to gain investor confidence and enhance intra-regional equity investment, there is a need to strengthen market regulations and surveillance to ensure transparency, fairness and stability, promote research, and improve data availability in these markets. This includes enforcing regulations on insider trading and market manipulation, ensuring proper disclosure of information and conducting rigorous research. This will enhance informed decisions based on robust analysis and accurate information. Also, encouraging research collaborations, data-sharing initiatives, and investments in data infrastructure can contribute to better policy formulation and investment strategies. There is also a need to enhance investor education programmes to improve investment knowledge and awareness of the existing interdependencies between commodities and equities. Equity market regulators, security exchange commissions, and trade and industry ministries

within the sampled market can work with educational, financial, and industry associations to provide training and resources for investors to understand market dynamics and make informed investment decisions.

Considering the exposure of domestic currencies to shocks from the commodity markets and coupled with shock transmissions from the currency to equity markets of the sampled countries, especially in the long term, central banks and equity market regulators within the sampled markets should strengthen their market surveillance capabilities to monitor and assess the transmission of risk and implement robust risk management frameworks and macroprudential policies that take into account the interlinkages between commodities, exchange rates, and equities. This includes enhancing their ability to detect and respond to potential systemic risks, market manipulations, and excessive volatility. Also, central banks can implement stress testing and establish contingency plans to address potential market disruptions. These contingencies could include the need for a common currency to enhance intra-regional trade. But considering that we only considered a few countries from the numerous SSAs, making such recommendations is outside the scope of our study.

Additionally, given the bidirectional transmission of risk between commodity, exchange rate, and equity markets, central bank regulators should coordinate their monetary policies with other relevant policy authorities to ensure coherence and effectiveness and further collaborate with equity market regulators to monitor and manage exchange rate fluctuations, considering the transmission within these markets. Also, collaborative efforts with fiscal authorities and

regulatory bodies in the form of exchange rate stability maintenance policies with managed movements that support competitiveness and investor confidence can help manage the impact of market fluctuations on the broader economy and financial system. Also, given the excessive risk transmissions in the long term, central banks can augment their usual currency market intervening role to mitigate these risks. This notwithstanding, the need to conduct regular comprehensive assessments of financial stability to identify potential vulnerabilities and evaluate the resilience of the financial system.

Finally, considering the causal impact of commodities and exchange rate movement on equities in the sampled markets, regulators should adopt proactive measures to stabilise these markets, especially in the long term where these impacts were found to be excessive. This may involve central banks initiating foreign currency repatriation thresholds to ease the burden on domestic currencies, equity market regulators insisting on listed firms regularly providing both foreign and domestic investors with financial reports to enhance investor confidence and enable them to adhere to the threshold-based policies, governments diversifying the economy with innovative sectors to ease the burden on commodities or improving production and enhance value.

Subject to the aforementioned, appropriate measures could include investments in the highly intensive innovative sector, as asserted in the most recent UNCTAD report. According to the report, these sectors include fintech, health-tech, agri-tech, and the solar industries, which have a lot of opportunities for the growing number of middle-aged and educated citizens within the SSA with a

promise to improve their economies. Also, governments investing in technology-based education and infrastructure could further enhance the knowledge of its citizens, which will be an added advantage in improving commodity value and increasing production, which could address the import deficit in the region and ease the persistent shocks from the commodity market.

Suggestions for Further Research

Future research could consider an extended number of SSA equities to enhance the limited recommendations on the need for intra-regional currency. Also, these studies could further use different currencies such as the British pound and the Euro as benchmarks instead of the US dollar, considering their relevance in the global space. The use of different estimation models could also present an opportunity to affirm or refute the findings of the current study. For instance, future studies could employ conditional quantile causality in the mean instead of Diks and Panchenko for causal relationship estimation, and other volatility-based models, including long- and short-term memory neural networks and multivariate GARCH, could also be employed.

REFERENCES

Addison, T., Ghoshray, A., & Stamatogiannis, M. P. (2016). Agricultural commodity price shocks and their effect on growth in Sub-Saharan Africa. *Journal of agricultural economics*, *67*(1), 47-61.

Agya, A. A., Samuel, P. A., & Amadi, K. W. (2022). Shocks and volatility transmission between oil price and Nigeria's exchange rate. *SN Business & Economics*, *2*(6), 1-17.

Alfelt, G., Bodnar, T., & Tyrcha, J. (2020). Goodness-of-fit tests for centralized Wishart processes. *Communications in Statistics-Theory and Methods*, *49*(20), 5060-5090.

Ahnert, T., & Bertsch, C. (2022). A wake-up call theory of contagion. *Review of Finance*, *26*(4), 829-854.

Bank of Ghana. (2022). *Merchandise Trade Flow*. Retrieved from https://www.bankofghana.gov.gh/

Baruník, J., & Křehlík, T. (2018). Measuring the frequency dynamics of financial connectedness and systemic risk. *Journal of Financial Econometrics*, *16*(2), 271-296.

Bergman, M. (2016). Positivism. *The International Encyclopaedia of Communication Theory and Philosophy*, 1-5.

Bianchi, R. J., Fan, J. H., & Todorova, N. (2020). Financialization and de-financialization of commodity futures: A quantile regression approach. *International Review of Financial Analysis*, *68*, 101451.

Biswas, D. (2015). The effect of portfolio diversification theory: Study on modern portfolio theory of stock investment in the national stock exchange. *Journal of Commerce and Management Thought*, *6*(3), 445.

Boako, G., & Alagidede, P. (2017). The stock market development and economic growth puzzle: Empirical evidence from Africa. *Development Finance: Challenges and Opportunities*, 207-240.

Boako, G., Omane-Adjepong, M., & Frimpong, J. M. (2016). Stock Returns and Exchange Rate Nexus in Ghana: A Bayesian Quantile Regression Approach. *South African Journal of Economics*, *84*(1), 149-179.

Bolokwe, K., & Sedimo, K. (2021). *Market Capitalisation on Botswana*. Retrieved from https://www.cfainstitute.org/

Bossman, A., & Agyei, S. K. (2022). Interdependence structure of global commodity classes and African equity markets: A vector wavelet coherence analysis. *Resources Policy*, *79*, 103039.

Bossman, A., Junior, P. O., & Tiwari, A. K. (2022). Dynamic connectedness and spillovers between Islamic and conventional stock markets: time-and frequency-domain approach in COVID-19 era. *Heliyon*, *8*(4), e09215.

