UNIVERSITY OF GHANA

ASSESSING THE CO-MOVEMENT AND CAUSALITY BETWEEN AFRICAN STOCK MARKETS, COMMODITIES, CURRENCIES AND EMERGING ASSETS: THE ROLE OF INTERNATIONAL SHOCKS

BY

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DECLARATION

I, **AGYEMANG-OPAMBOUR, RICHARD,** declare that this thesis is my original work, and therefore has not been submitted by me or any other party to this university or elsewhere for another degree. All materials used therein has been acknowledged duly.

3rd December, 2025

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AGYEMANG-OPAMBOUR RICHARD **DATE**

CERTIFICATION

This is to certify that this thesis has been supervised with the laid down principles for thesis writing at the university.

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ABSTRACT

Understanding how markets interact is crucial for financial decision-making, therefore for an investor or financial institution holding a variety of assets, market dynamics are crucial. Using Wavelet Analysis, this study examines the co-movement and causality between Africa's equity markets, commodities and financial assets. Also, the study sought to determine how these relationships' dynamics have been affected by the COVID-19 pandemic and the Russia/Ukraine disturbances. The study relied on secondary data from DataStream database. To offer a description of the data used for the empirical analysis, plots and tables were used. Furthermore, the study uncovered intricate patterns in the relationships among stock exchanges (GSE, BRVM, NSE, DSE, and JSE) and important variables such as exchange rates (EXC), Bitcoin, gold, cocoa, and crude oil spanning from 2012 to 2023. The use of these equity markets is because of their regional diversity, economic significance and emerging market dynamics. This finding offers valuable information regarding the varying degrees of correlation, interactions with opposing phases, and shifting patterns observed throughout different time periods and frequency ranges. Furthermore, the examination of partial wavelet coherence throughout the COVID-19 period unveiled complex and ever-changing connections among different financial indicators and commodities. The results indicate that there were diverse degrees of correlation and anti-phase dynamics between the Ghana Stock Exchange (GSE) and numerous variables, such as EXC, Bitcoin, Gold, Cocoa, and Crude oil, throughout specific intervals. This study recommends that Financial decision-making methods like Risk management, Diversification, Quantitative modeling and Value investing should carefully analyze the impact of external factors, such as global economic conditions and geopolitical events.

DEDICATION

This thesis is dedicated to the Almighty God and my family, who have provided me with the necessary support to fulfill this journey. This piece is dedicated to my son and niece in particular. With this small step, I aim to inspire them to greater accomplishments in the future.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Since early 2020, the global financial markets have been shaken by significant international shocks, such as the COVID-19 pandemic and the Russia/Ukraine disturbances. These events have had profound impacts on financial systems worldwide, prompting numerous studies examining their effects on various financial and economic indicators. Numerous research on the financial and economic repercussions of COVID-19 have emerged in finance literature as a result of the virus's enormous global impact. (Alamgir, Campbell, Sloan, Goosem, Clements, Mahmoud and Laurance, 2017; Goodell & Goutte, 2021; Karabo, 2017; Tiwari, Abakah, Adewuyi and Lee, 2022; Tiwari, Abakah, Karikari, et al., 2022a; Topcu & Gulal, 2020; Urom, Ndubuisi, Del Lo and Yuni, 2022a)

Additional research that examined the Covid-19 eruption and international shocks revealed how the epidemic affected the markets for commodities, minerals, stocks, and cryptocurrency. (Karabo, 2017; Korotayev, Bilyuga, Belalov and Goldstone, 2018; Tiwari, Abakah, Adewuyi, et al., 2022; Tiwari, Aikins Abakah, et al., 2022)

The study aims to explore the complex dynamics and linkages between African stock markets and other commodities and financial assets. This research is based on the understanding that financial markets are intricate ecosystems that are impacted by several elements, such as economic conditions, geopolitical events, and global market patterns.(Do et al., 2016; Gil-Alana et al., 2018; Tweneboah et al., 2020) In light of Africa's distinctive economic environment, which is marked by

a variety of commodities and expanding financial markets, it is crucial to comprehend the co-movements.

This study is based on the changing structure of African economies, where stock markets play a vital role in indicating economic well-being and stability. Africa, being a continent abundant in natural resources, encounters distinctive correlations between its stock markets and crucial commodities such as oil, gold, cocoa, and others.(Mailey, 2015; The Political Economy of Natural Resources, n.d.) Moreover, the incorporation of these marketplaces with worldwide financial assets, such as Bitcoin and exchange rates, introduces an additional level of intricacy to their interaction.(Goodell & Goutte, 2021b)

The study acknowledges that African economies have been significantly affected by the substantial changes in the global financial landscape.(Topcu & Gulal, 2020b; Urom et al., 2022a) The COVID-19 pandemic and Russia/Ukraine disturbances has presented unparalleled difficulties, altering the interactions between stock markets and different assets. It is crucial for investors, politicians, and researchers to reevaluate and comprehend these correlations in light of the epidemic and other global influences.

The theoretical basis for this study is derived from fundamental financial theories and frameworks like the Harry Markowitz's Modern Portfolio Theory (MPT) to emphasize the importance of diversification in building a portfolio. Modern Portfolio Theory (MPT) seeks to construct efficient portfolios by investing in assets that have low correlations, hence reducing risk.

Also, the Efficient Market Hypothesis (EMH) states that financial markets rapidly assimilate all pertinent information. Assessing the efficiency of information integration into market pricing is crucial for comprehending the correlations between African stock markets and various assets.

Behavioral finance theories, which concentrate on psychological elements that influence financial choices, assist in comprehending investor behavior in African stock markets. Behavioral biases can influence the occurrence of co-movements and herding behavior.

The stock markets are influenced by the supply and demand dynamics of commodity markets. An analysis of co-movements entails examining the impact of fluctuations in commodity prices on correlated equities.

Another important framework backing this study is the Contagion and Systemic Risk frameworks which analyze how disturbances in one market might cause simultaneous moves in other markets, evaluating the interdependence of African stock markets with global financial systems.

Time-Series Analysis approaches, such as wavelet analysis and correlation dynamics, provide a scientific foundation for evaluating the motions that occur together across time. These technologies detect patterns, periodicities, and changes in relationships.

The theories of Financial Integration and Globalization examine the level of interdependence between African stock markets and worldwide markets. This includes analyzing the effects of cross-border capital flows and trade linkages.

By combining these theories, the thesis builds a complete framework for evaluating co-movements, providing a holistic understanding of the intricate interactions influencing African financial markets.

The study seeks to provide significant insights into the correlations, and potential influencing factors that characterize the links between African stock markets and commodities and financial assets. This research aims to provide valuable insights for making strategic decisions, developing risk management strategies, and formulating policies that are crucial for the economic prosperity and resilience of African nations in the midst of a rapidly evolving global financial environment.

1.2 Problem Statement

It is now more important than ever for investors, regulators, and scholars to comprehend how Sub-Saharan African equities markets connect with significant global financial assets. While earlier research has examined the connections between African and worldwide markets (Beirne & Gieck, 2014; Belke & Dubova, 2018; Raddant & Kenett, 2021), the swift evolution of global financial institutions and increased vulnerability to external shocks necessitate ongoing evaluation. In particular, despite mounting empirical evidence that such events significantly affect the amount, direction, and structure of financial connection, little is known about how African equities markets behave during global crises.

Recent quantitative findings emphasize this vulnerability. Urom, Ndubuisi, Del Lo, and Yuni (2022) show that the total connectedness index (TCI) among 12 African equity markets and major global assets rose sharply from 8.79% in stable periods to 37.39% during COVID-19, indicating that more than one-third of return variation during the crisis was driven by external spillovers. Their investigation also finds that global energy markets were leading transmitters of shocks, while French and South African equities markets emerged as key volatility hotspots. According to this research, even while African financial systems are modestly connected under

normal circumstances, they become significantly more vulnerable to global risk during times of extreme stress.

These interdependencies are non-linear and regime-dependent, according to additional empirical research. According to quantile-based connectedness models, connectivity between African and worldwide markets can surpass 90% in extreme market states (91st–95th percentiles), with spillover directions changing between regimes (Mensi et al., 2023). Larger markets, especially South Africa, Nigeria, and Tunisia, frequently turn into net transmitters during bullish extremes, whereas African markets like Ghana, Kenya, and Morocco typically behave as net receivers of shocks during bearish conditions. The necessity for analytical frameworks that can capture changes in co-movement, causation, and volatility under various stress circumstances is highlighted by these tail-risk dynamics.

Additional evidence connects equity behavior in Africa with current global health statistics. Rising COVID-19 instances have a substantial detrimental impact on African stock returns, according to Feudjio (2022), with the biggest effect being shown in lower quantiles linked to weak market conditions. Financial stress indices (FSI) have been demonstrated to significantly impact African returns, particularly in abnormal market regimes (Korsah & Mensah, 2024). Bello, Guo, and Newaz (2022) find significant regional contagion among African markets during the Global Financial Crisis.

There are still a lot of unanswered questions. Few studies have looked at the interactions between a variety of global financial assets (such as gold, crude oil, Bitcoin, and global equity indices) and several African equity markets (such as GSE, BRVM, NSE, JSE, SEM, and DSE) under a single dynamic connectedness and spillover paradigm. Furthermore, little research has been done on how these linkages change under other global shock scenarios, including pandemics, crashes

in commodity prices, geopolitical upheavals, and systemic financial crises. Africa's exposure pathways, resilience mechanisms, and possible chances for diversification during times of global volatility are thus still poorly understood by policymakers and market actors.

By offering a thorough, data-driven analysis of the dynamic connectivity and volatility transmission between African equity markets and important global financial assets across several shock regimes, this thesis seeks to close these gaps. The study aims to improve knowledge of Africa's financial integration within the global system, evaluate the evolution of interconnectedness during crisis and non-crisis periods, and identify the factors that amplify or dampen spillovers. The ultimate goal of this research is to produce knowledge that will aid in better risk management, informed policymaking, and the growth of robust and sustainable financial markets throughout the African continent.

Market participants, decision-makers, and academics must comprehend how the equities market in Sub-Saharan Africa is linked to global assets. Numerous studies like (Beirne & Gieck, 2014; Belke & Dubova, 2018; Raddant & Kenett, 2021) have been conducted on the interaction between regional markets and global financial systems, but ongoing revisions are necessary to take into account the changing dynamics of the world economy. Furthermore, a closer examination of this interdependence in the context of global shocks offers important new perspectives on the transmission mechanisms and spillover effects that affect the equity market in Africa during times of economic unrest.

As asserted by (Urom, Ndubuisi, Del and Yuni, 2022) in investigating Connectedness between Defi assets and equity markets during COVID-19, although the connections between these markets and African equities markets are currently modest, they considerably increased during the

pandemic. According to Yousaf, Jareno and Tolentino7, (2023), they discovered that static connectivity has a small sector- and economy-dependent component. The overall spillover index for the dynamic connection fluctuates over time, as is to be expected, demonstrating the devastating effects of the global pandemic declaration.

The issue raised by this thesis is the lack of knowledge on the connections between Africa's equity markets and foreign assets, as well as the effects of those connections during times of global shocks. Although the mechanisms of transmission, contagion, and spillovers have been studied in the past (Belke & Dubova, 2018; Mensi et al., 2023), it is necessary to revisit these dynamics in the context of global shocks to provide a more complete understanding of the risks and opportunities faced by market participants and policymakers in the area.

By addressing this issue, the thesis seeks to shed light on the fundamental forces that define how the equities market in Africa interacts with other global assets during unstable economic periods. In addition to evaluating the effects of foreign shocks on the region's equity market, the research aims to pinpoint the variables that either amplify or reduce the transmission of shocks. In the end, this thesis seeks to contribute to the body of knowledge by addressing the issue of limited understanding of Africa's equity markets and the co-movement of global assets and causalities under international shocks. It also seeks to provide valuable insights for market participants, policymakers, and scholars seeking to navigate the complexities of global financial systems and foster sustainable financial integration in the region.

1.4 Objective

General Objective

This study aims to give a thorough analysis of the relationships between the equity market in Africa and global assets, with a focus on how these relationships change in response to external shocks. By thoroughly examining the causes, contagion effects, and spillovers that occur during times of economic upheaval. This study intends to shed light on the African equities market's dynamics and its relationship to global assets in the face of external shocks. The results of this study can aid market players, policymakers, and academics in Africa in making knowledgeable decisions, managing risks, and developing a robust and interconnected financial system.

1.4.2 Objectives

i. to investigate the lead-lag relationship for Africa's equity markets, commodities and financial assets.
ii. to investigate the causality between African stocks, commodities and financial assets under different market conditions.
iii. examine the link between Africa's equity markets, financial assets and commodities in the period of COVID-19 and Russia/Ukraine disturbances.

1.5 Research questions

i. What is the lead-lag relationship between Africa's equity markets, commodities and financial assets?

ii. What is the causality between Africa's stocks, commodities and financial assets under different market conditions?

iii. What is the link between Africa's equity markets, commodities and financial assets during COVID-19 pandemic and Russia/Ukraine disturbances?

1.6 Significance of the study

Policymakers can employ insights on co-movements to develop efficient risk mitigation methods. Analyze the correlation between different assets and stock markets to create strategies that promote financial stability in times of market volatility. Recognizing the relationship between African stock markets and global assets should motivate governments to encourage international cooperation. The partnership is essential for establishing synchronized strategies to address economic difficulties and guaranteeing stability in both regional and global financial systems.

Investors and financial institutions might utilize the findings of the study to enhance their investment decision-making process. Gaining insight into the correlations between different assets helps in constructing diversified portfolios that exhibit greater resilience to fluctuations in market conditions. Practitioners have the ability to create adaptive techniques that take into account the co-movement patterns that have been found. By integrating this knowledge into financial planning and decision-making processes, individuals can improve their capacity to navigate and take advantage of market changes.

The study advocates for further investigation into strategies to improve economic resilience. Researchers can further investigate specific patterns of co-movement that have been observed

throughout the COVID-19 and Russia/Ukraine disturbances era, revealing the elements that contribute to resilience and suggesting measures for economic recovery.

1.7 Scope and limitations of the study

This study focuses only on Sub-Sahara Africa's equity market. The Sub-Sahara equity markets have regional economic blocs and these were sampled for the study considering the availability of data.

1.8 Organization of the study

The rest of the study is organized as follows: Chapter two focuses on literature about Africa's Equity Market, Currencies, Commodities and Emerging assets. It consists of theoretical literature review and empirical literature review. More emphasis is placed on how Sub-Saharan equity market react to international shocks. Chapter three, the research methodology. The chapter entails data sources and scope of study, model specification, model estimation, explanations to the variables adopted for the study. Chapter four consists of the presentation of results and discussion of results. Chapter five consists of the summary of findings, conclusion, recommendations, scope and limitation of the study and direction for further research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter provides a conceptual review of the available information regarding the topic under study. This provides an abstract of concepts or ideas based on analyzing available information on Africa's stock markets, currencies, commodities and emerging assets co-movement. The next session provides a theoretical review of concepts relating to the topic followed by an empirical review of available literature relating on Africa's stock markets, currencies, commodities and emerging assets co-movement while taking into consideration international shocks like Covid-19 and Russia/Ukraine disturbances.

2.2 Conceptual Review

2.2.1 Equity Market

The buying and selling of firm stocks or shares take place on equity markets, commonly referred to as stock markets or share markets. By issuing shares to investors, corporations can raise funds through these markets, turning them into partial owners (shareholders). Equity markets play a crucial role in the overall financial system by easing capital allocation and giving investors the chance to take part in company ownership and potential future growth. Through a variety of financial intermediaries, including stock exchanges, brokers, and online trading platforms, investors can purchase and sell shares.

Equity markets serve a number of crucial functions like cash Formation; through initial public offers (IPOs) or subsequent offerings, businesses can raise cash by issuing shares to the general

public. This funding can be put to use for acquisitions, corporate growth, and other investment-related operations.

Another function of equity markets is the opportunities for Investment where the equity markets offer both individual investors and institutional investors the chance to put money into businesses with the possibility to profit from capital appreciation (an increase in share prices) and dividends (the distribution of profits to shareholders).

Also, equity market liquidity enables investors to manage their investment portfolios with flexibility and liquidity by making it simple for them to acquire and sell shares. Due to this liquidity, investors can swiftly turn their assets into cash. Furthermore, equity markets are essential in fostering accountability and openness among listed corporations. Voting on significant corporate decisions, choosing the board of directors, and influencing corporate governance standards are all ways that shareholders exercise their ownership rights.

Equity markets are also frequently utilized as economic indicators to gauge more generalized economic circumstances. Stock market indices, such as the S&P 500 or the FTSE 100, give information about the market's overall performance and mood, which can reflect investor confidence and economic developments.

Equity markets function according to supply and demand dynamics, where the interaction of buyers and sellers determines the price of a stock. Company performance, market trends, economic

indicators, geopolitical events, and investor attitude are some of the variables that affect equity market movements.

It is crucial to remember that investing in equity markets entails risk because returns cannot be guaranteed and share values might change depending on a variety of variables. Before investing in the equity markets, investors should perform thorough research, assess their risk tolerance, and seek professional guidance.

2.2.2 International Assets

Financial instruments or investments held outside of an investor's place of residence are referred to as international assets. These assets may consist of a variety of financial instruments, including, but not limited to, equities, bonds, mutual funds, exchange-traded funds (ETFs), real estate, money, and derivatives. Investors have the chance to diversify their portfolios and get exposure to various global markets and economies through international assets. Investors that invest in assets outside of their native nation may profit from the expansion and success of international markets and seize opportunities not present domestically.

Some typical forms of global assets include; Shares of businesses that are listed on stock markets outside of the country of the investor are known as foreign stocks. By purchasing foreign equities, investors can benefit from the expansion and success of businesses operating in many nations and sectors. Bonds issued by foreign governments, businesses, or other organizations are known as foreign bonds. Foreign bond investments can expose investors to a range of interest rates, currencies, and credit markets.

Furthermore, investment funds that contain a diverse portfolio of securities from several nations include global mutual funds and exchange-traded funds (ETFs). These funds, which are managed by qualified fund managers, can give investors broad exposure to global markets.

International real estate is another form of International or global assets, which include houses that can be bought for investment purposes in other nations. International real estate can provide benefits for diversity, as well as the chance for capital growth and rental income.

Again, investments made in currencies other than the investor's home currency are known as foreign currencies. Forex trading, currency ETFs, currency options, and currency futures contracts are all ways to invest in foreign currencies. Finally, investments in global commodities like gold, silver, oil, or agricultural goods are referred to as commodities. These investments can expose investors to the dynamics of supply and demand around the world and act as a protection against inflation and currency volatility.

International asset investing entails a unique set of concerns and hazards. Changes in currency exchange rates, political and regulatory risks in foreign markets, variations in accounting standards and disclosure requirements, and geopolitical events that may have an effect on global markets can all be considered among these. Before purchasing international assets, investors should do extensive research, comprehend the dangers involved, and take into account their investment goals and risk tolerance. Consulting financial specialists or subject matter experts with understanding of overseas marketplaces might also be helpful.

This study looks at worldwide financial assets including Bitcoin, gold, and crude oil in addition to a number of African stock markets, including the GSE, BRVM, NSE, JSE, SEM, and DSE. These assets and markets were chosen due to their varying degrees of financial development, economic significance, and structural diversity. Particularly in times of increased global uncertainty, their features offer a solid foundation for analyzing volatility, contagion, spillover effects, and safe-haven qualities inside African financial institutions.

Low liquidity, considerable information asymmetry, a small number of listed companies, and a high degree of susceptibility to macroeconomic shocks like inflation and exchange-rate volatility are characteristics of the Ghana Stock Exchange (GSE), which is representative of a typical frontier African market. Understanding how small, illiquid markets react to regional and global volatility can be gained by studying the GSE.

As a regional stock market that serves eight West African nations within a same monetary and regulatory framework, the BRVM is distinct. Its cross-national investor base, unified regulatory framework, and pivotal position in regional financial integration are the reasons for its significance. Examining cross-border connections, policy coordination effects, and regional contagion that are absent from national exchanges is made possible by BRVM.

One of East Africa's busiest and most liquid exchanges is the Nairobi Securities Exchange (NSE). The NSE is a standard for examining spillovers in more globally integrated African markets because of its significant foreign investor engagement, diverse listings, and reasonably advanced trading infrastructure. Its actions set it apart from frontier markets with less liquidity.