Botswana Stock Exchange. (2022). *Annual Report, 2022: Re-Investing Success*. Gaborone, Botswana: Author.

Burton, M. (2022, June 26). Metals Haven't Crashed This Hard Since the Great Recession. Retrieved from https://www.bloomberg.com/news/articles/

Cain, M. K., Zhang, Z., & Yuan, K. H. (2017). Univariate and multivariate skewness and kurtosis for measuring nonnormality: Prevalence, influence and estimation. *Behaviour research methods*, *49*, 1716-1735.

Chartered Financial Analyst Research Institute. (2021). Key Developments and Reforms in African Capital Market. Retrieved from https://www.cfainstitute.org/en/research

Danmola, R. A. (2013). The impact of exchange rate volatility on the macroeconomic variables in Nigeria. *European Scientific Journal, 9*(7).

de Boyrie, M. E., & Pavlova, I. (2018). Equities and commodities comovements: evidence from emerging markets. *Global Economy Journal*, *18*(3).

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American statistical association, 74(366a), 427-431*.

Diebold, F. X., & Yilmaz, K. (2012). Better to give than to receive: Predictive directional measurement of volatility spillovers. *International Journal of forecasting*, *28*(1), 57-66.

Diks, C., & Panchenko, V. (2006). A new statistic and practical guidelines for nonparametric Granger causality testing. *Journal of Economic Dynamics and Control*, *30*(9-10), 1647-1669.

Dragomiretskiy, K., & Zosso, D. (2013). Variational mode decomposition. *IEEE transactions on signal processing*, *62*(3), 531-544.

Elshqirat, D. (2019). An empirical examination of the arbitrage pricing theory: Evidence from Jordan. Retrieved from https://papers.ssrn.com/sol3/

Entezami, A. (2021). *Structural health monitoring by time series analysis and statistical distance measures*. Springer International Publishing.

Enwereuzoh, P. A., Odei-Mensah, J., & Junior, P. O. (2021). Crude oil shocks and African stock markets. *Research in International Business and Finance*, *55*, 101346.

Fernández-Macho, J. (2012). Time-localized wavelet multiple regression and correlation. *Physica A: Statistical Mechanics and its Applications*, *492*, 1226-1238.

Gençay, R., Selçuk, F., & Whitcher, B. J. (2001). *An introduction to wavelets and other filtering methods in finance and economics*. Elsevier.

Ghana Stock Exchange. (December 2022). *Equity Market Report, 2022*. Accra, Ghana: Author.

Ghosh, I., & Chaudhuri, T. (2019). A wavelet approach towards examining dynamic association, causality and spillovers. *International Journal of Data and Network Science*, *3*(1), 23-36.

Goldberg, L. S. (2019). *Is Optimum Currency Area Theory Irrelevant for Economies in Transition*? In *Exchange-Rate Policies for Emerging Market Economies* (pp. 45-60). Routledge.

Haider, S., Nazir, M. S., Jiménez, A., & Qamar, M. A. J. (2021). Commodity prices and exchange rates: evidence from commodity-dependent developed and emerging economies. *International Journal of Emerging Markets*, (ahead-of-print).

Hall, S. G., & Asteriou, D. (2016). *Applied econometrics*. Palgrave MacMillan.

Hegerty, S. W. (2018). Exchange market pressure, stock prices, and commodity prices east of the Euro. *Journal of Economics & Management*, *31*, 74-94.

Henriques-de-Brito, M. (2018). Framework for Debating Finance with Publications and Films. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?

Hiemstra, C., & Jones, J. D. (1994). Testing for linear and nonlinear Granger causality in the stock price-volume relation. *The Journal of Finance*, *49*(5), 1639-1664.

Hurd, T. R. (2016). *Contagion: Systemic Risk in Financial Networks* (Vol. 42). Berlin: Springer.

Idan, A. M. (2022). Effect of Oil Prices, Inflate Rate, Energy Consumption, Gross Domestic Product on Stock Market Performance of Iraq Stock Exchange. *Cuadernos de Economía*, *45*(128), 45-52.

International Monetary Fund (2023). "*Managing Exchange Rate Pressures in Sub-Saharan Africa—Adapting to New Realities*." *In Regional Economic Outlook: Sub-Saharan Africa—The Big Funding Squeeze*, Washington, D.

Isham, M. F., Leong, M. S., Lim, M. H., & Ahmad, Z. A. (2018). Variational mode decomposition: mode determination method for rotating machinery diagnosis. *Journal of Vibroengineering*, *20*(7), 2604-2621.

Jacobsen, B., Marshall, B. R., & Visaltanachoti, N. (2019). Stock market predictability and industrial metal returns. *Management Science*, *65*(7), 3026-3042.

Jain, A., & Biswal, P. C. (2016). Dynamic linkages among oil price, gold price, exchange rate, and stock market in India. *Resources Policy*, *49*, 179-185.

Johannesburg Stock Exchange. (December 2022). *Summarised Consolidated Annual Financial Results and Ordinary Cash Dividends Declaration Report*. Johannesburg, South Africa: Author.

Julien, O. A., Robert, B. P., & Grace, O. A. (2017). Commodity prices, exchange rate and economic growth in West Africa: Case study of Cote dâ€™ Ivoire and Ghana. *Journal of Development and Agricultural Economics*, *9*(9), 269-277.

Katusiime, L. (2018). Investigating spillover effects between foreign exchange rate volatility and commodity price volatility in Uganda. *Economies*, *7*(1), 1.

Kaufman, R. L. (2013). *Heteroskedasticity in regression: Detection and correction*. Sage Publications.

Kočenda, E., & Černý, A. (2015). *Elements of time series econometrics: An applied approach.* Charles University in Prague, Karolinum Press.

Leković, M. M. (2021). Historical development of portfolio theory. *Tehnika*, *76*(2), 220-227.

Lesotho, O. K., Motlaleng, G. R., & Ntsosa, M. M. (2016). Stock market returns and exchange rates in Botswana. *African Journal of Economic Review*, *4*(2), 16-42.

Lundgren, A. I., Milicevic, A., Uddin, G. S., & Kang, S. H. (2018). Connectedness network and dependence structure mechanism in green investments. *Energy Economics*, *72*, 145-153.