Africa's biggest, most liquid, and most globally integrated stock exchange is the Johannesburg Stock Exchange (JSE). It is crucial for comprehending how a developed developing market behaves in comparison to smaller African markets because of its extensive capital base,

sophisticated trading system, and interaction with global markets. Assessing whether contagion effects vary by market maturity and regulatory strength is made easier by including the JSE.

Despite its modest size, the Stock Exchange of Mauritius (SEM) boasts robust governance frameworks, excellent regulatory standards, and substantial international involvement. SEM makes a case for examining whether institutional strength increases market resilience and how well-regulated local markets handle shocks from around the world.

The Dar es Salaam Stock Exchange (DSE) is an example of an East African frontier market that is expanding quickly but is still relatively small. The DSE captures the bottom end of the liquidity and integration spectrum in African markets thanks to its inadequate liquidity, small industry basis, and moderate foreign participation.

The analysis includes Bitcoin, gold, and crude oil; three international assets that have unique functions during times of financial stress to supplement these stock markets. Due to widespread retail use, Bitcoin is becoming more and more transacted throughout Africa. It is essential for determining if digital assets serve as safe havens or sources of contagion for African stocks due to their excessive volatility and speculative nature. Given that Ghana, South Africa, and Tanzania are significant gold-producing nations, gold; the classic safe-haven asset is particularly pertinent. Gold offers a standard by which to measure the possibility for hedging and diversification. Because crude oil is essential to many African economies, it is included. Oil price shocks are a crucial conduit for global volatility since they have a direct impact on currency rates, inflation, government revenue, and stock market performance.

All things considered, the chosen markets and assets collectively offer a fair depiction of regional diversity ;West, East, Southern Africa, and the Indian Ocean while capturing variations in market development, liquidity, foreign investor involvement, and regulatory depth. Comprehensive

examination of cross-market relationships, contagion patterns, and safe-haven dynamics is made possible by pairing African stock markets with Bitcoin, gold, and crude oil. The study's empirical basis is strengthened by this varied but complementary selection, which also improves its capacity to evaluate how African financial markets react to shocks from around the world.

2.2.3 International Shocks

International shocks are sudden, substantial occurrences or elements that affect the world economy or financial markets. These shocks can come from a variety of causes, including geopolitical events, economic crises, natural disasters, changes in policy, or unanticipated developments in important economies.

Beyond the countries or regions directly affected, international shocks can have wide-ranging repercussions. They have repercussions for global economic growth and stability by having an impact on trade flows, altering investor sentiment, and upsetting global financial institutions. These shocks have an effect on economies and financial markets in various areas and nations and can span international borders.

2.3 Theoretical Review

The Efficient Market Hypothesis (EMH), Modern Portfolio Theory (MPT), Contagion and Spillover Theory, and Systemic Risk Theory are the four main financial theories that this thesis uses to explain and interpret how Sub-Saharan African (SSA) equities markets behave in the face of global shocks. Combining these frameworks with the unique characteristics of SSA markets

offers a sophisticated analytical foundation for comprehending cross-market connectivity in times of global instability.

The basis for examining the advantages of diversification across African and international assets is provided by Modern Portfolio Theory (MPT). SSA markets like the GSE, NSE, and BRVM have minimal market depth, concentrated listings, and significant exposure to a few dominating industries (banking, telecommunications, mining), in contrast to mature markets with broad sectoral representation. As a result, the risk-return trade-offs that MPT predicts take on special dimensions: co-movement with global assets (such as Bitcoin, gold, and crude oil) is an essential external source of diversity because diversification inside local markets is intrinsically limited. Therefore, MPT supports the necessity of doing an empirical analysis of how global shocks affect African investors' cross-asset diversification efficiency, especially when commodities dependence increases vulnerability to global supply-and-demand cycles.

The behavior of SSA markets, which have historically shown informational inefficiencies, delayed price discovery, and structural frictions such little liquidity, little analyst coverage, and lax regulatory control, is further contextualized by the Efficient Market Hypothesis (EMH). These features suggest that the assumptions of semi-strong efficiency may be challenged by African equities markets' potential to respond to global shocks with delay, asymmetry, or amplification. Therefore, statistical variations found during times of crises reflect deeper structural limits that affect how information from global assets is valued and assimilated rather than just being noise.

The theory of contagion and spillover provides a useful framework for understanding the susceptibility of SSA markets to outside disruptions. Due to their continued reliance on the export of commodities like oil, gold, cocoa, and minerals, nations like Nigeria, Ghana, and South Africa are particularly vulnerable to changes in international prices. Spillovers from global equity,

commodities, and cryptocurrency markets have traditionally grown during significant events like the COVID-19 pandemic, oil shocks, or U.S. interest rate hikes, with African markets exhibiting enhanced cross-market co-movement and heightened volatility transmission. These dynamics highlight how important contagion models are for capturing time-varying and non-linear relationships that conventional linear approaches might miss.

Finally, the study of how shocks spread through interconnected financial institutions is informed by Systemic Risk Theory. Despite being smaller and less globally integrated, African markets are disproportionately vulnerable to global systemic disruptions due to structural weaknesses like exchange-rate volatility, concentrated banking systems, and reliance on outside capital flows. The idea facilitates the investigation of whether global shocks (such as financial crises, commodities collapses, or geopolitical unpredictability) cause systemic stress in African markets through channels like capital flight, investor herding, or liquidity withdrawal.

When taken as a whole, these theoretical frameworks demonstrate the need for approaches that can capture time-frequency dynamics, structural breaks, and changing correlations when analyzing African markets. Additionally, they reaffirm the importance of researching SSA markets in the context of the global financial architecture, recognizing that the scale, routes, and durability of international shock transmission are shaped by their distinct structural features.

2.3.1 Interdependence Theory

A social psychological paradigm called explains how the degree of interdependence between people in interpersonal interactions affects the people in those connections. Harold Kelley and John Thibaut first suggested it in the 1950s, and several researchers have since modified and improved upon it.

Interdependence theory in finance refers to the study of the connections and interactions among financial markets, assets, institutions, and individuals. It focuses on comprehending how different financial system actors interact with and depend on one another, and how this interaction affects market dynamics and results. (Jung & Maderitsch, 2014)

The financial interdependence theory includes the following significant elements like,

Market Interdependence which examines how several financial markets, including the equities, bond, commodity, and foreign exchange markets, are linked to one another. It looks at how market fluctuations can have an impact on other markets, causing spillover effects, cross-market correlations, and the spread of shocks across asset classes. Financial institutions, such as banks, investment companies, and central banks, are interdependent and essential to the operation of the financial markets. The interdependence hypothesis in finance looks into how these institutions' decisions and activities, such as their monetary policies, investment plans, and lending practices, affect one another and the larger financial system.

Individual and institutional investors are interdependent on one another in the financial markets. The interdependence theory looks at how investor choices, trading patterns, and risk preferences affect market results and other market participants' actions. It examines ideas that can encourage investor interdependence, including as herding behavior, information cascades, and investor sentiment. The idea of systemic risk, which relates to the possibility of broad disruptions or failures in the financial system, is also covered by the interdependence theory. It examines how financial institutions' and markets' interconnection can magnify and spread shocks, resulting in systemic crises. For evaluating the stability and resilience of the financial system, it is essential to

comprehend systemic risk. Financial concepts like contagion effects, market volatility, correlations, and the transmission of shocks are all better understood with the aid of interdependence theory. It offers insights into the functioning of financial markets, how asset prices are determined, how market participants behave, and how these factors affect risk management and regulatory practices.(Jung & Maderitsch, 2014)

In addition, the interdependence hypothesis in finance has applications in risk management, portfolio management, and financial regulation. In order to ensure financial stability, it emphasizes the significance of taking interdependencies and systemic risks into account when creating investment portfolios, assessing risk exposures, and developing regulatory frameworks.

In general, the interdependence theory in finance offers a framework for comprehending the intricate connections and links that exist throughout the financial system. It clarifies the behavior of market participants, the dynamics of financial markets, and the implications for risk management and systemic stability.

Authors have recently classified "linkage" in the financial market into "interdependence" and "contagion." According to (Jung & Maderitsch, 2014), interdependence is a state of stable long-term connections that are governed by fundamentals. In both crisis and non-crisis situations, this interdependence hypothesis places a strong emphasis on genuine connection and fundamental integration as transmission shock pathways between two markets. According to Flavin and Sheenan (2015), interdependence is the term used to describe market correlations that exist under all global situations and are brought on by exposure to shared risk sources and standard asset market connections.

2.3.2 Portfolio Theory

Also, Harry Markowitz, an economist, created the framework known as portfolio theory (sometimes referred to as modern portfolio theory, or MPT), in the 1950s. It offers a mathematical method for building investment portfolios that aims to maximize the trade-off between anticipated profits and risk. According to portfolio theory, an investor should analyze the total portfolio as well as the relationships between the many assets inside it rather than concentrating exclusively on the qualities of individual assets. The theory is predicated on the idea that investors can create a more effective portfolio that gives a desirable amount of return for a given level of risk or vice versa by combining assets with varying risk and return profiles. (Aloui & Hkiri, 2014)

2.3.3 Financial Contagion Theory

This theory explores the transmission of financial shocks across different markets and regions. In the context of the study, it could be employed to understand how disruptions in Sub-Saharan Africa's equity markets during the COVID-19 pandemic and Russia/Ukraine disturbances might have influenced or been influenced by other asset classes, considering the potential ripple effects and interconnectedness.

Globalization Theory

This theory examines the increasing interconnectedness of financial markets globally. In the context of the study, it can be utilized to analyze how the integration of Africa's stock markets

with currencies, commodities and emerging assets has evolved, especially during the unique circumstances presented by the COVID-19 pandemic and Russia/Ukraine disturbances.

To comprehend the behavior of African financial markets, this study makes use of a number of important financial and economic theories, including Modern Portfolio Theory (MPT), the Efficient Market Hypothesis (EMH), Contagion and Systemic Risk frameworks, Financial Contagion Theory, Globalization Theory, and Interdependence Theory. Limited market depth, low liquidity, substantial information asymmetry, concentrated investor bases, and high sensitivity to macroeconomic and global shocks are some of the distinctive features of these markets. By combining these theories, it becomes easier to understand how these structural characteristics affect market performance, volatility, and the spread of shocks throughout the continent.

Although MPT offers the framework for analyzing risk-return trade-offs, it is limited in African markets by the predominance of systemic macroeconomic risks, thin trading, high transaction costs, and few options for diversification. Because return distributions frequently depart from normality, conventional portfolio optimization is less useful in real-world situations. In this situation, EMH also has difficulties. The majority of African markets, at best, resemble weak-form efficiency due to institutional shortcomings, behavioral biases, retail investor domination, delayed corporate reporting, and poor information disclosure.

Africa's structural weaknesses make the frameworks of contagion and systemic risk extremely pertinent. Many economies are vulnerable to external shocks because they rely significantly on commodity exports and are susceptible to attitude toward global risk. Financial stress can spread both domestically and regionally due to concentrated banking sectors and the existence of major international financial institutions. Strong behavioral contagion among retail investors and co-

movements motivated by common commodity exposure are highlighted by Financial Contagion Theory, which expands on this. Due to low regional capital integration, external contagion especially from global financial hubs remains more significant than intra-African contagion.

Africa's increasing financial integration, which is fueled by capital flows, foreign direct investment, technology diffusion, and a slow convergence of regulations with international norms, is explained by globalization theory. Globalization boosts financial inclusion and economic prospects, but it also makes people more susceptible to market instability. The impact of African regional blocs (ECOWAS, SADC, EAC, and BRVM) on boosting cross-border trade and financial ties is further contextualized by interdependence theory. Regulatory fragmentation and low capital mobility restrict the full benefits of integration while progressively increasing avenues for cross-border spillovers, notwithstanding the growing regional financial interconnectedness.

When taken as a whole, these frameworks show how the structure, efficiency, and shock sensitivity of African financial markets are significantly different from those of industrialized markets. Analyzing market behavior, particularly in times of volatility, requires an understanding of these distinctions. Together, the theories highlight how important it is for imperfect knowledge, external dependencies, macroeconomic vulnerability, and changing regional integration to influence financial dynamics throughout the continent.

2.4 Empirical Literature Review

Particularly in the wake of significant worldwide shocks like the COVID-19 epidemic, the conflict between Russia and Ukraine, and increased commodity volatility, the relationship between Sub-Saharan African (SSA) equities markets and global financial assets has grown in importance. According to fundamental research (Beirne & Gieck, 2014; Belke & Dubova, 2018), emerging

markets show time-varying spillover behavior, with shock transmission becoming more intense during times of crisis. These early studies, however, mostly concentrate on the economies of Asia and Latin America, providing little understanding of the distinctive structural features of Africa, such as its shallow market depth, poor liquidity, and strong reliance on commodities.

In order to close this gap, recent research examines Africa's place in international financial networks. According to Urom, Ndubuisi, Del, and Yuni (2022), spillover intensities increased significantly during COVID-19, despite the fact that African stock markets originally showed minimal connectivity with global and DeFi assets. According to Yousaf, Jareño, and Tolentino (2023), dynamic spillover indices exhibit significant fluctuations over time and intensify during periods of global uncertainty. The two studies use distinct empirical frameworks (quantile VAR versus the Diebold–Yilmaz dynamic spillover model), which leads to discrepancies in the extent and persistence of discovered spillovers even though they arrive at similar results. These methodological discrepancies draw attention to a more general issue with model comparability and the handling of non-linear relationships in the literature.

More recent viewpoints are offered by studies released between 2021 and 2024, however they also highlight methodological flaws. Strong bidirectional volatility transmission between crude oil and African stocks is demonstrated by Mensi et al. (2023); however, multi-scale co-movement or structural breaks cannot be fully captured by their GARCH-based approaches. Adam and Tweneboah (2022), on the other hand, use cointegration approaches to study commodity-equity relationships in Ghana and Nigeria. However, their static framework ignores time-varying dynamics, which are particularly noticeable in times of crisis. These drawbacks highlight the need for more reliable approaches that can record changing co-movement patterns over various time periods.

There are still conflicting results about how alternative assets behave. For instance, Corbet et al. (2021) and Dyhrberg and Foley (2024) record growing correlation between cryptocurrencies and traditional markets during global stress, challenging the safe-haven narrative, while Bouri et al. (2022) propose that Bitcoin provides a safe haven for African equities during extreme volatility. These discrepancies highlight the fragmented character of empirical evidence and are caused by differences in data frequency, time spans, and methodological decisions.

Additionally, the literature frequently ignores structural characteristics of SSA markets that increase susceptibility to external shocks, such as a strong reliance on exports of minerals, oil, gold, and cocoa; concentrated sectoral listings; and exposure to exchange-rate swings. While some research (e.g., Narayan et al., 2022) try to describe these features using regime-switching frameworks, they frequently fall short of capturing the layered structure of spillovers across short- and long-term horizons.

Overall, the literature shows that spillovers to African markets are substantial, highly time-varying, and crisis-dependent; however, the intricacy of these linkages is not well captured by current approaches. Due to these constraints, sophisticated, multi-resolution techniques that take into consideration structural breaks, frequency-specific behavior, and non-linear contagion effects are obviously needed, such as wavelet-based analysis. By filling in these gaps, the current study will be able to make a significant contribution to our knowledge of Africa's financial integration in an increasingly unstable global system.

It would be necessary to look at how different facets of equity markets in Sub-Saharan Africa interact with international assets, while taking international shocks like COVID-19 and Russia-Ukraine disturbances in consideration in order to determine the precise relationship between Sub-

Sahara equity markets and international assets. Most empirical literature on equity markets and international assets focuses on the relationship between one or two indices on a particular equity market and an economic variable and to an extent an international asset.

So, on the Ghana stock exchange, Owusu Junior et al., (2018), found that there is narrowly identifiable lead-lag relationship between GSE-CI and USD/GHS and GSE-FSI and USD/GHS. Amewu et al., (2022), also demonstrate how the dynamics of co-movement or interconnectivity between the exchange rate and the composite index of the Ghana Stock Exchange have changed through time and between frequencies. They also found evidence to support low-medium term lead-lag relationships between the Ghana Stock Exchange Composite Index and the currency rate in the years 2013–2014 and 2016. Additionally, there is a limited correlation at all scales between the movement of the exchange rate or the Ghana Stock Exchange Composite Index and global equity markets.

Also, most empirical evidences focus on developed economies, see Aftab et al., (2015), in their findings suggest that, exchange rate and stock price are related negatively, which increases during financial crises period. According to their findings, currency may be considered a diversifier against equity in China. Do et al., (2016), also examined the linkages both within and between stock and foreign exchange with three moments of returns distribution (volatility, skewness and kurtosis). They posit that foreign exchange markets linkages in the second and fourth moments are relatively more prominent in developed markets. They also believe that cross-asset markets in emerging countries are more likely to be negatively linked through the 3rd moment but they are

positively associated via the 2nd and 4th moments in developed markets indicating common concerns regarding tail risks in the former.

Thai Hung, (2020), looked at stock market volatility and exchange rate movements in the Gulf Arab countries and found that exchange rate changes do not have an influence on the stock market returns of the Gulf Arab countries, regardless of the volatility regimes. Barakat et al., (2015), also found a relationship between stock market and exchange rate which plays important role in stock market fluctuations.

Another strand of literature which is similar to my work examined relationship between equity markets and other assets and also co-movement between commodities and other international assets but didn't consider international shocks. Arezki et al., (2012) in their work, commodity prices and exchange rate volatility posit that gold price volatility plays a key role in explaining both the excessive exchange rate volatility and current disproportionate share of speculative inflows in South Africa. Vivian & Wohar, (2012b) also examined commodity volatility breaks and found that commodity volatility persistence remains very high for many commodities returns even after structural breaks are accounted for. The same way, Wadud et al., (2023), in studying co-movement between commodity and equity markets found that there is asymmetric effect in cross-scale co-movement between various commodities and equities. They again found weak co-movement between equity and specific commodity which indicates diversification benefits for short-term and long-term investors. A study by Thenmozhi & Srinivasan, n.d. on co-movement of oil price, exchange rate and stock index of major oil importing countries using a wavelet coherence

approach revealed that, in the long and medium terms, but not in the short term, there is a correlation between the price of oil and the stock indices of the major oil-importing nations.

The lead-lag relationship between the price of oil and macroeconomic indices is seen to fluctuate through time and frequency. Stock market indices don't offer diversification opportunities, whereas exchange rates do, because stock market indices and oil prices fluctuate in a similar fashion across all oil-importing nations. There are also works by researchers like Khan et al (2016) which indicates relationship between exchange rate and stock market prices.

In examining the dynamic relationship between stock market prices and exchange rates movement in seven African countries, Adjasi et al., (2011), found that Tunisia alone exhibited a stable a long-run relationship between stock market prices and exchange rate among the seven African countries. According to a study by Maitra et al., (2022), the findings show optimal investments in Bitcoin and Ethereum have reduced during the COVID-19 pandemic, while the cost of hedging has increased during this period. The findings also confirm that cryptocurrencies cannot provide incremental gains by hedging stock market risk during the COVID-19 pandemic

The last strand of literature which are similar to my work looked at the relationship between equity markets, international assets and international shocks but focus on a particular stock market. In response to the financialization of the commodities markets, the prices of oil, gold, the US dollar, and stocks have all acquired additional diversification characteristics and started to share statistical traits with other common characteristics (Vivian & Wohar, 2012b; (Chkili et al., 2014) (Arfaoui & Ben Rejeb, 2017). They are connected to one another and to forecasts of the global business cycle.

The price movements of all these assets are significantly associated with market expectations for the future state of the global economy and investment horizons, according to that theory. Those pricing may serve as an indicator of how investors feel about the future. Commodity prices have an effect on economic growth and standard of life in emerging or low-income countries, which have been empirically described as import-dependent with relatively low exports compared to aggregate imports (Arezki et al., 2012). Because exchange rates indirectly dictate trade volumes, commodity prices in these countries may have an impact on the supply and demand for other trading currencies (Barson et al., 2022).

Furthermore, Ahmed (2018), which looked at the effect of financial crises on the dynamic relation between foreign exchange and stock returns, assert asymmetric relation between stock returns and changes in exchange rates during pre-crises and post-crises periods. Rosenkranz & Melchor (2022), also posits that, financial interconnection grew throughout Asia and the Pacific, becoming especially apparent during previous crises, such as the ongoing COVID-19 pandemic. Additionally, the authors discover that the likelihood of a crisis starting is highly and favorably related to growing interconnection. Amewu et al., (2022b) in their work, co-movement between equity index and exchange rate found that interdependencies among the variables are more intense during Covid-19 than during the pre-Covid-19 period.

2.5 Chapter summary

This chapter examined the key literary pieces that dealt with this subject and cogently explained the information they contained. The relationship between the equity market in Sub-Saharan Africa and international assets, with an emphasis on the effects of global shocks is an untouched area in

extant literature. Establishing such a relationship would aid in making informed decisions in terms of policy making for Sub-Sahara African equity markets and players on the market.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

In this chapter, the approach, techniques, and data used in the study are all addressed. The research design, demographics, sample, data source, method of data analysis, and methods of data presentation are given more attention. The method is selected in accordance with the objectives of the study in order to address the research issues. This chapter discusses the method of analysis and financial techniques that were used to analyze the data.

3.2 Study population

This study will use data on Sub-Saharan equity markets, international assets and international shocks like Covid-19 and Russia-Ukraine disturbances which will be sourced from DataStream database. Geographical closeness, regional economic integration, and shared trading currencies serve as the foundation for these blocs. Among the notable blocs which my work considered are: West African Economic and Monetary Union (UEMOA), Benin, Burkina Faso, Cote d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal, and Togo are the eight nations that make up this bloc. Two stock exchanges, the Ghana Stock Exchange (GSE) and the Bourse Régionale des Valeurs Mobilières (BRVM), are going to be considered.

Another bloc that was considered in this work is the East African Community which comprises of six countries, namely Burundi, Kenya, Rwanda, South Sudan, Tanzania, and Uganda. The Nairobi Securities Exchange (NSE) and the Dar es Salaam Stock Exchange (DSE) are the two main stock

exchanges in the EAC. The NSE has the highest market capitalisation and is the biggest exchange in the EAC.

The final block this study considered is the Southern African Development Community (SADC) which comprises of 16 Countries. Angola, Botswana, Democratic Republic of the Congo, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe are among the 16 nations that make up this group. There are numerous stock markets in the SADC region, the biggest and most important of which is the Johannesburg Stock Exchange (JSE) followed by the Mauritius Stock Exchange (SEM)

Also, International Assets in my work will focus on Gold, Cocoa and Crude oil; and the US dollar-Cedi exchange rate. International shocks in my work will consider Covid-19 and Russia-Ukraine disturbances.

A fair and thorough depiction of Sub-Saharan Africa's financial scene is provided by the choice of the Ghana Stock Exchange (GSE), Bourse Réionale des Valeurs Mobilières (BRVM), Nairobi Securities Exchange (NSE), Dar es Salaam Stock Exchange (DSE), and Johannesburg Stock Exchange (JSE). These exchanges, which cover West, East, and Southern Africa, capture differences in investor engagement, institutional frameworks, market development, and economic structures. They are suitable for analyzing the heterogeneous propagation of global shocks throughout the region due to their combined properties.

The key economic blocs in Sub-Saharan Africa are represented by the selected markets. The GSE and BRVM represent West Africa. The GSE is a prime example of a frontier market that is highly impacted by the export of commodities, especially agricultural and gold, rendering it susceptible to changes in world prices. Operating as a regional exchange for eight West African

nations under a single monetary system, BRVM provides a unique viewpoint on shared-currency dynamics, cross-border capital flows, and financial integration in the African environment.

The NSE and DSE encompass East Africa. With a wide range of sector listings, comparatively strong liquidity, and substantial interest from overseas investors, the NSE is a prominent East African exchange. It is crucial to comprehend how global risks spread throughout East Africa as a regional financial center. On the other hand, because of its limited depth and heavy reliance on agriculture, the DSE represents a thinner, smaller market that is more prone to volatility. Its inclusion makes it possible to evaluate how shocks spread in markets with weaker institutional capability and resilience.

The JSE, the biggest and most advanced market on the continent, represents Southern Africa. The JSE is the main entry point for foreign investors into Africa, accounting for more than 70% of the continent's overall market capitalization. It is a perfect baseline for analyzing how international shocks infiltrate and spread through African financial institutions because of its high degree of global interconnectedness, sophisticated regulatory frameworks, and diverse listings.

The structural diversity of African economies is reflected in these trades taken together. The NSE integrates the financial services, manufacturing, and telecommunications sectors, whereas the GSE and BRVM show a considerable reliance on commodities. The DSE is a prime example of a market with considerable exposure to domestic economic fundamentals and little liquidity. The JSE includes features including deep liquidity, sophisticated financial instruments, and a high level of international investor activity that are typical of advanced developing markets.

This variety is crucial for assessing how various market settings react to shocks from around the world. It enables research into whether more insulated or shallow markets, like the GSE and DSE, absorb and propagate shocks differently than fully connected markets, like the JSE. Furthermore,

BRVM's inclusion sheds light on how a regional, multi-country exchange behaves, which is uncommon in international financial systems.

In order to ensure that the analysis is not skewed toward any particular structural type, the chosen markets collectively represent the entire range of market development in Africa, from frontier to developing markets. They also show the region's varied sectoral mix, degrees of global integration, and monetary regimes (independent currencies versus monetary unions). This set's representativeness improves the policy relevance in Sub-Saharan African contexts and reinforces the thesis findings' external validity.

All things considered; this group of markets offers a strong, regionally balanced, and analytically rich basis for investigating the co-movement and shock transmission between key global financial assets and African equity markets.

3.3 Data

This study makes use of COVID-19 infection cases' daily data as well as the Ghanaian cedi's exchange rate to the US dollar (EXC), daily data from the Ghana Stock Exchange (GSE), Bourse Régionale des Valeurs Mobilières (BRVM), The Nairobi Securities Exchange (NSE), the Dar es Salaam Stock Exchange (DSE), the Johannesburg Stock Exchange (JSE) and finally the Mauritius Stock Exchange (SEM). The data series covers a period from January 19, 2012, to December 19, 2022. However, to gain a deeper understanding of the relationship between the selected variables, the data divided the into two distinct periods: pre-COVID-19 (January 19, 2012, to February 24, 2020) and the COVID-19 period (February 25, 2020, to December 19, 2022). This division allows the study to provide more insightful analysis on how the variables co-move during these specific

timeframes. The study starts analyzing the COVID-19 data on February 25, 2020, since that was the day, the disease was first identified and made public in the Sub-Saharan Africa region, while December 19, 2022 completes the ten years span chosen for the study. The period considered for the Russia/Ukraine disturbances from 24th February, 2022 to 31st August 2023. For the sake of uniformity, price level data of all the equity markets are denominated in dollars.

Analyzing the dynamic linkages between global financial assets (like gold, crude oil, cocoa, and Bitcoin) and Sub-Saharan African equities markets (such the GSE, NSE, BRVM, JSE, SEM, and DSE) requires high-quality data. Gaps, inconsistent reporting, and erratic trade patterns are common in financial time-series data from frontier and emerging markets. The data preparation techniques used to guarantee precision, consistency, and dependability throughout the empirical study are described in this subsection.

To span a uniform study period across assets and markets, all datasets were initially harmonized and aligned to a daily frequency. Timestamp checks were used to find and eliminate duplicate entries. Interquartile range (IQR) analysis and visual examination of line plots were then used to filter the dataset for outliers and incorrect observations. Only when they were verified as errors were suspicious entries such as abrupt zero prices or drastic spikes at odds with market behavior corrected after being cross-checked against secondary data sources.

Given the asynchronous trading calendars across African and worldwide markets, calendar harmonization was implemented. To avoid distortions in return computations, non-trading days (public holidays or exchange-specific closures) were identified and handled correctly. Before beginning wavelet analysis or causality modeling, this stage makes sure that all series reflect similar time points.

Due to thin trading, delayed reporting, or brief market suspensions, missing observations are frequent in African stock markets. To prevent time-series estimation biases: For predictable non-trading days (such public holidays), forward-fill was employed because prices don't move when markets are closed.

Short, isolated gaps resulting from small data vendor errors were filled in using linear interpolation. Because interpolation produces false patterns, it was purposefully avoided during long gaps (such as extended periods of market inactivity); these times were eliminated from model estimation windows.

This hybrid method avoids distortions in Granger causality tests and wavelet-based multi-scale analysis while maintaining the data's original structure.

All price series were converted into log returns in order to prepare the dataset for analysis. This typical approach improves stationarity, lowers heteroscedasticity, and makes it easier to compare markets of different sizes. ADF, PP, and KPSS tests were used to further assess stationarity and make sure the data fulfilled the specifications of the econometric models used.

Descriptive statistics (mean, variance, skewness, kurtosis) and autocorrelation diagnostics were conducted to discover abnormal patterns that could signal data quality issues. The accuracy of the retrieved series was also confirmed through cross-validation with other databases and official market reports.

To guarantee transparency and reproducibility, every data cleaning intervention—including identified abnormalities, performed remedies, and omitted periods—was methodically documented. The ensuing wavelet estimation and Granger causality studies that are essential to this study are made more reliable by this strict methodology for data preparation.

3.4 Method of Analysis

Because the wavelet estimation approach provides a particularly potent framework for analyzing the time-frequency dynamics that define the linkages between global financial assets and Sub-Saharan African (SSA) equities markets, this study uses it. Wavelet techniques break down financial series over short-, medium-, and long-term time horizons while taking non-stationarity, structural breaks, and changing co-movement patterns into account. Because of these qualities, wavelets are particularly well-suited for SSA markets, where complex and dynamic interactions with global assets are produced by volatility, liquidity limitations, and commodity-driven cycles.

The capacity of wavelet analysis to capture relationships that vary over time and across frequencies is a major advantage over traditional Vector Autoregressive (VAR) models. VAR models only work in the time domain and make the assumption that all of the sample's parameters are constant, which is rarely true for African markets. Static, fixed-parameter models are unable to reflect the episodic and scale-specific consequences of global shocks like the COVID-19 epidemic, oil price collapses, interest rate increases, or cryptocurrency crashes. By offering a dynamic picture of how dependency increases, decreases, or reverses under various market regimes, wavelet estimation overcomes this constraint.

Additionally, wavelets are resilient when non-stationarity, a prevalent characteristic of SSA financial data, is present. In order to attain stationarity, traditional methods frequently call for differencing or detrending, which results in the loss of crucial long-term data. The examination of markets influenced by regime shifts, policy shocks, currency pressures, and commodity price cycles is made possible by wavelet transforms, which maintain both time and frequency patterns without imposing restrictive assumptions.

Additionally, wavelet estimation makes it possible to clearly identify multi-scale spillover pathways, differentiating between longer-term contagion caused by macroeconomic fundamentals and short-term market noise and speculative events. This distinction is particularly crucial in SSA markets, where long-term co-movement frequently results from persistent commodities dependency or global risk sentiment, but short-term volatility may signal liquidity problems or capital flight.

Wavelets provide better localization than other time-frequency methods like Fourier transforms. Fourier methods fail to detect structural changes because they break down data globally. Wavelet transforms provide very accurate information about crisis episodes, contagion periods, and stages of market decoupling by precisely identifying the timing and intensity of co-movements.

Additionally, wavelets perform better than GARCH-type volatility models, which are mainly concerned with variance dynamics and cannot reveal the frequency-specific co-movement structure that underlies spillovers. Volatility clustering is captured by GARCH models, but they are unable to determine whether spillover effects are mostly long-term or short-term. On the other hand, wavelets offer a comprehensive, multi-resolution perspective of frequency dependency.

Finally, the wavelet estimation approach compliments the usage of Granger causality in this thesis. Wavelets show where and when these causal linkages are most noticeable throughout time horizons, whereas Granger causality determines the direction of predicted associations. A deeper and more thorough understanding of the shock transmission mechanisms between global assets and African equity markets is provided by this integrated approach.

In conclusion, wavelet estimation is favored due to its ability to: (1) capture time-varying and scale-dependent behavior; (2) handle non-stationarity and structural breaks; (3) detect multi-

horizon spillover effects; (4) facilitate localized crisis detection; and (5) successfully integrate with causality testing. Wavelet methods are the most suitable and reliable instrument for analyzing the changing interdependence of SSA equities markets in a volatile global financial climate because of these advantages.

The study uses the wavelet estimation approach in line with contemporary econometric models for the analysis of variable connection or interrelations. Despite being novel, this strategy has not been applied frequently in this field of finance. Since it can better balance detecting inconsistency and fluctuations in the time series data, the wavelet approach proves the best suitable for my investigation. Unlike other models that solely focus on time, wavelet analysis takes into account the behaviour of the data in both the time and frequency domains. In order to study the specifics of joint movements over a range of time horizons without distorting the truth, it has the ability to analyse variables at multiple frequencies (Boako & Alagidede, 2016a).

Because wavelet analysis captures the time-frequency dynamics of financial connectivity in a unique way and enables the simultaneous analysis of short-, medium-, and long-run co-movements between African equity markets and global financial assets, it is the most appropriate methodological approach for this study. Wavelet approaches successfully manage the extreme non-stationarity, structural discontinuities, and varied market behaviors typical of African financial data, in contrast to traditional econometric models that presume stationarity or produce static full-sample estimates. Furthermore, a precise understanding of how spillover intensities, transmission mechanisms, and lead-lag connections change during global shocks like COVID-19 is provided by wavelet coherence and wavelet-based causation. Wavelet analysis is the most methodologically

sound and empirically suitable framework for addressing the main goals of this thesis because of its multi-scale, time-varying, and shock-sensitive analytical power.

A wavelet is a tiny wave that can be stretched out over time to reveal the frequency components of complex signals. The null mean of the wavelet function is localized in time and frequency. The normalization component, represented by 1/q, makes sure that the variance is uniform. The terms t, q, and stand for time scale and time position, respectively. In light of these factors, the mother wavelet function, also known as the wavelet transform, can be stated mathematically as follows

$$\Phi_{\tau,q}(t) = \frac{1}{\sqrt{q}}\Phi\left(\frac{t-\tau}{q}\right)$$

In finance research, various types of wavelets are utilized, and one of them is the Morlet Wavelet, which is considered suitable for our analysis. The Morlet Wavelet is a daughter wavelet derived from the mother wavelet. It is particularly favored because it possesses excellent localization characteristics in both the frequency and time domains, similar to the Gaussian function. Mathematically, the Morlet wavelet can be expressed as

$$\Phi_0(\gamma) = \frac{1}{\sqrt[4]{\pi}} e^{i\eta w_0} \cdot \frac{1}{\sqrt{e^{\eta^2}}}$$

A normalization term involving the negative fourth root is applied, where η represents the ratio of time to scale (t/q), and w_0 denotes the dimensionless central frequency parameter. In the context of our analysis, the Morlet wavelet is recommended by Rua and Nunes (2009), with a suggested value of 6 for w_0 as it provides optimal time-frequency localization. To analyze my continuous dataset {x(t), 1, . . . n} using wavelets, we require either a discrete or continuous transformation.

In our case, the appropriate transformation is the Continuous Wavelet Transform (CWT) due to the nature of my data being continuous.

The purpose of this transformation is to preserve the energy of the data series, which can be later utilized to investigate the power spectrum. In terms of the resultant function of the CWT, it can be expressed as follows, taking into account the function Φ(t),

$$V_x(\tau,\ q) = \frac{1}{\sqrt{q}} \int_{-\infty}^{+\infty} x(t) \Phi^* \left(\frac{t-\tau}{q} \right) dt$$

Which show $*$ is a complex conjugate

To detect and quantify the relationship between two variables using wavelets, the most effective tools are the Cross-wavelet power (CWP), wavelet phase-difference (WPD), and wavelet coherence (WC). These tools are especially useful when working with two different continuous wavelet transforms, denoted as Vx and Vy.

The Cross-wavelet power (CWP) [43]is a valuable measure that reveals the local covariance between the two signals at various scales and frequencies. It provides insights into how the signals interact with each other. Mathematically, the CWP can be expressed as

$$V_{xy} = |V_x V_y|$$

The Cross-wavelet power (CWP) serves as a correlation measure and relies on the cross-wavelet coherence to provide a more comprehensive understanding of the time-varying relationship between a pair of bivariate data series, as explained in reference (Boako & Alagidede, 2016b). Just like the Fourier coherency transformation, wavelet theory utilizes wavelet coherency, which involves smoothing the cross-wavelet spectrum and localizing the individual wavelet power

spectra. The bivariate wavelet coherence, following the approach of Torrence and Webster (Torrence & Webster, 1999) , can be mathematically expressed as,

$$R_t^2 = \frac{|S(V_t^{xy})(s)|^2}{S(s^{-1}|V_t^x(s)|^2).\ S\left(s^{-1}|V_t^y(s)|^2\right)}$$

The wavelet coherence can be viewed as a localized correlation in the time-frequency domain, represented by the operator S for smoothing. Similar to the traditional correlation measure, a wavelet coherence value close to 1 indicates a strong similarity between the two variables, while a value of zero (0) suggests no relationship (Boako & Alagidede, 2016b). Additionally, the Wavelet Coherence (WC) is calculated as the modulus of the wavelet cross spectrum, which is standardized by the individual wavelet spectra. This normalization process is crucial as it highlights the frequency and time intervals where the two signals exhibit strong connections. The WC can be interpreted as the correlation between the two signals in the time-frequency space. The statistical significance of the WC at a 5% level is indicated by a thick black contour within the cone of influence.

According to Madaleno and Pinho as cited by (Amewu et al., 2022b), the Wavelet Phase Difference (WPD) function illustrates the lead/lag relationships between two given signals. It provides insights into the temporal alignment or time delay between the signals. Mathematically, the WPD can be expressed as follows,

$$\theta_{xy} = tan^{-1}\left\{\frac{I(V_t^{xy})}{R(V_t^{xy})}\right\},\ \theta_{xy} \in [-\pi,\ \pi]$$

To determine the phase characteristics of a series, the absolute value of θxy is utilized. If the value is less than π/2, it indicates that the series are in phase, while a value greater than π/2 suggests they are out of phase (anti-phase). Moreover, the sign of the phase determines which signal leads the other [M. Ranta as cited in (Amewu et al., 2022b)]. Essentially, the phase information serves as a local measure of the phase delay between two signals in relation to both frequency and time. It is represented graphically using arrow orientations to depict the relative phasing or lead/lag relationships between the two signals. For example, arrows pointing right (left) indicate that the signals are in phase (anti-phase). Arrows pointing right and up indicate lagging, while right and down indicate leading of the second variable. Conversely, arrows pointing left and up signify that the second variable is leading, and left and down indicate lagging of the second variable.

The phase information is indicated within the graphical region characterized by high coherence and phase difference. However, the Continuous Wavelet Transform (CWT) has certain challenges. Firstly, Vx (q, τ) is a function of two parameters, containing unnecessary information. Additionally, analyzing time series data using all the wavelet coefficients can be computationally intensive. Despite these challenges, the CWT remains widely used in finance research due to its valuable contribution in exploring how different periodic components of a signal change over time, either individually or jointly.

Partial wavelet coherence (PWC)

The study employed both the Zivot and Andrews unit root test and the Narayan and Popp structural breaks test, both of which indicated structural break points that did not coincide with the COVID-

19 pandemic. Therefore, to analyze the co-movement between variables while accounting for the impact of COVID-19 infections, a partial wavelet analysis was conducted.

This involved examining the difference between the wavelet coherence (representing pre-COVID-19 co-movements) and the partial wavelet coherence (representing the COVID-19 period where coherence was adjusted for COVID-19 infections). By directly incorporating the pandemic into the analysis rather than simply dividing the data into two periods, we gain insights into the specific impact of the pandemic.

Analogous to partial correlation, the partial wavelet coherence (PWC) suppresses the effect of a third variable, z(t), on the relationship between two variables, x(t) and y(t). In this case, the study controlled for COVID-19 cases (z(t)) in examining the relationship between the selected indices. This was achieved through the application of partial wavelet coherence (Wu n.d. et al 2020) . Following the approach of Ng and Chan (2012) and (Wu et all n.d.2020), the PWC is defined as follows,

$$R_p^2(x,y,z) = \frac{\left|R(x,y) - R(x,z) \bullet R(x,y)^*\right|^2}{[1-R(x,z)]^2[1-R(x,z)]^2}$$

where $0 \leq R2p(x, y, z) \leq 1$ and follows the interpretation for R2(x, y). If there is no difference between R2p and R2, then both y and z significantly influence x.