Maitra, D., & Dawar, V. (2019). Return and volatility spillover among commodity futures, stock market and exchange rate: Evidence from India. *Global Business Review, 20*(1), 214-237.

Markowitz, H. (1959). *Portfolio selection: Efficient diversification of investments* (Vol. 16). New York: John Wiley

Mollick, A. V., & Sakaki, H. (2019). Exchange rates, oil prices and world stock returns. *Resources Policy, 61*, 585-602.

Mongale, I. P., & Eita, J. H. (2014). Commodity prices and stock market performance in South Africa. *Corporate Ownership & Control*, *370*.

Moradi, M., Jabbari Nooghabi, M., & Rounaghi, M. M. (2021). Investigation of fractal market hypothesis and forecasting time series stock returns for Tehran Stock Exchange and London Stock Exchange. *International Journal of Finance & Economics*, *26*(1), 662-678.

Musawa, N., & Mwaanga, C. (2017). The impact of commodity prices, interest rate and exchange rate on stock market performance: evidence from Zambia. *Journal of Financial Risk Management, 6*(03), 300.

Nairobi Stock Exchange. (December, 2022). *Integrated Annual Report and Financial Statement, 2022: Looking Forward*. Nairobi, Kenya: Author.

Nandi, S. (2017). *Economics of the international financial system*. New Delhi, ND: Routledge India.

Ngouhouo, I., & Nchofoung, T. N. (2022). Economic resilience in Sub-Saharan Africa: Evidence from composite indicators. *Journal of the Knowledge Economy*, *13*(1), 70-91.

Nordin, N., Nordin, S., & Ismail, R. (2014). The impact of commodity prices, interest rate and exchange rate on stock market performance: An empirical analysis from Malaysia. *Malaysian Management Journal*, *18*, 39-52.

OECD (2021). *Africa's Development Dynamics 2021: Achieving Productive Transformation.* Addis Ababa. OECD Publishing

Ofori, I. K., Obeng, C. K., & Mwinlaaru, P. Y. (2022). *Exchange Rate Volatility and Tax Revenue Performance in Sub-Saharan Africa*. In *The Palgrave Handbook of Africa's Economic Sectors* (pp. 1039-1062). Cham: Springer International Publishing.

Ogbulu, O. M. (2018). Oil price volatility, exchange rate movements and stock market reaction: The Nigerian experience (1985-2017). *American Finance & Banking Review*, *3*(1), 12-25.

Ogotseng, O. T. (2017). *Stock Returns Behaviour and the Pricing of Volatility in Africa's Equity Markets* (Doctoral dissertation, University of the Witwatersrand, Faculty of Commerce, Law and Management, Wits Business School).

Ogundipe, A. (2020). Commodity price volatility and economic growth in Africa: The mitigating role of trade policy. *Problems and Perspectives in Management*, *18*(3), 350-361.

Okot, A. (2022). *EIB Working Paper 2022/12-Determinants of the exchange rate, its volatility and currency crash risk in Africa's low and lower-middle-income countries*. European Investment Bank.

Ouma, W. N., & Muriu, P. (2014). The impact of macroeconomic variables on stock market returns in Kenya. *International Journal of Business and Commerce*, *3*(11), 1-31.

Owusu Junior, P., Alagidede, I. P., & Tweneboah, G. (2020). Shape-shift contagion in emerging markets equities: evidence from frequency-and time-domain analysis. *Economics and Business Letters*, *9*(3), 146-156.

Oyelami, L., & Yinusa, D. (2019). Global Commodity Prices and Stock Market Nexus: Sub-Sahara African Perspective. *Acta Universitatis Danubius: Oeconomica*, *15*(4).

Panhwar, A. H., Ansari, S., & Shah, A. A. (2017). Post-positivism: An effective paradigm for social and educational research. *International Research Journal of Arts & Humanities (IRJAH)*, *45*.

Phillips, P. C., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika*, *75*(2), 335-346.

Queku, I. C., Gyedu, S., & Carsamer, E. (2022). Stock prices and macroeconomic information in Ghana: speed of adjustment and bi-causality analysis. *International Journal of Emerging Markets*, *17*(1), 47-70.

Ramji, A. Z., Wairimu, V., Mwita, M., & Mwanyasi, R. (2021). East Africa Equity Market Capitalisation. Retrieved from https://www.cfainstitute.org/

Roll, R., & Ross, S. A. (1984). The arbitrage pricing theory approach to strategic portfolio planning. *Financial analysts journal*, *40*(3), 14-26.

Rossi, B. (2012). The changing relationship between commodity prices and equity prices in commodity exporting countries. *IMF Economic Review*, *60*(4), 533-569.

Sadiq, M., Lin, C. Y., Wang, K. T., Trung, L. M., Duong, K. D., & Ngo, T. Q. (2022). Commodity dynamism in the COVID-19 crisis: Are gold, oil, and stock commodity prices, symmetrical? *Resources Policy*, *79*, 103033.

Saville, A., & Gopaidas, R. (2021). Market Capitalisation on South African and Namibia. Retrieved from https://www.cfainstitute.org/

Seth, N., & Panda, L. (2018). Financial contagion: Review of empirical literature. *Qualitative Research in Financial Markets*, *10*(1), 15-70.

Siddiqui, S., & Roy, P. (2019). Predicting volatility and dynamic relation between stock market, exchange rate and select commodities. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, *67*(6), 1597-1611.

Singhal, S., Choudhary, S., & Biswal, P. C. (2019). Return and volatility linkages among international crude oil price, gold price, exchange rate and stock markets: Evidence from Mexico. *Resources Policy*, *60*, 255-261.

Sokhanvar, A., & Bouri, E. (2023). Commodity price shocks related to the war in Ukraine and exchange rates of commodity exporters and importers. *Borsa Istanbul Review*, *23*(1), 44-54.

Tang, K., & Xiong, W. (2012). Index investment and the financialization of commodities. *Financial Analysts Journal*, *68*(6), 54-74.

Trevino, I. (2020). Informational channels of financial contagion. *Econometrica*, *88*(1), 297-335.

Tröster, B., & Küblböck, K. (2020). Unprecedented but not unpredictable: Effects of the COVID-19 crisis on commodity-dependent countries. *The European Journal of Development Research, 32*(5), 1430-1449.