Multivariate wavelets

To enhance the robustness and demonstrate the utility of the multivariate wavelet technique in this study, wavelet multiple correlation (WMC) and wavelet multiple cross-correlation (WMCC) frameworks introduced by Polanco-Martínez and Abadie (Polanco-Martínez & Abadie, 2016) is

utilized. The WMC and WMCC frameworks rely on the maximal overlap discrete wavelet transform (MODWT) to transform a signal into multiple wavelet and scaling coefficients. Compared to the discrete wavelet transform (DWT), the MODWT offers several advantages. For instance, the MODWT can be applied to signals of arbitrary length, whereas the DWT is limited to signals with lengths that are dyadic (i.e., integer multiples of powers of two). In practice, when used in the WMC and WMCC frameworks, the MODWT allows for comparison of a large number of time series variables simultaneously in a single plot. These plots enable me to identify the leading and lagging variables at different scales, eliminating the need for numerous pairwise comparisons. This simplifies the analysis process while maintaining accuracy and inferencing capabilities. The MODWT is described in detail in (Quilty & Adamowski, 2018), which serves as the basis for determining the WMC and WMCC.

Given a real-valued random variable Xt = x1t, x2t, . . ., xnt, we denote the corresponding scale λj wavelet coefficients obtained through the application of the MODWT as Wjt = w1jt, w2jt, . . ., wnjt. The WMC is defined as follows,

$$\Phi X(\lambda_j) = \sqrt{1 - \frac{1}{\max diag P_j^{-1}}}.$$

utilizing a MODWT with a Daubechies least asymmetric (LA) wavelet filter of length ρ (Gençay et al., 2002) .

The WMC (wavelet multiple correlation) is determined by selecting wij to maximize ΦX(λj), where w^i jt represents the fitted values obtained from regressing wij on the remaining wavelet coefficients at scale λj. In other words, the WMC quantifies the relationship between the observed variable and the fitted values at each scale, utilizing wavelet multiple correlation. On the other

hand, the WMCC (wavelet multiple cross-correlation) can be obtained by introducing a lag τ between the observed and fitted values of the variable at each scale λj. This allows for the analysis of the cross-correlation between the observed and fitted values at different time lags.

$$\Phi X, \tau\ (\lambda_j) = Corr\left(w_{i\ jt},\ \hat{w}_{i\ jt+\tau}\right) = \frac{Cov\left(w_{i\ jt},\ \hat{w}_{i\ jt+\tau}\right)}{\sqrt{Var\left(w_{i\ jt}\right)Var\left(\hat{w}_{i\ jt+\tau}\right)}},$$

The properties of a consistent estimator ΦX(λj) are discussed in (Fernández-Macho, 2012). Confidence intervals (CIs) for the WMC are obtained using Fisher's transformation, which is a well-known method for normalizing and stabilizing the variance of non-Gaussian sample correlations. For further information on the discrete wavelet transform (DWT), maximal overlap discrete wavelet transforms (MODWT), wavelet multiple correlation (WMC), and wavelet multiple cross-correlation (WMCC), extensive literature is available (see (Fernández-Macho, 2012), among others). Consequently, the WMC provides a single correlation value that helps understand the relationship among the chosen variables at different frequencies. Furthermore, the WMCC indicates whether an index/variable lags or leads in the system at various time lags. In simpler terms, the WMCC identifies the highest coefficient of determination in the linear combination of all variables at different frequencies. Positive lags indicate lagging variables, while negative lags indicate leading variables (Adam & Tweneboah, n.d.) .

In identifying market links, the wavelet methodology's advantages over other econometric models demonstrate its strength and robustness. Moreover, Ftiti et al. (2015) claim that the frequency-based component enables a thorough comprehension of the interlinkages based on the principles shown in the data. Furthermore, according to the same authors, the wavelet method decomposes

data easily into different time frequency components without the need for pre-treatment, guarding against anomalies in data structure and the loss of significant information.

More specifically, the method offers graphical tools that support studying heterogeneous market characteristics and detail whether the market displays short-, medium-, or long-term interlinkages. They aid in differentiating between investors that focus on short- to long-term investments. Furthermore, using wavelets to price dynamics in response to the increase in COVID-19 cases may offer new insights into how markets behave across these various asset classes.

Granger Causality Test

Granger (1969) developed Granger Causality test to evaluate the direction of relationship. If a variable X, is granger causing Yt then the changes in Xt are preceding changes in Yt. Thus, if X, is included in regression of Y, on its own and other variables lags, it helps to boost the forecasting of Yt. This is precisely what Granger Causality test determines whether one variable is useful in forecasting.

Given the equations

$$Y_t = \alpha + \sum_{i=1}^{k} \phi_i Y_{t-i} + \sum_{i=1}^{k} \gamma_i X_{t-i} + \mu_{1t}$$

$$X_t = \alpha + \sum_{i=1}^{k} \beta_i Y_{t-i} + \sum_{i=1}^{k} \vartheta_i X_{t-i} + \mu_{2t}$$

The null hypotheses which are tested are:

Ho: Y i = 0, / = 1, 2, 3, ... k; significance of this hypothesis means that X, doesn't granger cause Yt.

Ho: ßi = 0, i = 1, 2, 3, ... k; significance of this hypothesis means that Yt doesn't granger cause Xt.

Two variables are independent of each other if none of the hypothesis is rejected. It means neither X, causes Yt nor Yt causes Xt. If mere on hypothesis is rejected it means that there is one-way causality whereas if both hypotheses are rejected, it shows bidirectional relationship.

Due to its applicability for evaluating the directional transmission of shocks between global financial assets and Sub-Saharan African (SSA) equity markets, this study uses Granger causality analysis as a key analytical tool. Granger causality offers insights into temporal precedence and the causal ordering of financial market interactions by presenting a statistically sound framework for assessing whether historical values of one variable improve the predictive accuracy of another. These skills are crucial for comprehending how global disruptions, such shocks to commodities prices, the volatility of cryptocurrencies, or the COVID-19 epidemic, impact African economies. Granger causality's capacity to provide direct inference on causality rather than just interdependence is one of its main advantages over conventional Vector Autoregressive (VAR) models. Although mutual interactions between variables are captured by VAR models, prediction direction cannot be established by their coefficients alone. Granger causality tests, on the other hand, specifically ascertain whether changes in a global asset, like Bitcoin or crude oil, precede changes in African equity indices. In the framework of this thesis, which aims to determine whether observed co-movements develop concurrently or whether international shocks originate outside before being transmitted to African markets, this divergence is crucial.

Due to the unique structural features of SSA markets, such as low liquidity, market concentration, periodic structural breaks, and differing degrees of integration with international financial systems,

Granger causality is also especially well suited to these markets. In African markets, where regime transitions, policy changes, and crisis occurrences are frequent, conventional VAR models frequently break the premise of parameter stability. However, Granger causality is more resilient in the face of market fragility when applied to rolling-window, non-linear, or quantile-based frameworks that better account for time-varying linkages and non-linear shock patterns.

Furthermore, compared to other time-series techniques, Granger causality imposes fewer stringent assumptions. Long-term equilibrium connections are necessary for cointegration approaches, but they are frequently lacking in markets that are marked by political risk, currency rate volatility, and a strong reliance on a limited number of commodities. Similar to this, strong identification assumptions are required for structural equation modeling and structural VARs, which may be challenging to defend when institutional and economic systems differ greatly among African economies. Granger causality provides a versatile and broadly applicable causal inference technique appropriate for diverse and dynamic market situations by emphasizing prediction content rather than equilibrium circumstances or structural factors.

Granger causality also fits in well with the larger methodological framework of this study, which includes wavelet-based time-frequency decomposition. Wavelet techniques show how relationships improve or deteriorate throughout times of stability and crisis by identifying co-movement patterns over a variety of time ranges. By separating actual causal transmission from frequency-specific correlations, integrating Granger causality with wavelet analysis improves the empirical approach and provides a more complex understanding of how global shocks spread over short-, medium-, and long-term horizons.

Lastly, Granger causality is still visible, computationally effective, and simple to understand when compared to more sophisticated econometric techniques like Markov-switching models or

machine-learning-based causality estimators. These characteristics increase its applicability to African policymakers, regulators, and market practitioners who need robust and easily accessible analytical frameworks for tracking systemic risks and developing macroprudential policies.

In conclusion, Granger causality offers a flexible, context-appropriate, and methodologically sound way to analyze the direction and strength of global shock transmission to SSA equities markets. It is the best option for this thesis because of its flexibility in structurally unstable settings and interoperability with complementary methods like wavelet analysis.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

The data analysis and outcomes are reported in this chapter. The findings of the numerous preliminary tests are presented after a brief discussion of the summary statistics of the variables. Within this particular subsection, conduction of a study of co-movement of African equity markets, Currencies, Commodities and Emerging assets as variables using the application of bivariate wavelet coherence and Granger causality test, followed by a discussion of these findings, and then a summary of all the findings.

4.3 Descriptive statistics

Table 4.1 below gives a brief description of the measures of central tendency and dispersion of the individual variables under consideration in this study over time. Where:

GSE – Ghana Stock Exchange

BVRM- Bourse Régionale des Valeurs Mobilières

JSE – Johannesburg Stock Exchange

NSE – Nairobi Stock Exchange

DSE – Dar er Salaam Stock Exchange

SEM – Stock Exchange of Mauritius

GP – Gold Price

COP – Crude oil Price

BP – Bitcoin Price

CP- Cocoa Price

CU- Cedi to Dollar Exchange rate

The variables of most interest here are GSE, JSE, KSU, MRU, NSE, GP, CU, BP, COP and BVRM. On average, The GSE recorded approximately -0.0002 meaning that out of the total number of days under consideration within the ten-year span of this study, the expected index value is around -0.0002. The highest the index value is expected to be is around 0.2001 with the lowest index value recorded within the time frame of this study being -0.0929. In all the ten years, the highest Gold Price recorded was 0.0578 which was recorded on 2016-06-23. Whereas on the 2013-04-15 the least GP was recorded in our dataset. From the Jarque Bera statistic we reject the null hypothesis of normal distribution. Meaning that none of our variables of interest is normally distributed.

Table 4.1 Descriptive Statistics

	Mean	Median	Maximum	Minimum	Std.Dev.	Skewness	Kurtosis	Jarque-Bera	Probability	Observations
BP	0.0019	0	0.2974	-1	0.0405	-5.1158	138.756	2214859	0	2868
BRVM	0.0001	0.0001	0.0576	-0.0477	0.0101	0.1257	6.0442	1115.377	0	2869
CFU	7.41E-05	0	0.0496	-0.0509	0.0071	0.1334	13.8696	14132.18	0	2869
COP	-0.0009	0	0.3502	-3.0597	0.0679	-33.8005	1472.969	2.59E+08	0	2869
CU	0.0007	0	0.165	-0.1461	0.0118	0.3395	38.3248	149224.1	0	2869
CP	0.0002	0	0.0659	-0.0629	0.0151	0.0133	3.8159	79.6648	0	2869
DSE	0.0003	0	0.2633	-0.1923	0.0117	3.4292	170.6017	3361242	0	2867
GP	9.71E-05	9.30E-05	0.0578	-0.0846	0.0092	-0.3793	8.7588	4033.23	0	2869

GSE	-0.0002	0	0.2001	-0.0929	0.0115	1.9024	42.9602	192617.1	0	2869
JSE	8.92E-05	0.0004	0.0788	-0.1048	0.0143	-0.348	6.7039	1697.923	0	2869
KSU	0.0002	0	0.017	-0.0158	0.0018	-0.3352	13.0494	12126.4	0	2869
MRU	0.0002	0	0.0379	-0.0485	0.0057	-0.3718	11.2072	8118.201	0	2869
NSE	0.0001	0.0003	0.0949	-0.115	0.0154	-0.4231	7.2744	2269.669	0	2869
RU	0.000324	-3.35E-05	0.0502	-0.0486	0.0097	0.2741	4.1014	180.9371	0	2869
SEM	-1.23E-05	0	0.1048	-0.1014	0.0076	-0.6593	43.058	192029.7	0	2869
TSU	0.00017	0	0.0988	-0.0878	0.004	0.5087	274.0642	8783543	0	2869

Table 4.2 Stationarity and Correlation Matrix.

	GSE	BRVM	NSE	SEM	DSE	JSE	CU
GSE	1.0000						
BRVM	0.0219	1.0000					
	0.2412						
NSE	0.0212	0.0770*	1.0000				
	0.2563	0.0000					
SEM	0.0279	0.0563*	0.1301*	1.0000			
	0.1349	0.0026	0.0000				
DSE	-0.0009	0.0079	-0.0131	-0.0335	1.0000		
	0.9615	0.6739	0.4844	0.0726			
JSE	0.0185	0.0650*	0.8445*	0.1558*	-0.0309	1.0000	
	0.3217	0.0005	0.0000	0.0000	0.0975		
CU	-0.4282*	0.0261	-0.0088	-0.0050	-0.0098	-0.0207	1.0000
	0.0000	0.1615	0.6377	0.7872	0.5982	0.2678	
CFU	0.0037	-0.7003*	-0.1208*	-0.0449*	-0.0023	-0.1056*	-0.0347
	0.8441	0.0000	0.0000	0.0161	0.9032	0.0000	0.0634
RU	-0.0132	-0.1103*	-0.7349*	-0.0927*	0.0024	-0.4305*	-0.0013
	0.4807	0.0000	0.0000	0.0000	0.8983	0.0000	0.9454
KSU	-0.0208	-0.0084	-0.0357	-0.0790*	-0.0011	-0.0501*	0.0041
	0.2654	0.6533	0.0557	0.0000	0.9517	0.0073	0.8278
TSU	0.0230	0.0157	0.0162	0.0209	-0.1857*	0.0173	-0.0111
	0.2186	0.3998	0.3858	0.2640	0.0000	0.3550	0.5538
MRU	-0.0133	-0.0299	-0.0366*	-0.2712*	0.0312	-0.0630*	0.0126
	0.4752	0.1098	0.0499	0.0000	0.0950	0.0007	0.5002
BP	0.0170	-0.0127	-0.0262	0.0076	0.0157	-0.0277	0.0178

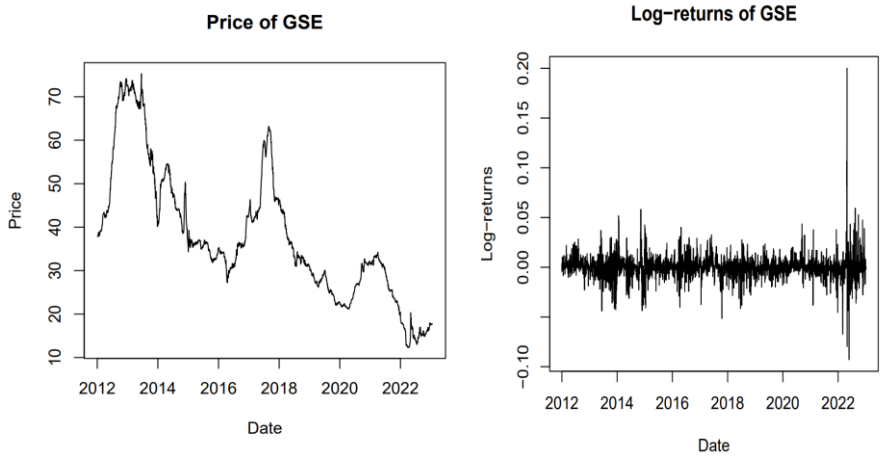
	0.3635	0.4950	0.1612	0.6822	0.3996	0.1377	0.3412
GP	-0.0185	0.0092	0.0149	-0.0362	0.0081	0.0194	0.0088
	0.3227	0.6233	0.4237	0.0523	0.6651	0.2994	0.6386
CP	0.0056	0.0349	0.1767*	0.0399*	-0.0268	0.1636*	0.0148
	0.7649	0.0619	0.0000	0.0326	0.1519	0.0000	0.4284
COP	-0.0145	-0.0071	0.1272*	0.0863*	-0.0068	0.1112*	-0.0078
	0.4378	0.7046	0.0000	0.0000	0.7167	0.0000	0.6776

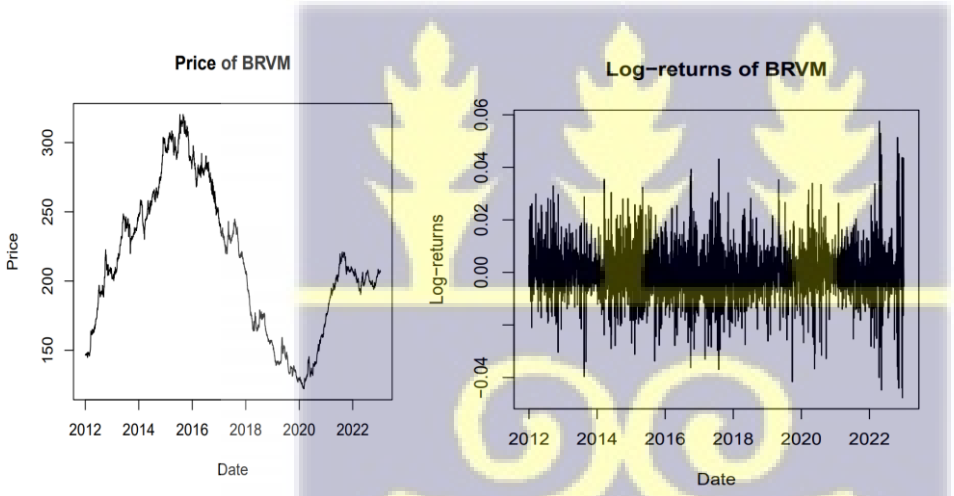
	CFU	**RU**	**KSU**	**TSU**	**MRU**	**BP**	**GP**	**CP**	**COP**
CFU	1.0000								
RU	0.1553*	1.0000							
	0.0000								
KSU	0.0349	0.0296	1.0000						
	0.0618	0.1124							
TSU	-0.0138	-0.0035	0.0569*	1.0000					
	0.4590	0.8506	0.0023						
MRU	0.0565*	0.0170	0.0044	-0.0020	1.0000				
	0.0025	0.3633	0.8153	0.9161					
BP	0.0289	0.0410*	0.0315	0.0025	-0.0137	1.0000			
	0.1217	0.0279	0.0916	0.8926	0.4633				
GP	-0.0196	-0.0431*	-0.0048	-0.0145	0.0020	0.0195	1.0000		
	0.2929	0.0210	0.7971	0.4370	0.9140	0.2964			
CP	-0.0612*	-0.1129*	-0.0017	-0.0013	0.0019	-0.0070	-0.0148	1.0000	
	0.0010	0.0000	0.9260	0.9442	0.9210	0.7064	0.4272		
COP	0.0053	-0.0786*	-0.0168	-0.0026	-0.0246	-0.0147	0.0015	0.0491*	1.0000
	0.7749	0.0000	0.3683	0.8914	0.1875	0.4306	0.9360	0.0085	