Tweneboah, G. (2019). Dynamic interdependence of industrial metal price returns: evidence from wavelet multiple correlations. *Physica A: Statistical Mechanics and Its Applications, 527*, 121153.

UNCTAD. (2021). *Economic Development in Africa Report 2021*. Retrieved from https://unctad.org/Africa/series

UNCTAD. (2022). *Economic Development in Africa Report 2022: Rethinking the Foundations of Export Diversification in Africa: The Catalytic Role of Business and Financial Services.* United Nations Publication, Geneva.

United Nations Conference on Trade and Development. (2022). World Investment Report: Regional Trends Africa. Geneva, Switzerland: UNCTAD.

Vardar, G., Coşkun, Y., & Yelkenci, T. (2018). Shock transmission and volatility spillover in stock and commodity markets: evidence from advanced and emerging markets. *Eurasian Economic Review, 8*(2), 231-288.

Von Furstenberg, G. M., Jeon, B. N., Mankiw, N. G., & Shiller, R. J. (1989). International stock price movements: links and messages. *Brookings papers on economic activity, 1989*(1), 125-179.

Woode, J. K., Idun, A. A. A., & Kawor, S. (2024a). Comovement between agricultural commodities and stock returns of commodity-dependant sub-Saharan Africa countries amidst the COVID-19 pandemic. *Scientific African, 23*, e01972.

Woode, J. K., Owusu Junior, P., & Adam, A. M. (2024b). Dynamic interdependence structure of industrial metals and the African stock market. *Resources Policy*, *88*, 104455.

Workman, D. (2022). Sub Saharan African Countries' Top 10 Exports. Retrieved from https://www.worldstopexports.com/botswanas-top-10-exports

World Bank. (2020). *Mauritania Country Economic Memorandum: Accelerating Growth Through Diversification and Productive Cities*. World Bank.

World Bank. 2022. World Bank Annual Report 2022. Washington, DC: World Bank. DOI: 10.1596/ AR2022EN. License: Creative Commons Attribution– Non-commercial–No Derivatives 3.0 IGO

World Federation of Exchange. (n.d.). Turnover ratios of domestic shares. Retrieved from https://data.worldbank.org/indicator/

World Integrated Trade Solutions (WITS). (2022). Ghana's Maize Exports Report. Retrieved from https://www.witsdata.com/ghana-maize-exports

Zankawah, M. M., & Stewart, C. (2020). Measuring the volatility spill-over effects of crude oil prices on the exchange rate and stock market in Ghana. *The Journal of International Trade & Economic Development*, *29*(4), 420-439.

Zaremba, A., Umar, Z., & Mikutowski, M. (2021). Commodity financialisation and price co-movement: Lessons from two centuries of evidence. *Finance Research Letters*, *38*, 101492.

Zikmund, W. G., Babin, B., Carr, J., & Griffin, M. (2012). *Basic and applied research*. Business Research Methods.

APPENDICES

Appendix A

Table 12: Results of the Time-varying Descriptive Statistics

Variables	Mean	SD	Skewness	Kurtosis	Jarque-Bera
Industrial metals			**Short-term**		
Aluminium	0.0001	0.2020	-0.0733	2.0447	479.590***
Copper	-0.0001	0.0260	-0.0253	3.8359	1677.7***
Nickel	0.0000	0.0084	1.7799	92.122	967894***
Zinc	0.0000	0.0620	0.0208	2.9448	989.17***
Agricultural commodities					
Cocoa	-0.0001	0.1691	0.1444	1.2086	176.450***
Coffee	-0.0001	0.0074	0.3329	5.3295	3287.6***
Corn	-0.0002	0.1605	-0.1089	1.9764	451.20***
Cotton	0.0000	0.0054	-1.0588	7.8032	7448.3***
Exchange rates					
Botswana Pula	-0.0020	0.0605	-0.1180	3.6413	1518.10***
Ghanaian Cedi	-0.0169	0.2249	-0.0637	3.6102	1487.90***
Kenyan Shilling	-0.0001	0.0029	-0.6596	13.2553	20213***
Namibian Dollar	-0.0018	0.0660	-1.0672	11.2166	14851***
South African Rand	-0.0033	0.0718	-0.3773	4.2907	2163.4***
Sub-Saharan African stocks					
BSE	0.0000	0.0277	-1.6844	18.6036	40713***
GSE	0.0001	0.0834	-0.1565	5.6421	3639***
NSE	-0.0001	0.0454	-0.7349	7.1601	6087.5***
NASE	0.0001	0.0608	0.1299	4.7363	2564.5***
JSE	0.0003	0.0946	-0.2718	3.4755	1410.9***
Industrial metals			**Intermediate-term**		
Aluminium	0.0000	0.0007	-15.1702	540.878	33419172***
Copper	0.0000	0.0002	-11.8632	604.102	41621886***
Nickel	0.0000	0.0085	-3.4214	81.976	770613***
Zinc	0.0000	0.0483	-0.0188	3.3990	1317.5***
Agricultural commodities					
Cocoa	0.0000	0.0014	-8.6678	519.492	30766201***
Coffee	0.0000	0.0064	0.0617	0.9951	2087.3***
Corn	0.0000	0.0006	14.1676	505.801	29224803***
Cotton	0.0000	0.0047	-0.3090	3.9351	1808.8***
Exchange rates					
Botswana Pula	0.0000	0.0005	11.7339	365.836	15303425***
Ghanaian Cedi	0.0000	0.0004	-0.3737	14.1909	23003***
Kenyan Shilling	0.0000	0.0002	13.8691	717.883	58774181***
Namibian Dollar	0.0000	0.0018	10.6259	665.305	50456389***
South African Rand	0.0000	0.0016	2.0776	346.168	13648039***
Sub-Saharan African stocks					
BSE	0.0000	0.0244	-0.3091	3.9367	1810.3***
GSE	0.0000	0.0420	-0.0025	13.2299	19938***
NSE	0.0000	0.0214	-0.0825	5.5946	3570.1***
NASE	0.0000	0.0483	-0.1149	2.7162	847.5***
JSE	0.0000	0.0399	-0.2741	4.8442	2708.8***
Industrial metals			**Long term**		
Aluminium	0.0000	0.0026	20.840	976.833	108858168***
Copper	0.0000	0.0009	25.885	936.810	100243782***
Nickel	-0.0001	0.0141	-1.0144	97.395	1080719***

Table 12, continued

Zinc	-0.0001	0.0959	0.0538	3.7877	1636.9***
Agricultural commodities					
Cocoa	0.0000	0.0048	22.612	1008.97	116161200***
Coffee	0.0000	0.0125	-0.3192	1.9777	346.08***
Corn	0.0000	0.0036	-1.9404	629.811	45171980***
Cotton	0.0000	0.0098	0.4071	9.6983	10791***
Exchange rates					
Botswana Pula	0.0000	0.0026	-6.4230	652.043	48434332***
Ghanaian Cedi	0.0000	0.0027	-0.8969	62.9378	451476***
Kenyan Shilling	0.0000	0.0004	-5.5999	507.001	29286094***
Namibian Dollar	0.0000	0.0069	-4.4115	716.899	58534692***
South African Rand	0.0000	0.0060	-2.4821	581.013	38444670***
Sub-Saharan African stocks					
BSE	0.0000	0.0475	0.2806	3.9574	1821.2***
GSE	0.0000	0.0664	0.5510	7.7718	7020.2***
NSE	0.0003	0.0461	0.2467	9.0718	9404***
NASE	0.0000	0.0974	0.0486	2.7230	846.81***
JSE	0.0000	0.0800	0.0894	4.5609	2374.8***

Notes: Jarque-Bera denotes the normality test, which is χ^2distributed asymptotically. *** denotes significance at the 1% level.

Source: Woode (2023)

Table 13: Results of Unit Root Test

Preliminary	Augmented Dickey-Fuller		Philips-Perron	
Original Series	With Drift	With Trend	With Trend	Without Trend
Industrial metals				
Aluminium	-38.095***	-38.089***	-55.376***	-55.385***
Copper	-35.461***	-35.616***	-51.600***	-51.486***
Nickel	-36.980***	-37.055***	-52.226***	-52.163***
Zinc	-36.281***	-36.294***	-53.043***	-53.034***
Agricultural commodities				
Cocoa	-35.643***	-35.693***	-50.698***	-50.663***
Coffee	-32.785***	-32.791***	-50.617***	-50.620***
Corn	-36.958***	-36.978***	-50.940***	-50.925***
Cotton	-33.500***	-33.499***	-48.838***	-48.843***
Exchange rates				
Botswana Pula	-41.586***	-41.592***	-60.018***	-60.006***
Ghanaian Cedi	-41.133***	-41.184***	-70.586***	-70.475***
Kenyan Shilling	-46.226***	-46.217***	-55.585***	-55.596***
Namibian Dollar	-38.687***	-38.708***	-51.708***	-51.687***
South African Rand	-35.005***	-35.067***	-46.507***	-46.473***
Sub-Saharan African stocks				
BSE	-39.469***	-39.665***	-56.187***	-55.933***
GSE	-37.238***	-37.338***	-59.532***	-59.458***
NSE	-32.950***	-33.112***	-46.078***	-45.999***
NASE	-39.980***	-40.104***	-52.068***	-51.927***
JSE	-38.346***	-38.345***	-51.626***	-51.629***
Industrial metals		**Short term**		
Aluminium	1.6796	-1.08	-0.5319	-0.1249
Copper	1.2734	0.2959	-4.9481***	-3.4797***
Nickel	-88.672***	-88.679***	-12.4585**	-12.462**
Zinc	-16.862***	-16.866***	-7.937***	-7.938***
Agricultural commodities				
Cocoa	-0.9031	-6.269***	-6.855***	-3.3034**
Coffee	-16.703***	-16.713***	-7.943***	-7.934***
Corn	1.5664	-1.9033	-3.9832**	-2.0151
Cotton	-29.773***	-29.774***	-11.569***	-11.565***
Exchange rates				
Botswana Pula	2.6408**	0.0595	-2.752**	-1.3998
Ghanaian Cedi	-3.5319***	-7.7707***	-1.282	-0.6939
Kenyan Shilling	-6.5782***	-9.4845***	0.625	0.8717
Namibian Dollar	-1.4476	-5.1439***	-8.7245***	-6.1962***
South African Rand	-0.3708	-4.6318***	-7.2995***	-3.7778***
Sub-Saharan African stocks				
BSE	-21.494***	-21.690***	-9.6654***	-9.5774***
GSE	-9.1626***	-9.1738***	-4.4692***	-4.4856***
NSE	-13.877***	-14.055***	-6.2677***	-6.1753***
NASE	-15.958***	-16.018***	-7.6988***	-7.6742***
JSE	-9.9200***	-9.9201***	-4.7812***	-4.7807***
Industrial metals		**Intermediate-term**		
Aluminium	-349.558***	-349.564***	-169.228***	-169.284***
Copper	-542.284***	-543.414***	-177.158***	-177.341***
Nickel	-318.956***	-318.903***	-251.033***	-251.073***
Zinc	-292.268***	-292.214***	-251.554***	-251.612***

Table 13, continued

Agricultural commodities				
Cocoa	-414.976***	-414.956***	-327.486***	-327.817***
Coffee	-280.320***	-280.269***	-252.825***	-252.884***
Corn	-304.277***	-304.365***	-161.138***	-161.382***
Cotton	-272.972***	-272.923***	-253.390***	-253.445***
Exchange rates				
Botswana Pula	-238.429***	-238.417***	-172.081***	-171.916***
Ghanaian Cedi	-215.626***	-215.588***	-189.238***	-189.277***
Kenyan Shilling	-637.422***	-637.253***	-153.320***	-153.366***
Namibian Dollar	-461.396***	-461.789***	-95.621***	-95.755***
South African Rand	-256.540***	-256.524***	-188.135***	-188.376***
Sub-Saharan African stocks				
BSE	-288.635***	-288.585***	-253.207***	-253.254***
GSE	-329.852***	-329.792***	-929.183***	-929.366***
NSE	-287.299***	-287.247***	-318.143***	-318.219***
NASE	-269.542***	-269.434***	-246.767***	-246.824***
JSE	-287.088***	-287.035***	-244.795***	-244.853***
Industrial metals			**Long term**	
Aluminium	1.4916	1.5314	-9.6819***	-9.6725***
Copper	-73.088***	-73.429***	-49.118***	-48.990***
Nickel	-34.159***	-34.241***	-65.947***	-65.835***
Zinc	-40.289***	-40.283***	-82.128***	-82.133***
Agricultural commodities				
Cocoa	-6.5939***	-6.5547***	-5.9612***	-5.9481***
Coffee	-36.213***	-36.207***	-77.095***	-77.105***
Corn	-17.650***	-17.651***	-21.790***	-21.789***
Cotton	-37.816***	-37.812***	-78.351***	-78.335***
Exchange rates				
Botswana Pula	-6.2731***	-6.3419***	-20.594***	-20.593***
Ghanaian Cedi	-11.794***	-11.790***	-14.520***	-14.518***
Kenyan Shilling	-32.270***	-32.263***	-59.119***	-59.088***
Namibian Dollar	-12.738***	-12.686***	-23.168***	-23.164***
South African Rand	-31.730***	-31.718***	-20.840***	-20.838***
Sub-Saharan African stocks				
BSE	-39.995**	-40.048**	-82.471****	-81.902***
GSE	-39.532***	-39.525***	-57.465***	-57.478***
NSE	-34.922***	-34.927***	-56.015***	-55.996***
NASE	-38.968***	-38.968***	-74.260***	-74.213***
JSE	-35.949***	-35.943***	-65.559***	-65.572***