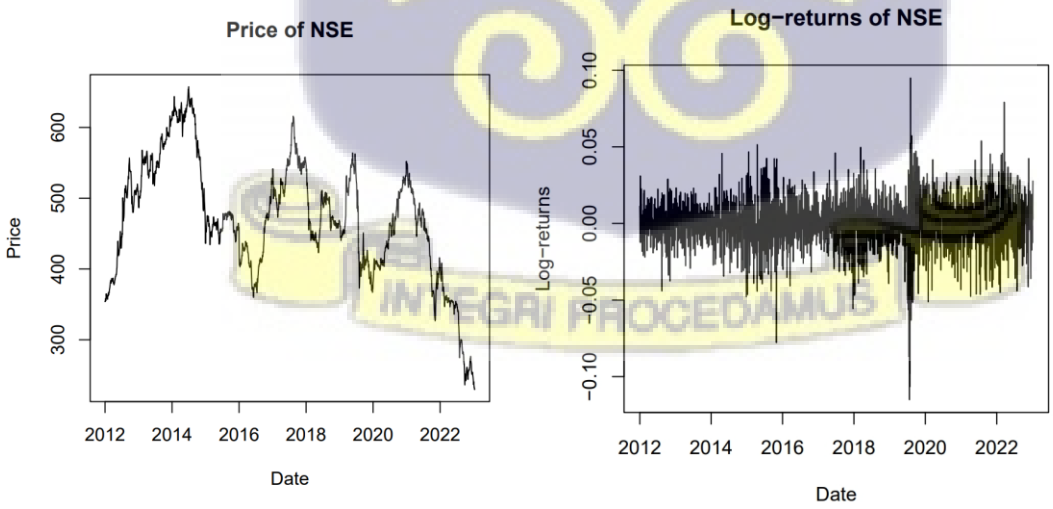
Source: Author's computation

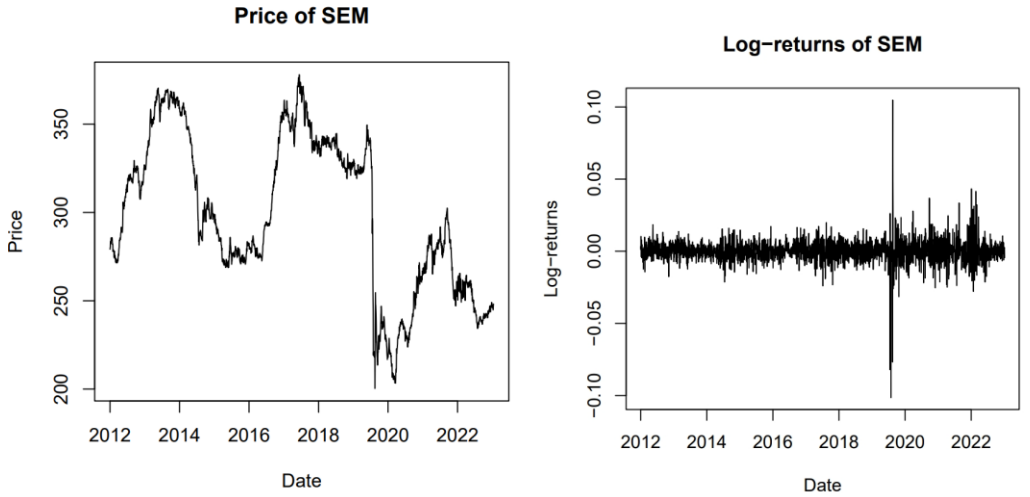
Price Series Plot and Log Returns for Variables

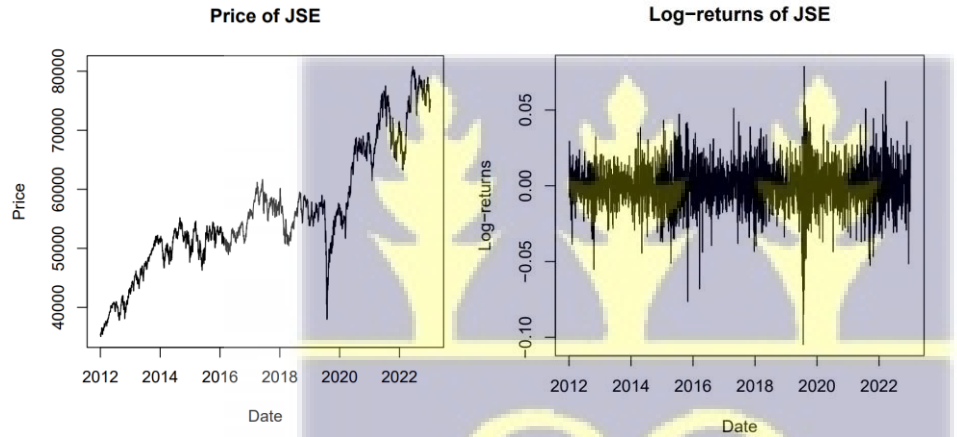
Stock Markets

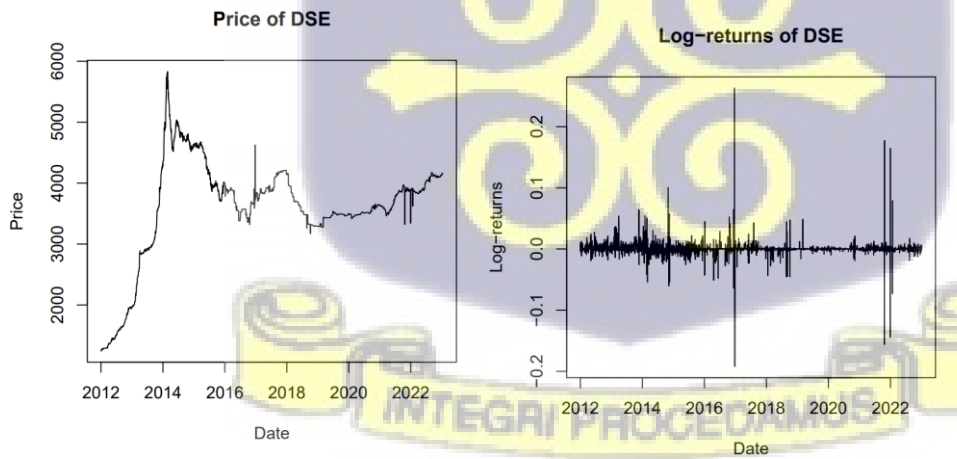




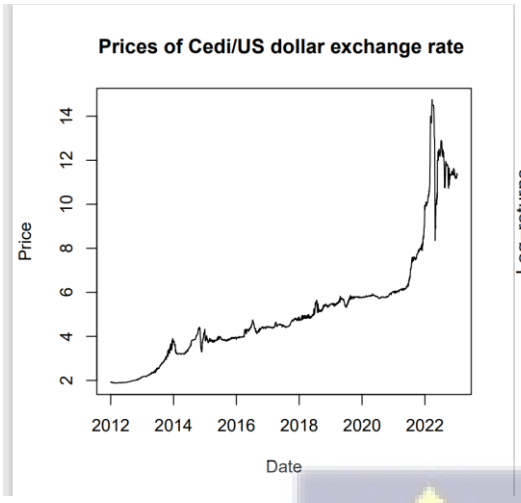


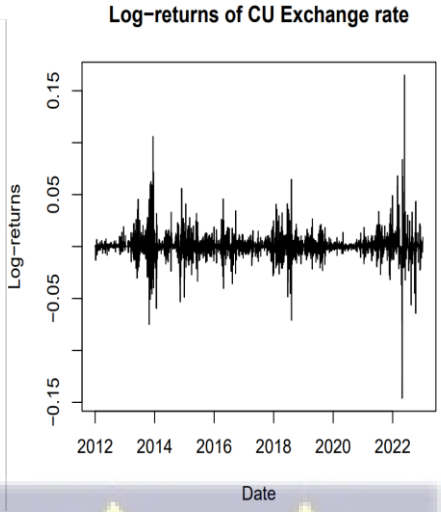


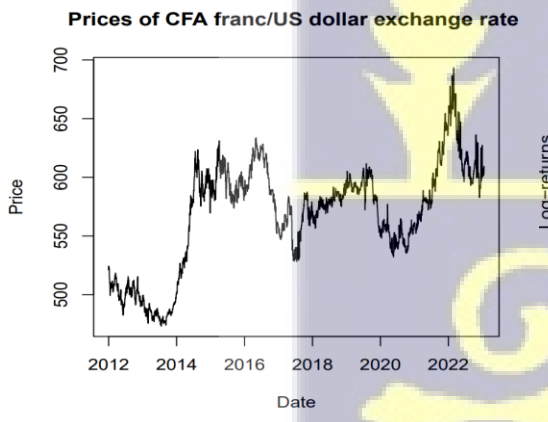


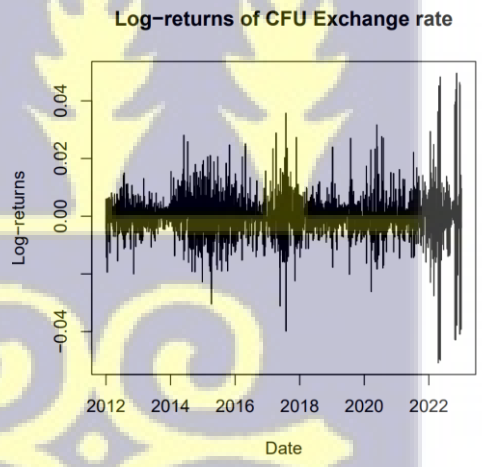


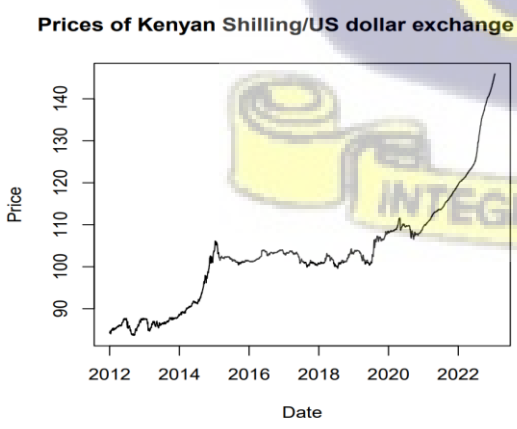
Currency

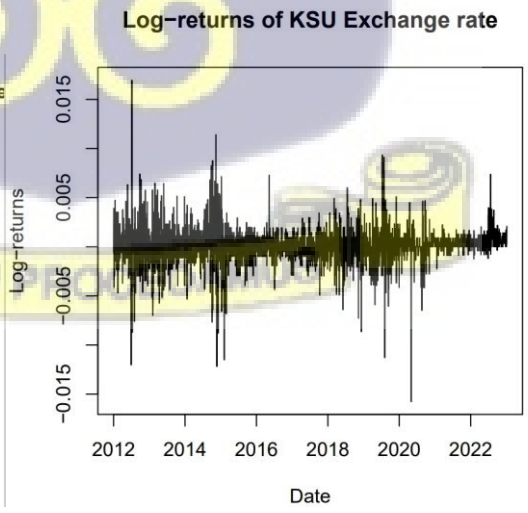


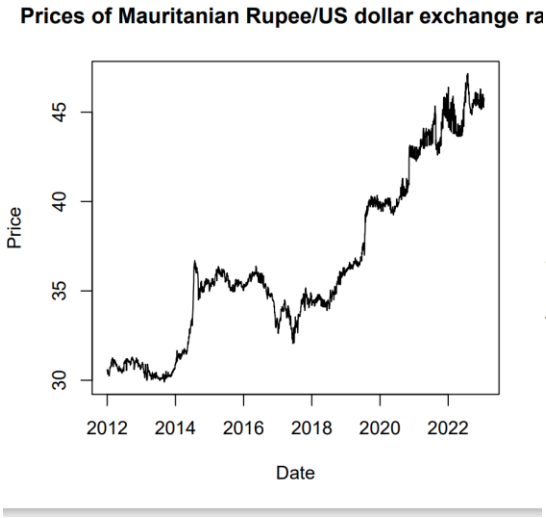


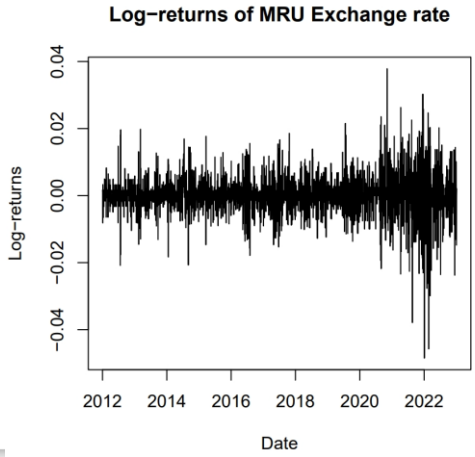


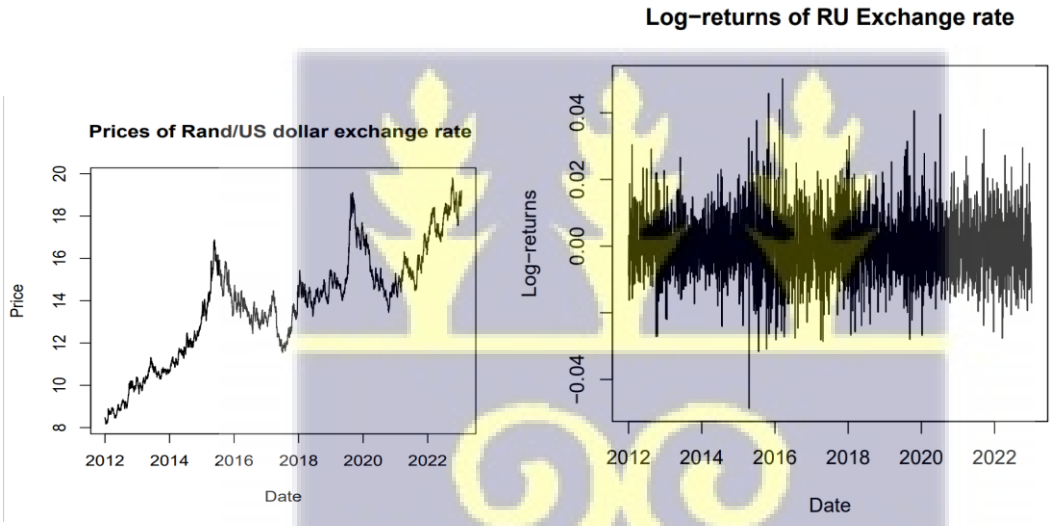


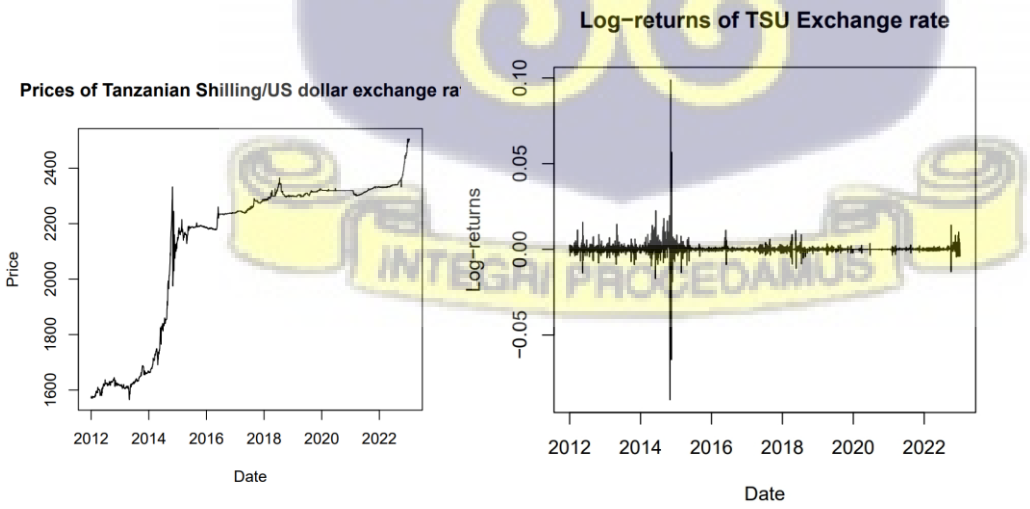




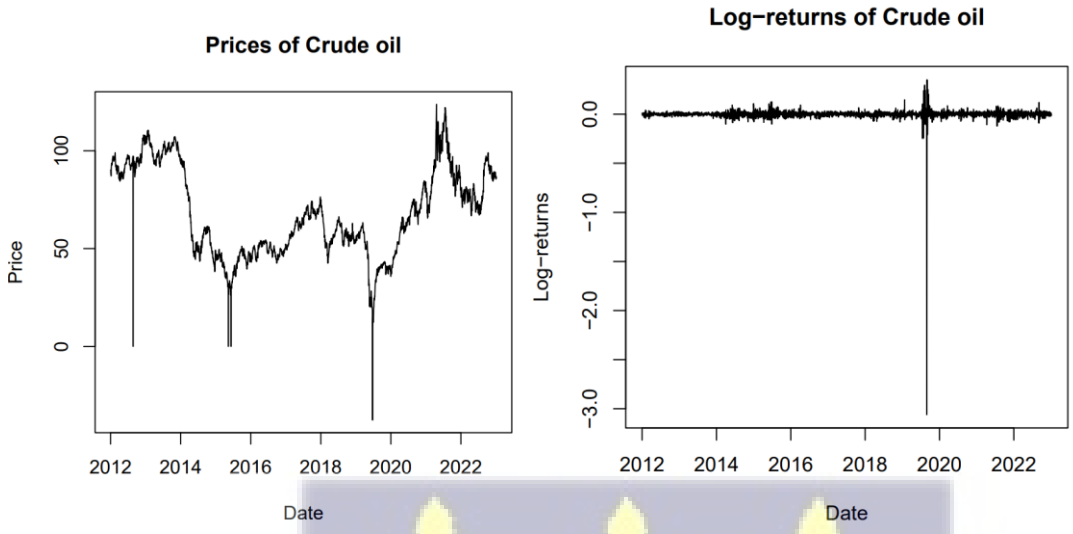


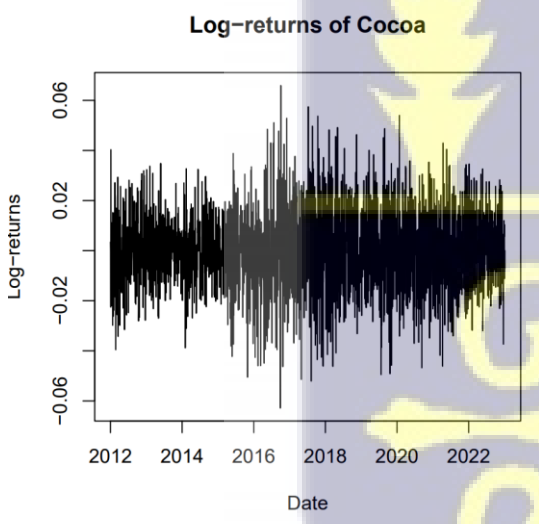


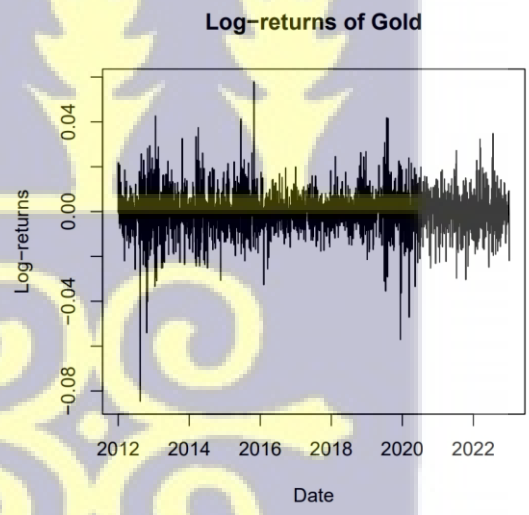




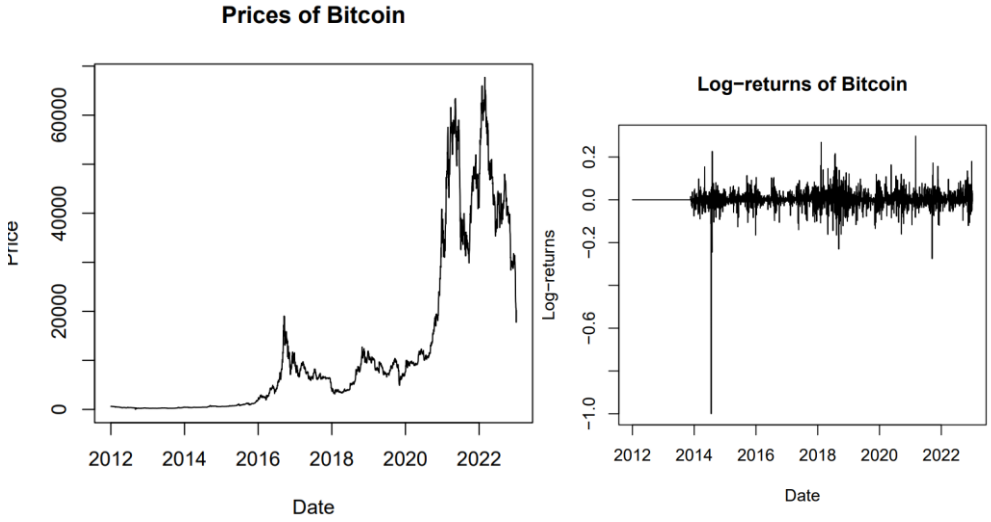
Commodities







Other Emerging Asset



4.2 Bivariate Wavelet Coherence Full Sample

Wavelet coherence (WC) is employed as a measure of local correlation, whereas the phase difference provides insights into any temporal relationship, such as lead or lag, between the variables. According to Rösch and Schmidbauer, the WC accounts for the individual disparities in power and offers collective periodic characteristics of several signals, akin to the coefficient of determination.