Notes: Optimal lag for ADF is determined using the AIC criteria. The bandwidth is chosen using the Bartlett Kernel, as suggested by Newey and West (1987) PP. ***, ** and * denote significance at the 1%, 5% and 10% level, respectively.

Source: Woode (2023)

Table 14: Results of Autocorrelation Test

Variables	LBQ [12]	LBQ^2 [12]
Industrial metals		
Aluminium	0.0003	0.0000
Copper	0.0016	0.0000
Nickel	0.0002	0.0000
Zinc	0.6751	0.0000
Agricultural commodities		
Cocoa	0.1507	0.0000
Coffee	0.0000	0.0000
Corn	0.4520	0.0000
Cotton	0.0000	0.0000
Exchange rates		
Botswana Pula	0.0000	0.0000
Ghanaian Cedi	0.0000	0.0000
Kenyan Shilling	0.0000	0.0000
Namibian Dollar	0.3756	0.9462
South African Rand	0.0000	0.0000
Sub-Saharan African stocks		
BSE	0.0166	0.0000
GSE	0.0000	0.0000
NSE	0.0000	0.0000
NASE	0.0019	0.0000
JSE	0.0993	0.0000

Source: Woode (2023)

Table 15: Bivariate Connectedness Between Commodities and Equities

Frequency bands: 3.14-0.79; corresponds to the short-term (1 to 4 days)			
BSE–Aluminium	BSE–Copper	BSE–Nickel	BSE–Zinc
-0.0143	-0.0014	0.0087	0.0092
BSE–Cocoa	BSE–Coffee	BSE–Corn	BSE–Cotton
-0.0068	0.0096	-0.0269	-0.0081
GSE–Aluminium	GSE–Copper	GSE–Nickel	GSE–Zinc
-0.0260	-0.0112	0.0004	-0.0008
GSE–Cocoa	GSE–Coffee	GSE–Corn	GSE–Cotton
-0.0205	0.0005	-0.0410	-0.0018
NSE–Aluminium	NSE–Copper	NSE–Nickel	NSE–Zinc
-0.0242	-0.0087	0.0010	-0.0004
NSE–Cocoa	NSE–Coffee	NSE–Corn	NSE–Cotton
-0.0189	0.0012	-0.0468	-0.0013
NASE–Aluminium	NASE–Copper	NASE–Nickel	NASE–Zinc
-0.0168	0.0018	0.0108	0.0098
NASE–Cocoa	NASE–Coffee	NASE–Corn	NASE–Cotton
-0.0085	0.0121	-0.0374	0.0059
JSE–Aluminium	JSE–Copper	JSE–Nickel	JSE–Zinc
-0.0223	-0.0076	0.0079	0.0091
JSE–Cocoa	JSE–Coffee	JSE–Corn	JSE–Cotton
-0.0085	0.0090	-0.0308	0.0059
Frequency bands: 0.79-0.10; corresponds to a week to month (4 to 32 days)			
BSE–Aluminium	BSE–Copper	BSE–Nickel	BSE–Zinc
-0.1147	-0.0072	0.0777	0.0765
BSE–Cocoa	BSE–Coffee	BSE–Corn	BSE–Cotton
-0.0544	0.0789	-0.2188	0.0676
GSE–Aluminium	GSE–Copper	GSE–Nickel	GSE–Zinc
-0.2128	-0.0917	0.0032	-0.0067
GSE–Cocoa	GSE–Coffee	GSE–Corn	GSE–Cotton
-0.1682	0.0039	-0.4026	-0.0137
NSE–Aluminium	NSE–Copper	NSE–Nickel	NSE–Zinc
-0.1985	-0.0711	0.0084	-0.0032
NSE–Cocoa	NSE–Coffee	NSE–Corn	NSE–Cotton
-0.1554	0.0099	-0.3839	-0.0101
NASE–Aluminium	NASE–Copper	NASE–Nickel	NASE–Zinc
-0.1355	0.0162	0.0915	0.0811
NASE–Cocoa	NASE–Coffee	NASE–Corn	NASE–Cotton
-0.0696	0.1000	-0.3065	0.0498
JSE–Aluminium	JSE–Copper	JSE–Nickel	JSE–Zinc

Table 15, continued

-0.1835	-0.0063	0.0678	0.0745
JSE–Cocoa	JSE–Coffee	JSE–Corn	JSE–Cotton
-0.0706	0.0736	-0.2540	0.0450
Frequency bands: 0.10-0.00; corresponds to long-term (32 to infinite days)			
BSE–Aluminium	BSE–Copper	BSE–Nickel	BSE–Zinc
0.5575	0.6949	0.3661	0.3618
BSE–Cocoa	BSE–Coffee	BSE–Corn	BSE–Cotton
-0.1017	0.3956	-0.9266	-0.0009
GSE–Aluminium	GSE–Copper	GSE–Nickel	GSE–Zinc
-0.7719	-0.3509	0.0162	-0.0360
GSE–Cocoa	GSE–Coffee	GSE–Corn	GSE–Cotton
-0.9016	0.0337	-2.1671	-0.0585
NSE–Aluminium	NSE–Copper	NSE–Nickel	NSE–Zinc
-0.6675	-0.1550	0.0492	0.0053
NSE–Cocoa	NSE–Coffee	NSE–Corn	NSE–Cotton
-0.8266	0.0534	-2.0898	-0.0194
NASE–Aluminium	NASE–Copper	NASE–Nickel	NASE–Zinc
0.7696	0.9196	0.5097	0.4639
NASE–Cocoa	NASE–Coffee	NASE–Corn	NASE–Cotton
-0.6428	0.5149	-1.6143	0.4414
JSE–Alumin	JSE–Copper	JSE–Nickel	JSE–Zinc
-0.9157	-0.3360	0.3837	0.3859
JSE–Cocoa	JSE–Coffee	JSE–Corn	JSE–Cotton
-0.3244	0.3340	-1.3302	0.1136