These are given in the figures in my work as heat maps. The significance level of the area of interest in the plots is set at 5%, and it is situated within the cone of influence (COI) as indicated by the white contours accompanied by arrows. The presence of a red color inside the black boundaries on the right (left) side suggests a pronounced correlation between the two signals towards the end (beginning) of the observed time intervals. Conversely, a red colour within the black boundaries at the upper (lower) section of the heat map signifies a robust correlation at higher (lower) frequencies. The examination of the arrows is conducted to determine the phase difference between the signals. For example, when arrows are oriented towards the right, it indicates that the series are in-phase, but arrows pointing towards the left indicate that the series are out-of-phase. Furthermore, the presence of arrows oriented towards the right and upward direction (right-up) indicates a lag in the first series, whereas an arrow pointing towards the right and downward direction (right-down) signifies that the first series leads. In a similar vein, a left-up orientation signifies that the initial signal is leading, whereas a left-down orientation suggests that the first series is behind. The objective of this study is to analyze and compare the co-movements between Africa's stock markets, currencies, commodities and emerging assets. By examining the leading and lagging correlations, we can determine the market strength and identify potential causal links in the time-frequency domain

Bivariate wavelet coherence analysis

Co-movement between African Stocks, Currency and Commodities (Full Sample)

Ghana Stock Exchange (GSE) and other Asset Classes

From Fig. 1, the bi-wavelet coherence analysis reveals interesting dynamics between the Ghana Stock Exchange (GSE) and the variable EXC. From 2013 to the end of 2016 and again from 2021 to 2023, there is a notable anti-phase relationship, indicating that changes in the US dollar/cedi exchange rate (EXC) lead and anticipate corresponding changes in the GSE. This suggests a predictive quality of the exchange rate movements on the stock exchange during these periods. This is in support of (Barakat et al., 2015) study which found a relationship between stock market and exchange rate which plays important role in stock market fluctuations.

In the short term, there is a low correlation between GSE and EXC, but this evolves into a significant long-term correlation from 2014 to 2016. Conversely, from 2017 to 2021, there is no correlation in the short term, but a high-frequency correlation emerges from 2021 to 2023 in the long term. This highlights the dynamic and evolving nature of the relationship between GSE and EXC over different timeframes.

In the early years (2012 to 2014), the lack of data on Bitcoin limits the analysis, resulting in no observed correlation. However, from 2015 to 2023, co-movements between GSE and Bitcoin become evident, spanning short to long-term durations.

A particularly interesting finding is the anti-phase relationship from 2014 to 2018, indicating that GSE leads Bitcoin in a negative direction during this period. This implies that movements in the Ghana Stock Exchange precede and influence corresponding changes in Bitcoin, showcasing a nuanced relationship between traditional stock markets and the cryptocurrency market.

In summary, my Bi-wavelet coherence analysis uncovers intricate patterns of correlation, anti-phase relationships, and evolving dynamics between GSE, EXC, and Bitcoin over different timeframes, providing valuable insights into the interplay of these financial variables.

The bi-wavelet coherence analysis indicates a consistently low correlation between the Ghana Stock Exchange (GSE) and gold from 2012 to 2023 in the short to medium term, particularly within the frequency band of 4-68. Interestingly, there is no correlation observed in the long term beyond the frequency band 68. This suggests that, while there may be some short to medium-term influences or shared patterns, the overall correlation between GSE and gold is limited.

The relationship between GSE and cocoa is characterized by low correlation from the short to long term spanning 2012 to 2023. Notably, there are periods of low and no correlation in the long term, particularly from 2012 to 2016 and in the middle term from 2019 to 2022. However, between 2017 and 2018, there is a shift where cocoa leads GSE in the long term, accompanied by a period of high correlation. This suggests a dynamic and changing relationship between the Ghana Stock Exchange and cocoa prices over different timeframes.

The analysis of GSE and crude oil reveals correlation patterns across different timeframes. From the short to medium term, there is a correlation observed, indicating some degree of shared movements. However, in the long term, the correlation is low from 2012 to 2016. There is no correlation from 2017 to 2019, but a bit of correlation resurfaces from 2019 to 2020. Interestingly, there is again no correlation from 2021 to 2023 in the long term. This suggests a complex and

changing relationship between the Ghana Stock Exchange and crude oil prices, with varying degrees of correlation over different time periods.

In summary, the bi-wavelet coherence analysis provides valuable insights into the dynamic and evolving relationships between GSE and key commodities, highlighting patterns of correlation and periods of low or no correlation over different timeframes.

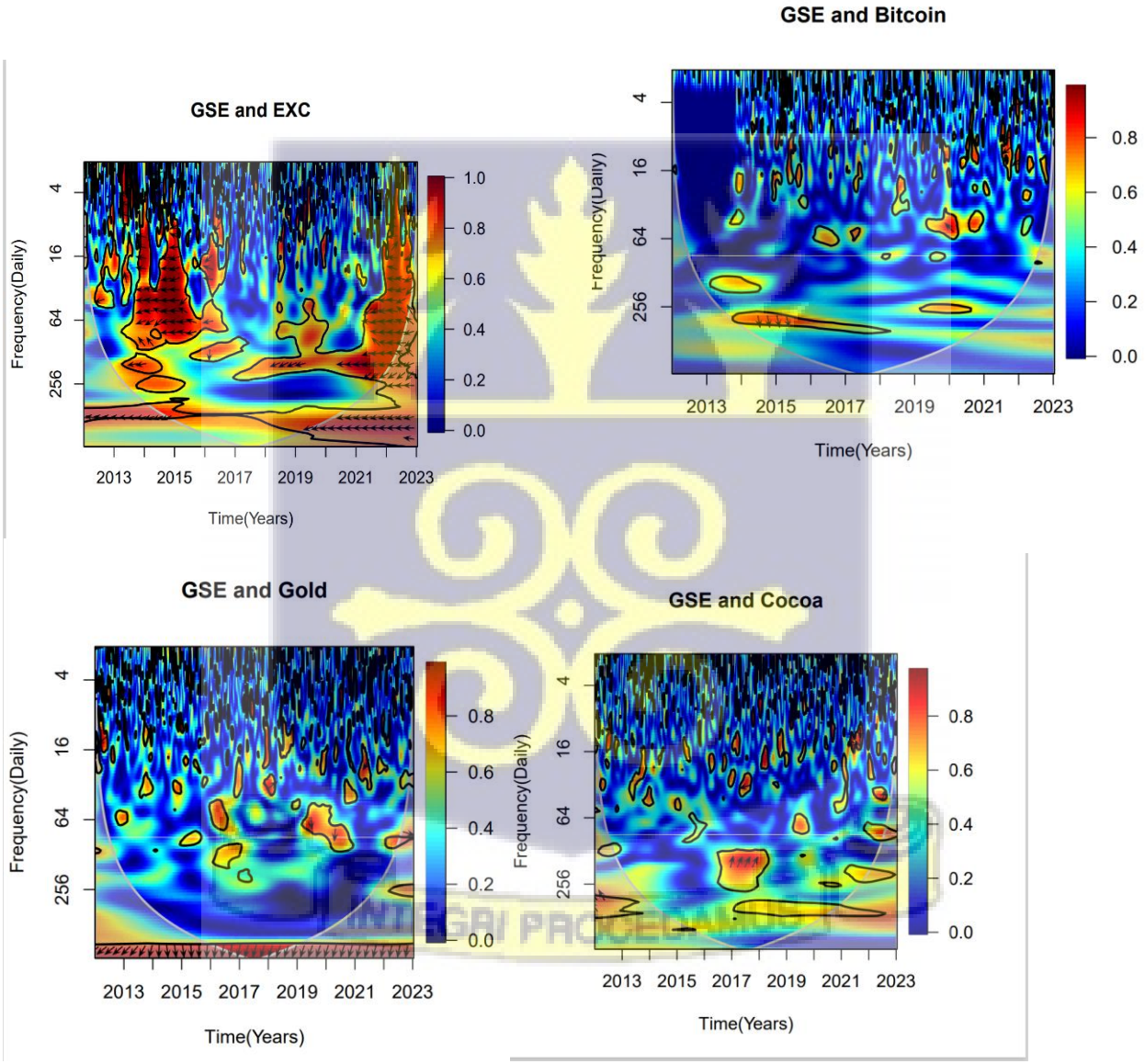
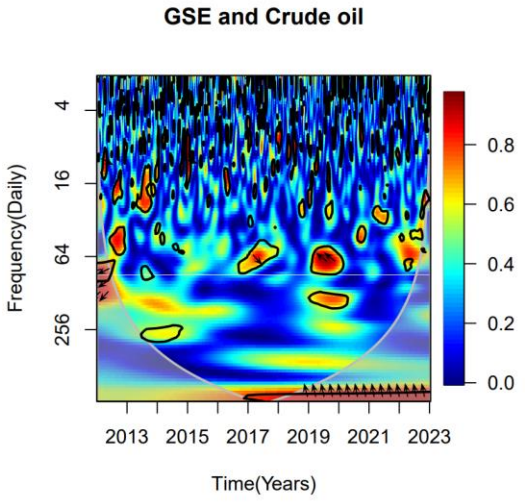


Fig. 1 Bivariate wavelet coherence Analysis



Direction of arrows	Interpretation
Rightward arrows	In-phase
Leftward arrows	Anti-phase
Rightward and up arrows	The second variable lead (cause) the first variable
Rightward and down arrows	The first variable lead (cause) the second variable
Leftward and up arrows	The second variable lead (cause) the first variable
Leftward and down arrows	The first variable lead (cause) the second variable
Cold (blue)	No correlation
Warm (red)	Correlation
Short term	0–4
Medium term	4–16
Long term	16–32
Low frequency	0–2
Medium frequency	2–6
High frequency	6–8

Source: authors compilation

Bourse Régionale des Valeurs Mobilières (BRVM) and other Asset Classes

The analysis reveals a robust and dynamic relationship between BRVM and the exchange rate (EXC) from 2012 to 2023 in the short to medium term. Notably, EXC leads BRVM in an anti-phase, indicating that changes in the exchange rate precede and anticipate changes in the BRVM equity market during this period. The correlation is strong, with evidence of a leading relationship from EXC to BRVM. Interestingly, there is no correlation between the two from medium to long term from 2012 to 2015. From 2016 to 2023, a strong correlation reemerges in the medium to long term, specifically within the frequency band 64 to 256. However, there is little to no correlation beyond frequency 256. This suggests a complex relationship, including periods of strong correlation and a clear indication of EXC leading BRVM.

From 2012 to 2014, the lack of data on Bitcoin limits the analysis, resulting in no observed correlation. However, from 2014 to 2023, some form of correlation emerges in the short to medium term. Interestingly, there is only correlation observed from 2014 to 2016 in the long term, and no correlation is found from 2016 to 2023 in the long term. This suggests that the relationship between BRVM and Bitcoin is not consistently present and varies across different timeframes.

The relationship between BRVM and Gold is characterized by pockets of correlation in the short to medium term from 2012 to 2023. In the period from 2020 to 2023, specifically between frequency bands 64 and 256, there is a correlation between them and in-phase, indicating that Gold leads BRVM in a positive direction during this period. However, no correlation is observed in the long term from 2012 to 2023.

In summary, the bi-wavelet coherence analysis provides a nuanced understanding of the relationships between BRVM, EXC, Bitcoin, and Gold, highlighting dynamic correlations and leading relationships across different timeframes and frequency bands.

The bi-wavelet coherence analysis unveils a complex relationship between BRVM and Cocoa. There is evidence of correlation between the two somewhere in time from 2012 to 2023 in the short to medium term. However, during the medium term, especially from 2015 to 2023, there is an intriguing absence of correlation. In the long term, from 2012 to 2015, there is no observed correlation. Surprisingly, a high-frequency correlation emerges from 2015 to 2023 in the long term, suggesting that Cocoa leads BRVM during this period. This dynamic relationship showcases varying degrees of correlation across different timeframes.

The analysis between BRVM and Crude oil reveals correlations in the short to medium term at different points in time between 2012 and 2023. Notably, there are periods of high frequency with crude oil leading BRVM, particularly around 2017 and 2018. However, there are also points in time, such as 2015 and 2016, and 2019 to 2023, where no correlation is observed in the medium term. In the long term, from 2012 to 2023, there is generally no correlation, except for a specific period between 2019 and 2021, indicating high frequency correlation with crude oil leading BRVM. This suggests a nuanced and changing relationship between BRVM and Crude oil over different timeframes.

In summary, the bi-wavelet coherence analysis provides valuable insights into the intricate relationships between BRVM, Cocoa, and Crude oil. The varying degrees of correlation and leading relationships observed across different timeframes highlight the dynamic nature of these interactions

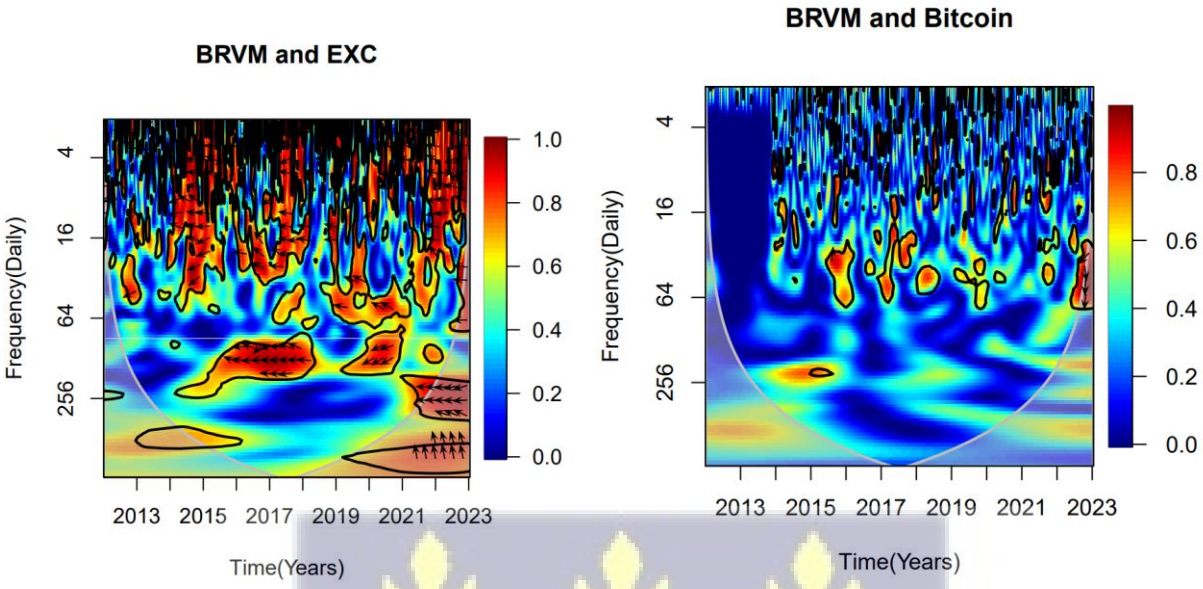
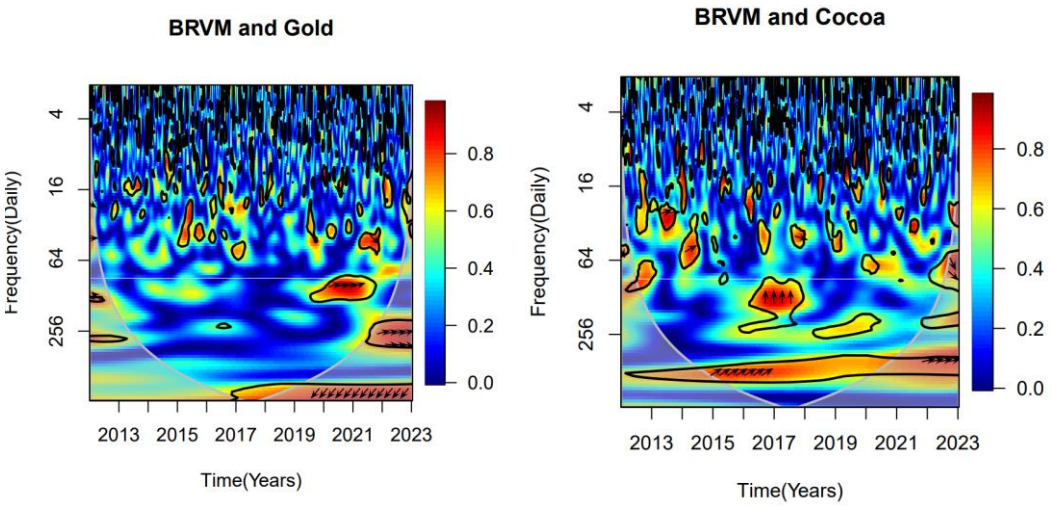


Fig. 1 Continued



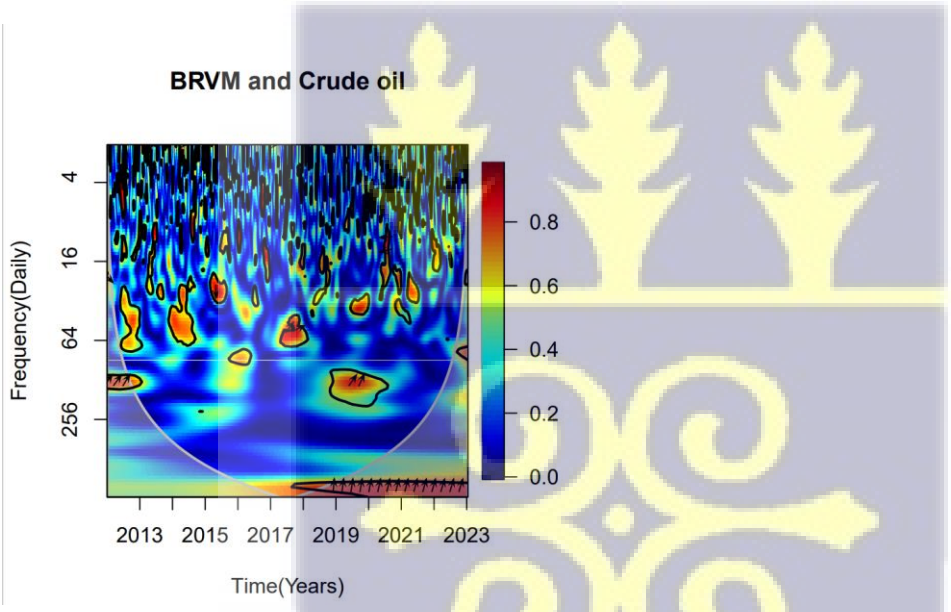


Fig. 1 Continued

Nairobi Stock Exchange (NSE) and other Asset Classes

The analysis reveals correlation between NSE and Exchange Rate (EXC) from 2012 to 2023 in the short to medium term, primarily with high frequency. However, most of the time within the same period shows low correlation. Interestingly, there's some form of correlation at high frequency between them in the medium term, yet low correlation is observed in the long term.

Moreover, evidence suggests that EXC leads NSE, indicating a predictive quality of exchange rate movements on the Nairobi Stock Exchange during certain periods.

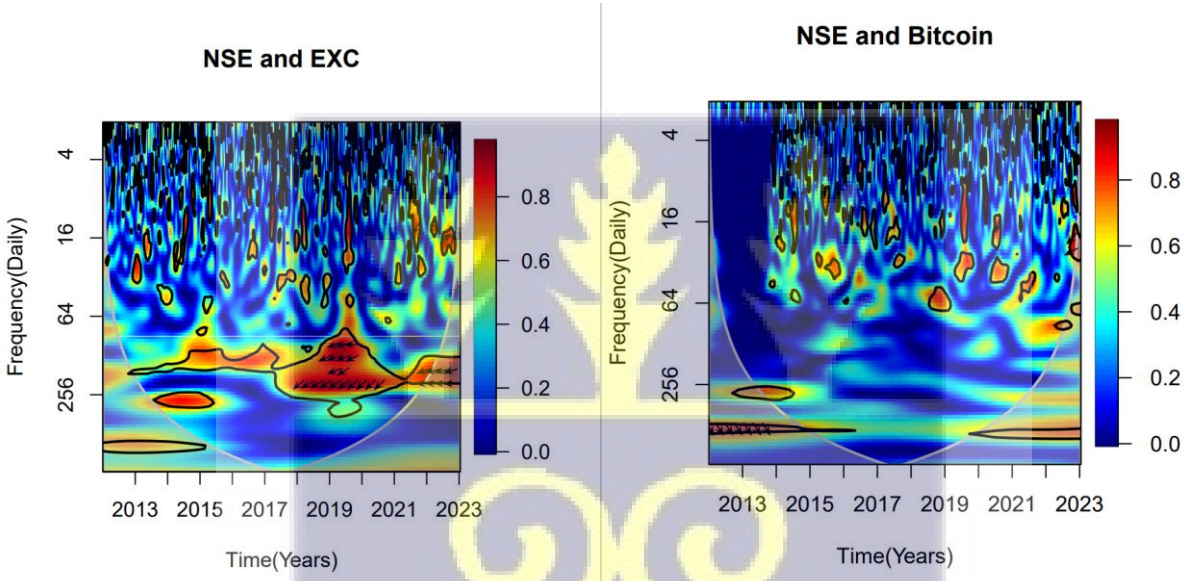
Between NSE and Bitcoin, no correlation is observed from 2012 to 2014 due to the unavailability of Bitcoin data. However, from 2014 to 2023, there is a correlation between them in the short and medium term. Notably, there is no correlation observed in the long term from 2012 to 2023, demonstrating a time-varying relationship between NSE and Bitcoin.

The relationship between NSE and Gold is nuanced. From 2014 to 2017, there is a correlation in the short term, but no correlation is observed in the medium term. From 2017 to 2023, correlation re-emerges in the medium term, with Gold leading NSE in-phase. In the medium to long term from 2012 to 2018, there is high-frequency correlation, again with Gold leading NSE. However, from 2018 to 2023, there is no correlation in the medium to long term, indicating changing dynamics between NSE and Gold.

There's a bit of correlation between NSE and Cocoa in the short to medium term from 2012 to 2023. High-frequency correlation is observed from 2014 to 2020, with NSE leading Cocoa. Correlation exists from 2012 to 2019, no correlation from 2019 to 2021, and a resurgence of

correlation from 2021 to 2023 in the short to medium term. In the long term, there's correlation from 2014 to 2017, with Crude oil leading NSE. Moreover, high-frequency correlation is noted from 2018 to 2021, with NSE leading Crude oil.

In summary, the bi-wavelet coherence analysis uncovers the dynamic and evolving relationships between NSE and various variables, showcasing intermittent correlations, leading relationships, and time-varying dynamics over different time frames.



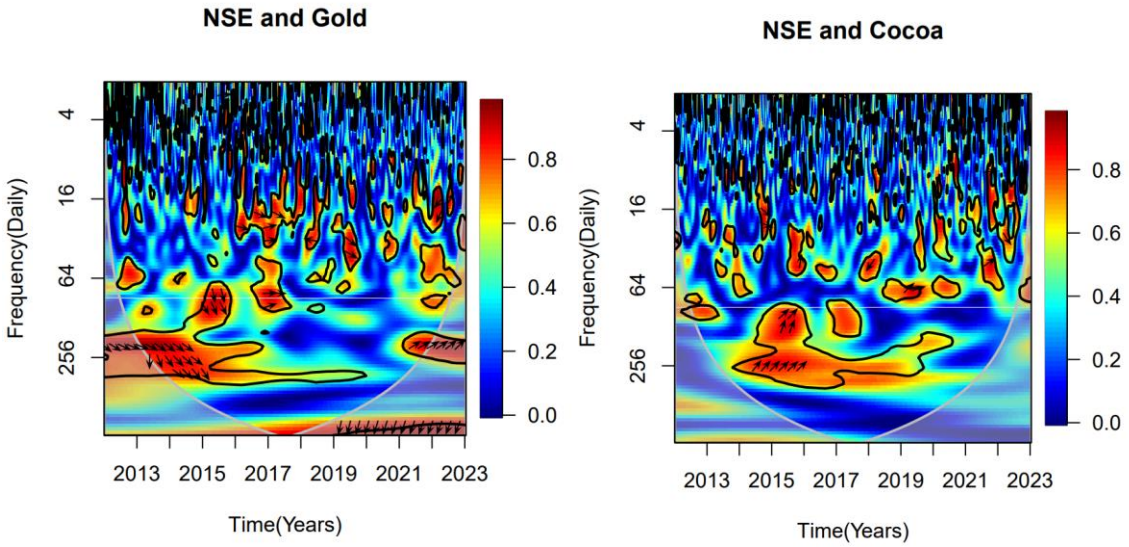
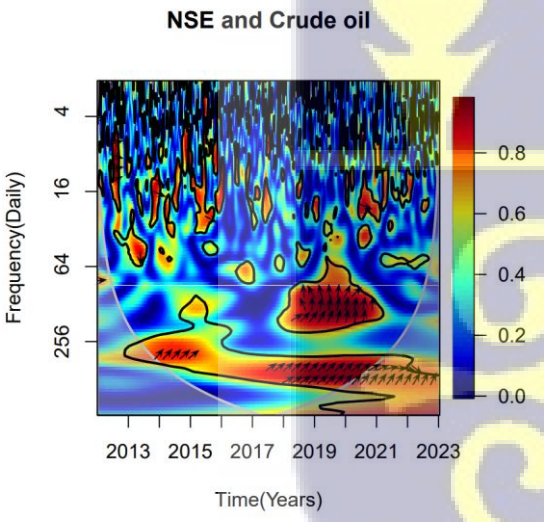


Fig 1 Continued



Stock Exchange Mauritius (SEM) and other Asset Classes

Between SEM and Exchange Rate (EXC), there's an intriguing correlation in the short to medium term, where SEM leads EXC in anti-phase. This suggests that changes in SEM precede and anticipate changes in the exchange rate. However, in the medium to long term, there is no

correlation between them during certain periods, emphasizing the dynamic nature of their relationship. The high-frequency anti-phase correlation from 2014 to 2023 indicates a complex interplay, where SEM's movements influence the exchange rate within shorter timeframes.

No correlation is observed between SEM and Bitcoin from 2012 to 2014, likely due to the unavailability of Bitcoin data. However, evidence of correlation emerges from 2014 to 2023 in the short to medium term. In the long term, the correlation from 2014 to 2015, with Bitcoin leading SEM with high frequency, showcases the influence of Bitcoin on SEM during this period. Conversely, the absence of correlation from 2018 to 2021, with Bitcoin leading SEM, suggests changing dynamics where Bitcoin's movements may not strongly affect SEM during certain timeframes.

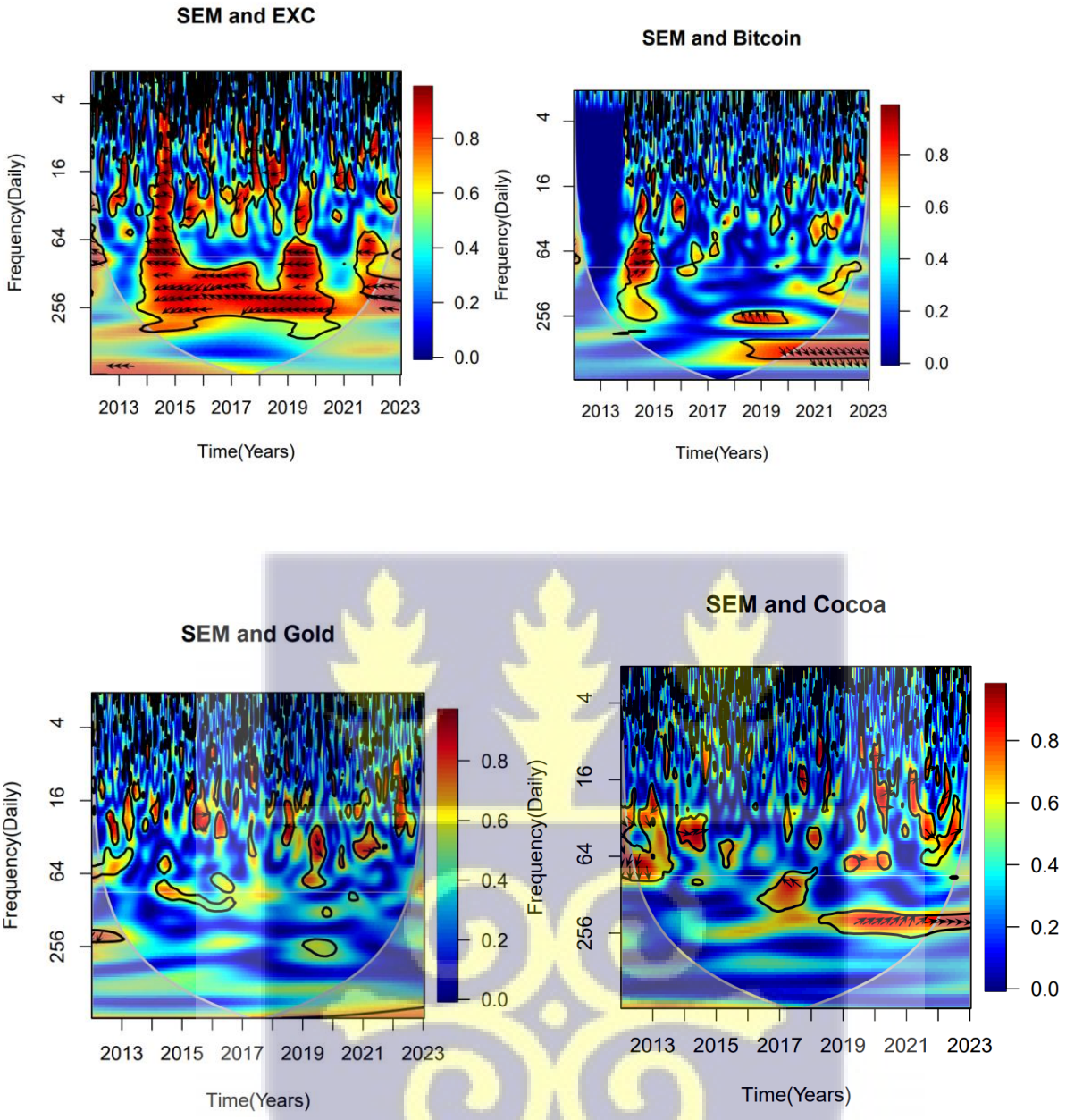
High-frequency correlation is evident between SEM and Gold in the short to medium term, with signs of anti-phase in 2023 and in-phase around 2016. In the long term, the low-frequency correlation around frequency band 256 and beyond indicates a more stable relationship. The anti-phase correlation in 2023 suggests that movements in SEM anticipate and offset Gold's changes. The in-phase correlation around 2016 indicates a synchronized movement between SEM and Gold, showcasing potential impacts on each other.

There's a low correlation between SEM and Cocoa in the short to medium term, with occasional high correlation at specific points like around 2013 and 2015. In the medium term, there is high correlation from 2012 to 2015, with SEM leading Cocoa in-phase, and a similar pattern is observed from 2021 to 2023. This indicates a more synchronized movement where changes in SEM

anticipate and align with Cocoa's changes. In the long term, the absence of correlation from 2012 to 2016 and the subsequent correlation from 2016 to 2018 with Cocoa leading SEM in anti-phase demonstrate changing influences over time.

Low correlation is observed between SEM and Crude oil in the short to medium term, with sporadic bits of correlation at certain points, such as around 2014 to 2016 and 2017 to 2018. In the medium term to long term, there is low correlation from 2012 to 2016. The absence of evidence of correlation between them at frequency band 64 to 256 from 2015 to 2019, followed by high correlation from 2018 to 2021 with Crude oil leading SEM in-phase, illustrates changing dynamics. SEM's movements appear to be influenced by Crude oil during specific periods.

In summary, the bi-wavelet coherence analysis highlights the dynamic and evolving nature of the relationships between SEM and various international assets. The effects these relationships have on each other are evident in the way movements in one variable can precede, synchronize, or offset changes in another, showcasing the complexity of their interplay over different timeframes.



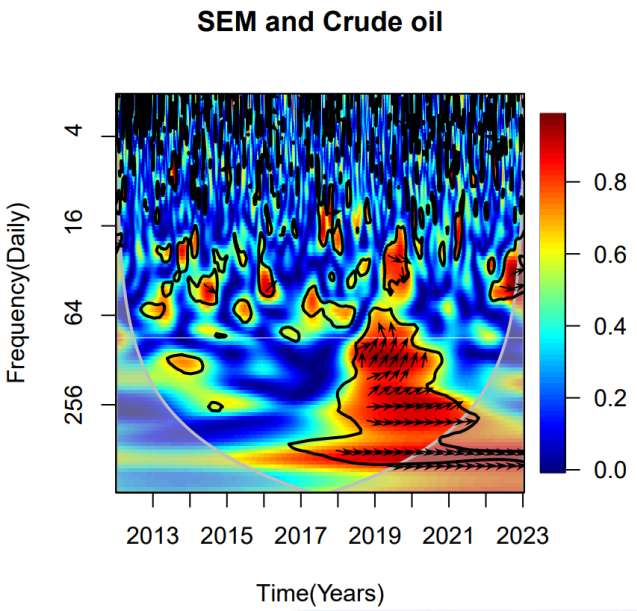


Fig. 1 Continued

Daar Salaam Stock Exchange (DSE) and other Asset Classes

The analysis between DSE and Exchange Rate (EXC) reveals sporadic correlations in the short to medium term, indicating moments of interplay between the two. Notably, from 2014 to 2015 in the medium term, high-frequency correlation is observed with EXC leading DSE in anti-phase. In the long term, there is no correlation, except for low-frequency correlations around 2016 to 2021 at frequency band 64. However, high-frequency correlation from 2012 to 2019, with EXC leading DSE in anti-phase, suggests a dynamic relationship during certain periods.

The relationship between DSE and Bitcoin showcases intermittent correlations in the short term, with pockets of correlation at specific points from 2014 to 2023. Notably, in the medium term around frequency band 64, correlations occur in 2014 to 2015, 2016 to 2017, and 2018 to 2022. In

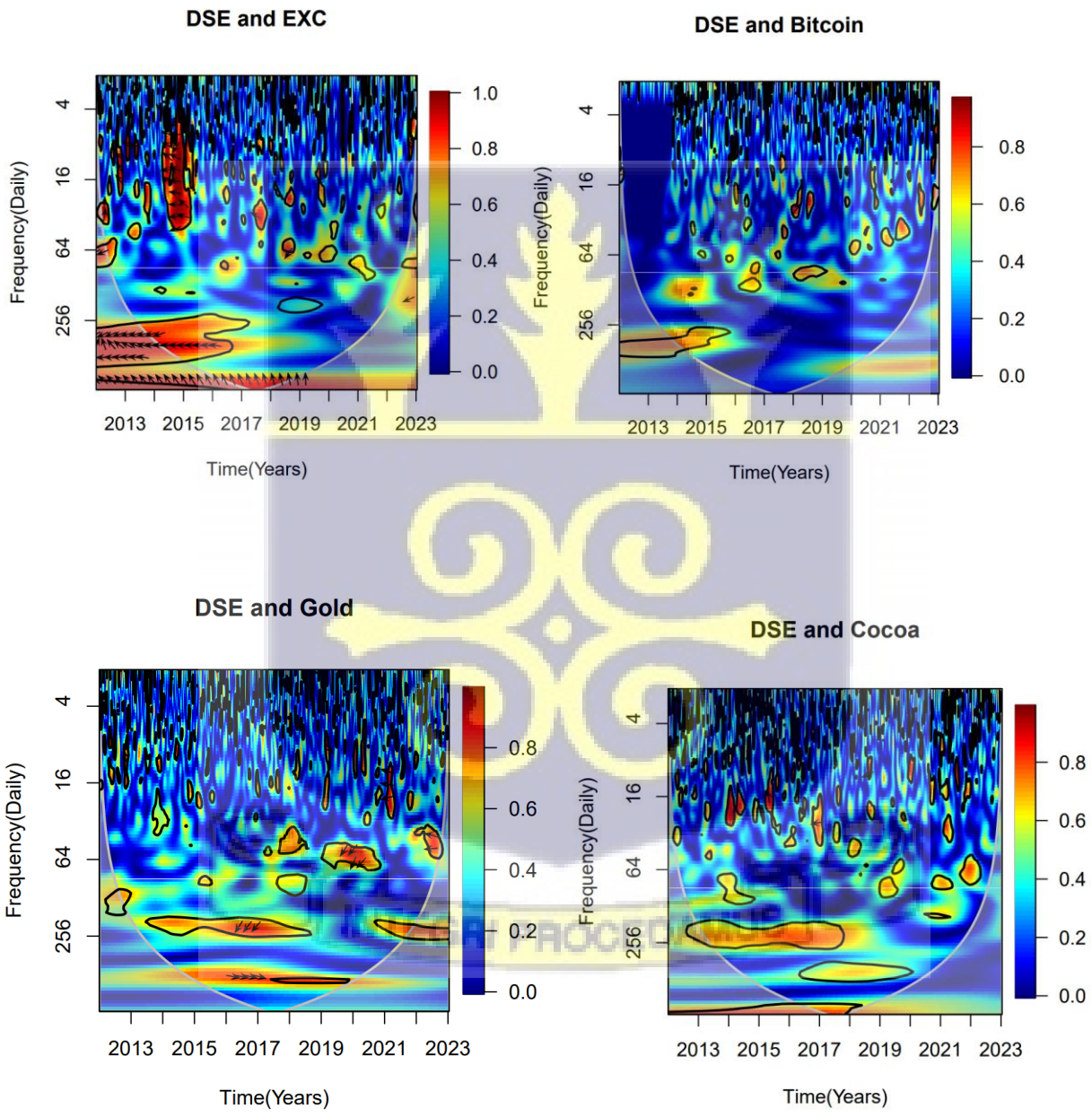
the long term, there is a lack of correlation from frequency band 256 onwards, except for 2012 to 2016, indicating a changing relationship over time.

The majority of the period between DSE and Gold shows no correlation. However, specific points in time, such as 2020 to 2021, reveal high-frequency correlation with Gold leading DSE in anti-phase. In the medium term around frequency band 64, from 2018 to 2023, high-frequency correlation is observed, with DSE leading Gold in anti-phase. In the long term beyond frequency band 64, correlation is present around 2014 to 2020, with DSE leading Gold in anti-phase around 2016 to 2017 and later leading in-phase up to 2020. This suggests changing dynamics and effects between DSE and Gold.

Correlation between DSE and Cocoa is noted around 2014 to 2016, with the greater part of the period showing no correlation in the short to medium term. In the long term around frequency band 256 and beyond, high-frequency correlation is observed from 2013 to 2019. This indicates a nuanced relationship where Cocoa's movements impact DSE over time, particularly in the long term.

In the short term, especially between frequency band 4 and 16, correlation is observed between DSE and Crude oil. Some form of correlation is also noted around band 64 at 2013 and 2014, as well as 2016 and 2017. In frequency band 256, high-frequency correlation is present from 2014 to 2016, with DSE leading Crude oil in anti-phase. Beyond 2016, in frequency band 256, no correlation is observed, except for the period from 2019 to 2022, indicating changing dynamics and influences.

In summary, the bi-wavelet coherence analysis reveals dynamic and changing relationships between DSE and various variables, showcasing intermittent correlations, leading relationships, and evolving dynamics over different timeframes. The effects between these variables are evident in the way their movements synchronize, lead, or show no correlation during specific periods, highlighting the complexity of their interactions.



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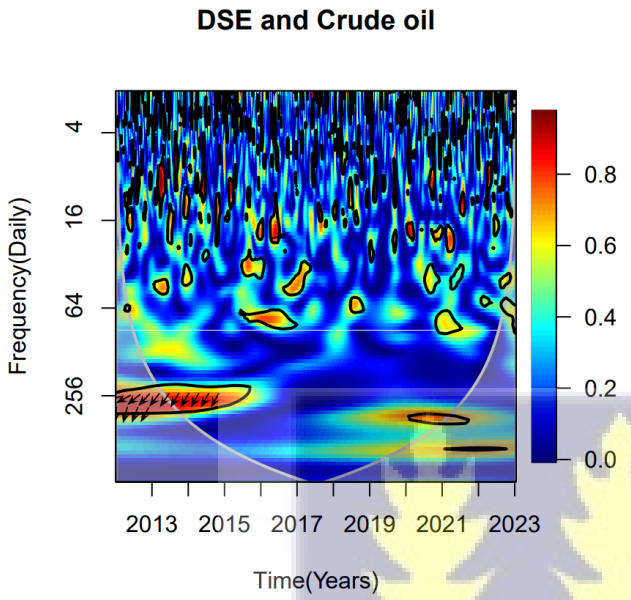


Johannesburg Stock Exchange (JSE) and other Asset Classes

The analysis between JSE and Exchange Rate (EXC) reveals high-frequency correlations in the short term, with EXC leading JSE in anti-phase at various points. However, there are instances of no correlation between them. In the medium to long term, there is less or no correlation around frequency band 64 from late 2016 to 2018 and somewhere in 2021. Beyond frequency band 64, high-frequency correlation is observed, with JSE leading EXC in anti-phase. This suggests that short-term movements in EXC may influence JSE, while long-term dynamics exhibit a more complex relationship.