Source: Woode (2023)

APPENDIX B

Trend Analysis of Decomposed Return Series and Multivariate Wavelet Analysis

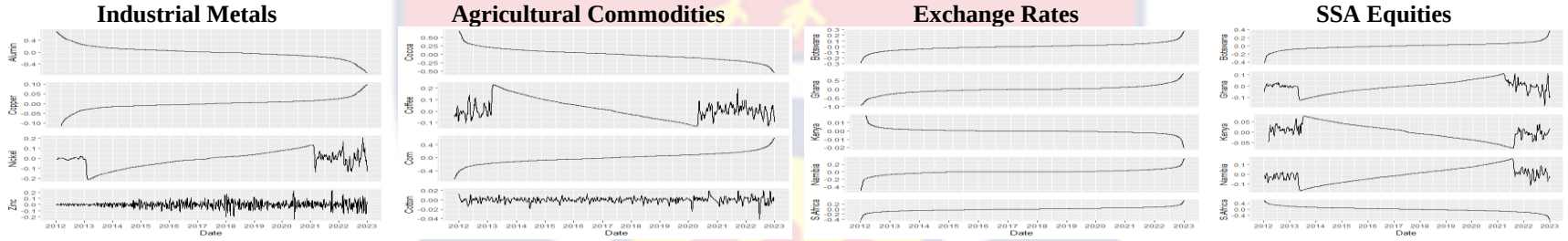

Figure 9. Plots of return series for commodities, exchange rates and SSA stocks in the short-term

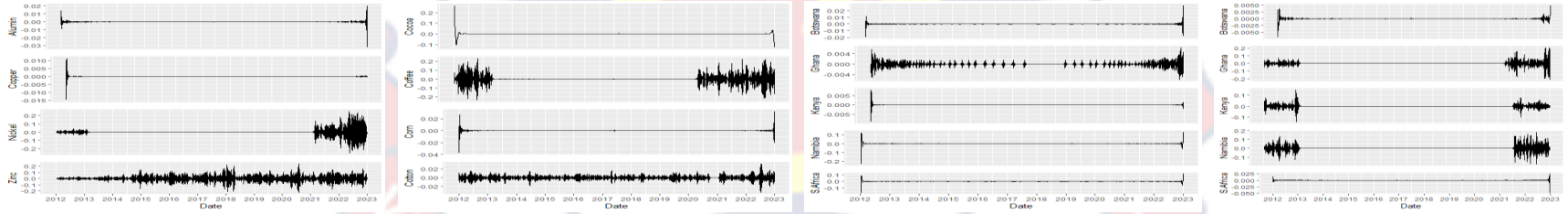

Figure 10. Plots of return series for commodities, exchange rates and SSA stocks in the intermediate-term

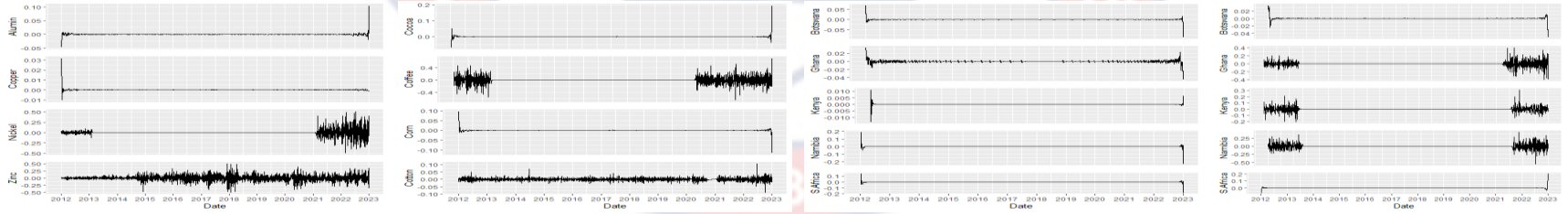

Figure 11. Plots of return series for commodities, exchange rates and SSA stocks in the long-term

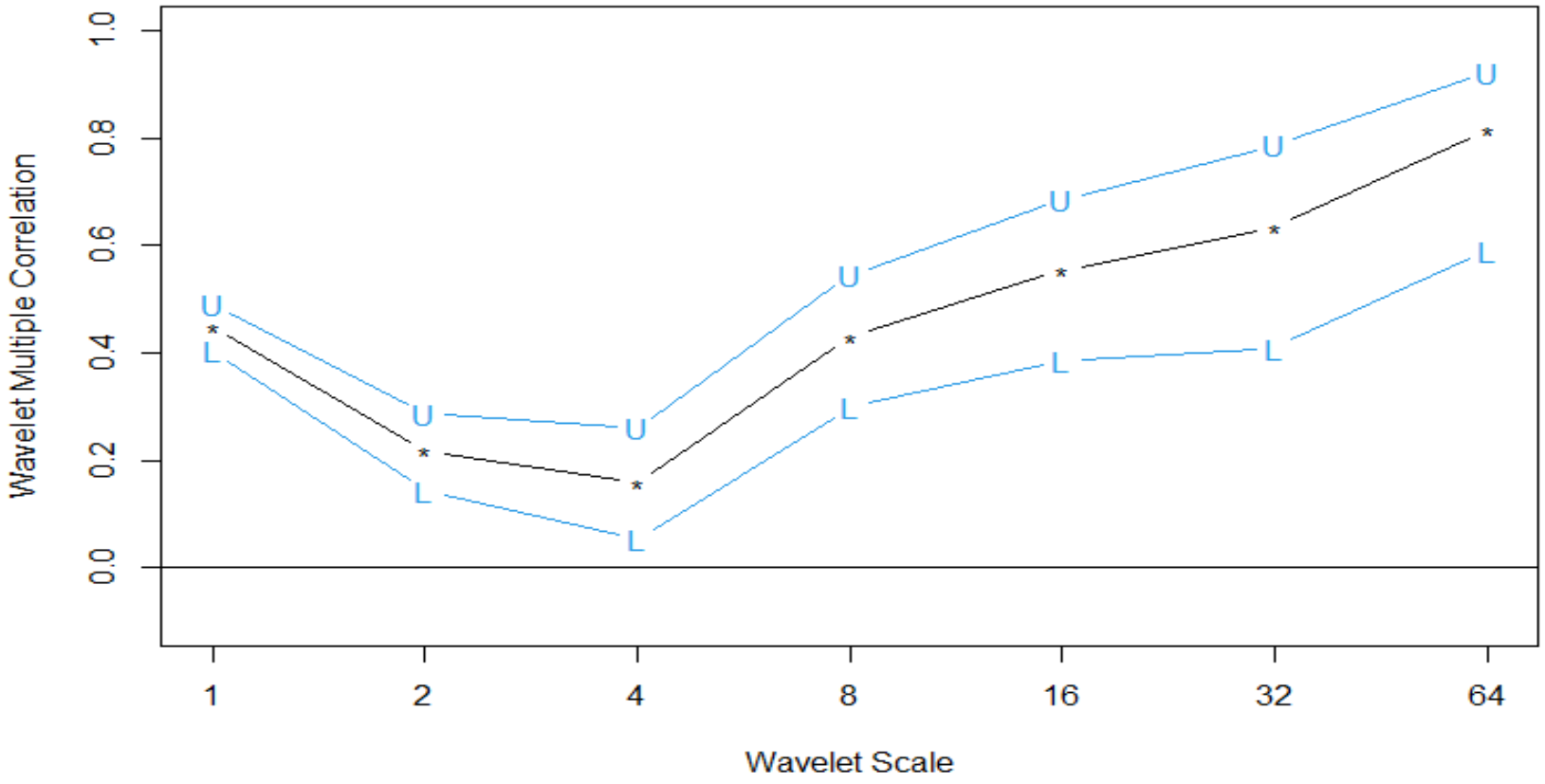

Figure 12: WMC plots for interdependencies between commodities and SSA stocks

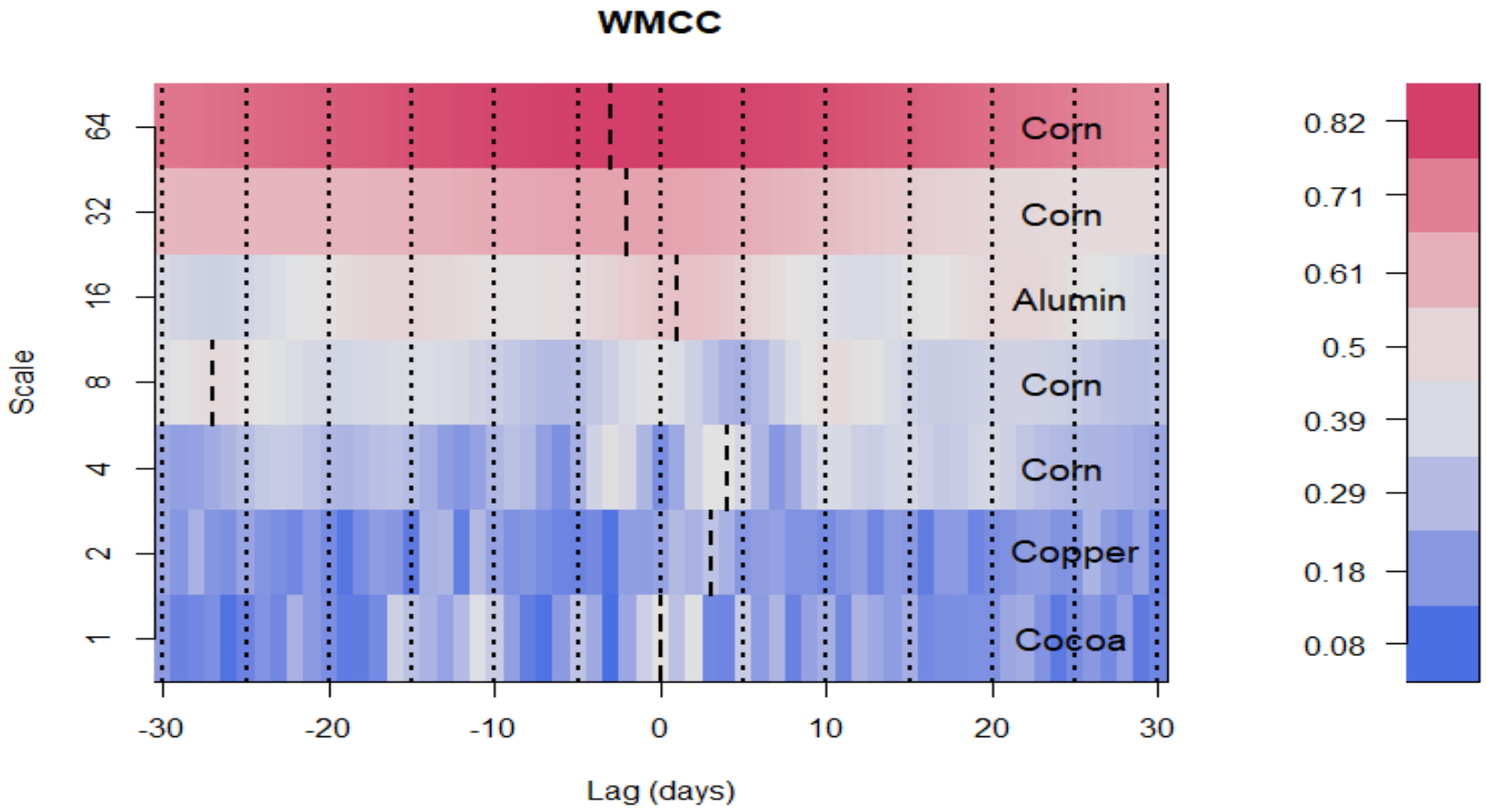

Figure 13: WMCC plots for interdependencies between commodities and SSA stocks