The relationship between JSE and Bitcoin shows correlations in the short to medium term, with intermittent pockets of correlation from 2014 to 2023. There is no correlation in the medium to long term, except around 2014 to 2015 around frequency band 256. This indicates that short to medium-term movements in Bitcoin may have some impact on JSE, but the long-term relationship is less evident.

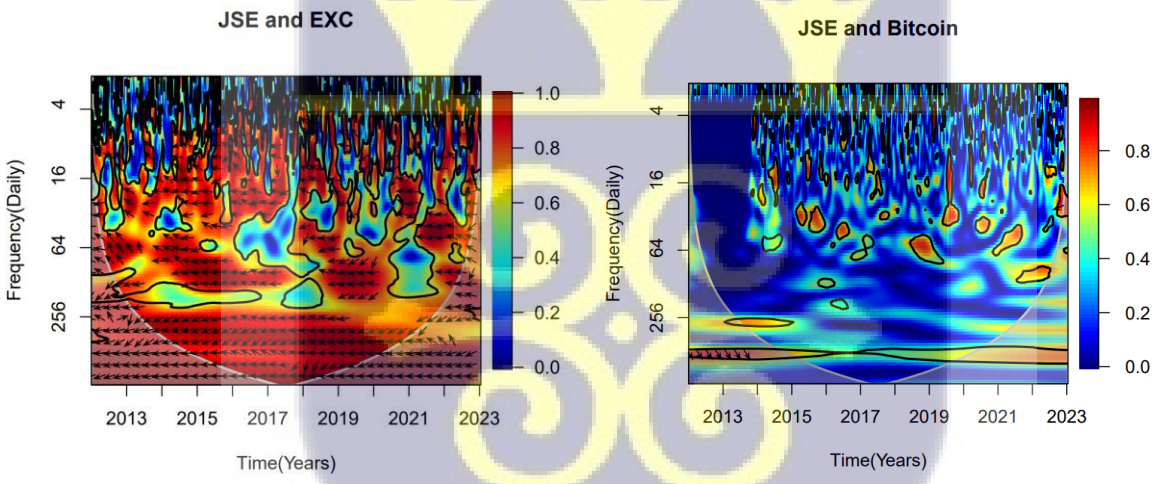
Evidence of correlation between JSE and Gold is observed from the short to medium term, with occasional points of no correlation. Most of these correlations are located between frequency band 16 and 64 around 2016 to 2023, beyond frequency band 64 up to 256, from 2013 to late 2017. Beyond 2017, there is no or less correlation between them. This suggests that short to medium-term movements in Gold may impact JSE during specific periods, but the long-term relationship is less pronounced.

The relationship between JSE and Cocoa doesn't show much correlation in the short term from 2012 to 2020 around frequency band 2 to 8. However, high-frequency correlation between them is observed beyond frequency band 8 up to 256, with Cocoa leading JSE in-phase from 2014 to 2021. This suggests that Cocoa's movements have an impact on JSE, particularly in the medium to long term, with certain periods showcasing synchronized movements.

Correlation is observed between JSE and Crude oil from frequency band 2 to 64, from 2012 to 2018, but shows no or less correlation between 2018 and 2020. Beyond 2020 to 2023, there is correlation, while beyond frequency band 64 to 256, there is no correlation from 2013 to 2015. However, there is correlation from 2015 to late 2016, then again no correlation from 2017 up to

2018. High-frequency correlation is observed, with Crude oil leading JSE in-phase. This suggests that Crude oil's movements may influence JSE, especially in the short term and specific periods.

In summary, my bi-wavelet coherence analysis provides a nuanced understanding of the relationships between JSE and various international assets. The effects these relationships have on each other are evident in the way short to medium-term movements in these assets may impact JSE during specific periods, while the long-term dynamics exhibit varying degrees of correlation. The complex interplay highlights the dynamic nature of financial markets and their interactions with global variables.



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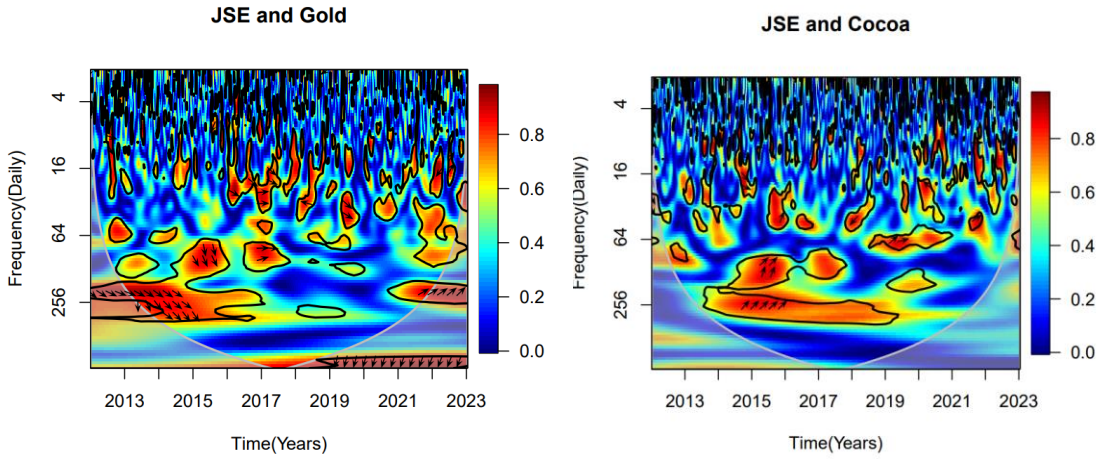


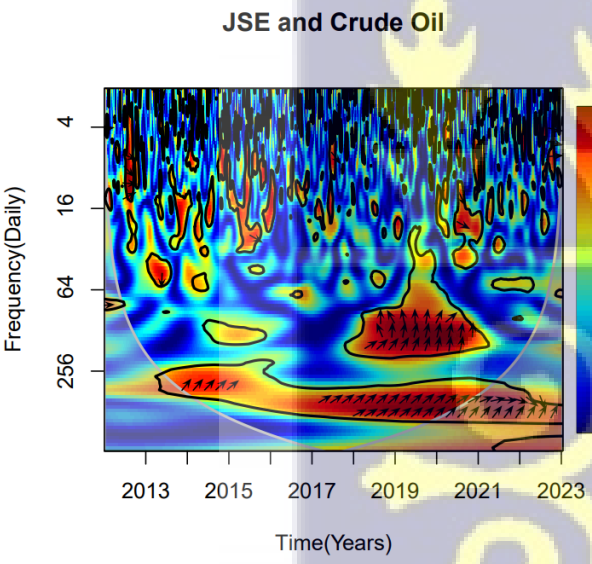


Fig. 1 Continued

4.4 Granger Causality Test Results for Variables

The Granger causality test results outlined provide a crucial lens through which to understand the interconnectedness of various stock market performance as against other commodities and financial assets.

FULL SAMPLE

Variables	F-Statistic	Probability	Significance
CU ⟶ GSE	19.6551	3.E-19*	Reject
GSE ⟶ CU	23.6752	2E-23*	Reject
BP ⟶ GSE	1.41093	0.2170	Fails to Reject
GSE ⟶ BP	0.41560	0.8382	Fails to Reject
GP ⟶ GSE	1.41093	0.2170	Fails to Reject
GSE ⟶ GP	0.41560	0.8382	Fails to Reject
COP ⟶ GSE	0.89429	0.4839	Fails to Reject
GSE ⟶ COP	0.15330	0.9791	Fails to Reject
CP ⟶ GSE	0.73703	0.5956	Fails to Reject
GSE ⟶ CP	1.02611	0.4004	Fails to Reject
MRU ⟶ SEM	2.70162	0.0192*	Reject
SEM ⟶ MRU	9.02636	2.E-08*	Reject
BP ⟶ SEM	1.37206	0.2316	Fails to Reject
SEM ⟶ BP	1.53621	0.1751***	Fails to Reject
GP ⟶ SEM	2.41759	0.0339**	Reject
SEM ⟶ GP	0.63005	0.6768	Fails to Reject

COP⟶SEM	6.93940	2.E-06*	Reject
SEM⟶COP	3.83891	0.0018*	Reject
CP⟶SEM	6.93940	2.E-06*	Reject
SEM⟶CP	3.83891	0.0018*	Reject
KSU⟶NSE	0.65599	0.6569	Fails to Reject
NSE⟶KSU	5.09412	0.0001*	Reject
BP⟶NSE	0.58267	0.7133	Fails to Reject
NSE⟶BP	0.95686	0.4430	Fails to Reject
GP⟶NSE	1.06494	0.3778	Fails to Reject
NSE⟶GP	1.09084	0.3633	Fails to Reject
COP⟶NSE	2.48436	0.0297**	Reject
NSE⟶COP	7.29610	8.E-07*	Reject
CP⟶NSE	0.88014	0.4934	Fails to Reject
NSE⟶CP	1.02857	0.3989	Fails to Reject
TSU⟶DSE	25.4626	3.E-25*	Reject
DSE⟶TSU	5.61583	4.E-05*	Reject
BP⟶DSE	1.22290	0.2956	Fails to Reject
DSE⟶BP	0.59995	0.7000	Fails to Reject
GP⟶ DSE	1.32419	0.2507	Fails to Reject
DSE⟶GP	0.96753	0.4362	Fails to Reject
COP⟶DSE	0.06259	0.9974	Fails to Reject
DSE⟶COP	0.21828	0.9548	Fails to Reject

CP⟶DSE	0.50805	0.7704	Fails to Reject
DSE⟶CP	1.32622	0.2499	Fails to Reject
RU ⟶JSE	100.287	1.E-97*	Reject
JSE⟶RU	1.75116	0.1196	Fails to Reject
BP⟶JSE	1.36753	0.2334	Fails to Reject
JSE⟶BP	0.64780	0.6632	Fails to Reject
GP⟶JSE	0.88052	0.4932	Fails to Reject
JSE⟶GP	1.27102	0.2735	Fails to Reject
COP⟶JSE	6.49753	5.E-06*	Reject
JSE⟶COP	5.25968	8.E-05*	Reject
CP⟶JSE	0.16999	0.9737	Fails to Reject
JSE⟶CP	0.81694	0.5374	Fails to Reject
CFU⟶BRVM	9.22232	1.E-08*	Reject
BRVM⟶CFU	1.31638	0.2540	Fails to Reject
BP⟶BRVM	0.65520	0.6575	Fails to Reject
BRVM⟶BP	1.59610	0.1577	Fails to Reject
GP⟶BRVM	0.79637	0.5521	Fails to Reject
BRVM⟶GP	1.33101	0.2479	Fails to Reject
COP⟶BRVM	0.46720	0.8009	Fails to Reject
BRVM⟶COP	0.66399	0.6508	Fails to Reject
CP⟶BRVM	3.63366	0.0028*	Reject
BRVM⟶CP	0.83693	0.5233	Fails to Reject

Notes: ***,** and * shows significance at 10%, 5% and 1% levels, respectively. Source: Authors computation

The Granger causality tests reveal significant predictive relationships among the stock market indices, commodities and financial assets. Cedi/U. S Dollar (CU), Stock Exchange of Mauritius (SEM), Nairobi Stock Exchange (NSE), and Dar Salaam Stock Exchange (DSE) emerge as key drivers or influencers. CU's past values significantly predict future values of Ghana Stock Exchange (GSE) and SEM, indicating its dominant role in the market. SEM, in turn, influences CU, GP, COP, and CP. NSE also impacts CU, COP, and CP, while DSE influences CU. These findings suggest that changes in these key indices, commodities and financial assets can have significant ripple effects on the broader markets.

COVID-19 DATA

VARIABLES	F-STATISTIC	PROBABILITY	SIGNIFICANCE
CU – GSE	15.7540	7.E-15*	Rejected
GSE - CU	3.71805	0.0025*	Rejected
BP- GSE	0.79491	0.5534	Fails to Reject
GSE- BP	0.20191	0.9617	Fails to Reject
CP- GSE	0.59380	0.7048	Fails to Reject
GSE-CP	0.72426	0.6053	Fails to Reject
COP-GSE	0.49681	0.7788	Fails to Reject
GSE-COP	0.16367	0.9758	Fails to Reject
GP-GSE	1.22474	0.2954	Fails to Reject
GSE-GP	0.45953	0.8065	Fails to Reject
CFU-BRVM	5.57221	5.E-05*	Reject
BRVM-CFU	1.09884	0.3594	Fail to Reject
BP-BRVM	1.67327	0.1384	Fail to Reject
BRVM-BP	0.38395	0.8600	Fail to Reject
COP-BRVM	0.38889	0.8566	Fail to Reject
BRVM-COP	0.29852	0.9138	Fail to Reject
CP-BRVM	3.05581	0.0096*	Reject
BRVM-CP	0.45440	0.8102	Fail to Reject

GP-BRVM	0.68084	0.6380	Fail to Reject
BRVM-GP	0.85804	0.5089	Fail to Reject
RU-JSE	14.4551	1.E-13*	Reject
JSE-RU	1.43190	0.2102	Fail to Reject
BP-JSE	0.27253	0.9282	Fail to Reject
JSE-BP	0.41553	0.8382	Fail to Reject
COP-JSE	3.16008	0.0078*	Reject
JSE-COP	2.80386	0.0160**	Reject
CP-JSE	1.05087	0.3864	Fail to Reject
JSE-CP	1.42577	0.2124	Fail to Reject
GP-JSE	0.39907	0.8496	Fail to Reject
JSE-GP	2.08870	0.0647***	Fail to Reject
TSU-DSE	1.14512	0.3347	Fail to Reject
DSE-TSU	0.39958	0.8493	Fail to Reject
BP-DSE	0.80965	0.5428	Fail to Reject
DSE-BP	0.69705	0.6258	Fail to Reject
COP-DSE	0.05106	0.9984	Fail to Reject
DSE-COP	0.16472	0.9754	Fail to Reject
CP-DSE	0.14473	0.9816	Fail to Reject
DSE-CP	1.69036	0.1343	Fail to Reject
GP-DSE	2.79005	0.0165**	Reject
DSE-GP	0.51263	0.7669	Fail to Reject
KSU-NSE	2.21719	0.0507***	Fail to Reject

NSE-KSU	4.29976	0.0007*	Reject
BP-NSE	0.30500	0.9100	Fail to Reject
NSE-BP	0.23366	0.9478	Fail to Reject
COP-NSE	1.71404	0.1287	Fail to Reject
NSE-COP	3.80510	0.0020*	Reject
CP-NSE	1.18270	0.3157	Fail to Reject
NSE-CP	1.32383	0.2516	Fail to Reject
GP-NSE	0.37215	0.8679	Fail to Reject
NSE-GP	2.37754	0.0372**	Reject
MRU-SEM	1.92525	0.0877	Fail to Reject
SEM-MRU	3.45644	0.0042*	Reject
BP-SEM	0.87765	0.4954	Fail to Reject
SEM-BP	1.17714	0.3184	Fail to Reject
COP-SEM	3.12993	0.0083*	Reject
SEM-COP	2.01990	0.0736***	Fail to Reject
CP-SEM	5.41378	6.E-05*	Reject
SEM-CP	0.41831	0.8362	Fail to Reject
GP-SEM	3.21621	0.0069**	Reject
SEM-GP	0.83799	0.5228	Fail to Reject

Notes: ***,** and * shows significance at 10%, 5% and 1% levels, respectively.

Source: Authors computation

The Granger causality test results outlined provide a crucial lens through which to understand the interconnectedness of various economic indicators and stock market performance during the Covid-19 era. The Covid-19 pandemic, with its unprecedented global economic disruption, significantly altered traditional economic relationships and introduced new dynamics that these results help to elucidate.

Currency and Stock Exchanges:

The strong bidirectional causality between currency movements and the Ghana Stock Exchange (GSE) during the Covid-19 period is particularly noteworthy. The pandemic induced significant volatility in global currency markets due to rapid changes in investor sentiment, government interventions, and shifts in international trade. In Ghana, the local currency's fluctuations likely reflected broader economic instability, which, in turn, impacted investor confidence and stock market performance. Conversely, the stock market's performance might have influenced currency markets through its impact on capital flows, indicating a tight interdependence heightened during the pandemic.

The unidirectional causality from CFU (CFA Franc/US Dollar Exchange Rate) to BRVM suggests that currency markets influenced the BRVM more than the other way around. This could be due to the BRVM's regional integration and its reliance on the CFA Franc, which is pegged to the Euro. The Covid-19 crisis might have exacerbated these effects, with external currency pressures driving stock market performance rather than domestic market movements influencing the currency.

Bitcoin and Stock Exchanges:

During the Covid-19 era, the lack of significant Granger causality between Bitcoin prices and stock exchanges suggests that Bitcoin's price fluctuations did not directly influence stock market movements. This disconnect likely stemmed from unprecedented monetary policies, such as aggressive quantitative easing and near-zero interest rates, which decoupled traditional economic indicators from market behavior. The extraordinary uncertainty of the pandemic further complicated this relationship, leading to a broader decoupling of economic fundamentals from market dynamics, resulting in unpredictable stock market behavior despite Bitcoin's volatility.

Crude Oil Prices and Stock Exchanges:

The bidirectional relationship between Crude Oil Prices (COP) and the Johannesburg Stock Exchange (JSE) is indicative of South Africa's heavy reliance on both commodity exports and energy imports, making it particularly sensitive to oil price fluctuations. During the pandemic, oil prices were exceptionally volatile, impacting energy costs, inflation, and ultimately, the performance of the JSE. Mauritius (SEM) also shows a significant unidirectional causality from COP, reflecting the country's sensitivity to oil prices as a small island economy dependent on imports.

Cocoa Prices and BRVM:

The significant causality from Cocoa Prices to BRVM highlights the importance of the commodity sector in West Africa, especially during the Covid-19 era when global supply chains and commodity markets were highly disrupted. The region's dependence on commodities such as oil, cocoa, and gold made the BRVM particularly sensitive to global price fluctuations, which were exacerbated by the pandemic.

Gold Prices and Stock Exchanges:

The strong unidirectional causality from gold prices to stock exchanges underscores the significant impact of gold market movements on stock market performance during the pandemic. As gold prices rose, driven by investor demand for safe-haven assets, this directly influenced stock market sentiment and performance. Conversely, in some regions, the reverse relationship—where stock exchange movements influenced gold prices—suggests that changes in the stock market during the pandemic may have impacted gold prices, possibly as investors adjusted their portfolios in response to shifts in economic stability and market conditions.

Rand and US Dollar exchange rate:

The predictive power of the Rand/US Dollar exchange rate on the JSE underscores the heightened sensitivity of the South African stock market to currency fluctuations during the Covid-19 period. Given the unprecedented global uncertainty, this relationship is expected, as investors closely tracked the exchange rate to gauge economic stability and make informed decisions, resulting in a predictive link between currency movements and stock market performance.

In conclusion, the Granger causality tests reveal that the Covid-19 era introduced unique dynamics between economic indicators and stock markets. The results suggest that during periods of extreme uncertainty, traditional economic relationships may evolve, with certain indicators like currency movements and gold prices playing more significant roles in predicting stock market behavior. These findings underscore the importance of understanding the context-specific nature of these relationships, particularly during periods of global crises.

RUSSIA/UKRAINE DATA

VARIABLES	F-STATISTIC	PROBABILITY	
CU-GSE	11.0118	6.E-10*	Reject
GSE-CU	1.97102	0.0821***	Fail to Reject
BP-GSE	1.13427	0.3416	Fail to Reject
GSE-BP	0.18849	0.9669	Fail to Reject
COP-GSE	0.34732	0.8839	Fail to Reject
GSE-COP	1.50804	0.1863	Fail to Reject
CP-GSE	0.89400	0.4851	Fail to Reject
GSE-CP	0.94550	0.4514	Fail to Reject
GP-GSE	1.93157	0.0882***	Fail to Reject
GSE-GP	0.19724	0.9635	Fail to Reject
CFU-BRVM	1.63370	0.1501	Fail to Reject
BRVM-CFU	0.89029	0.4875	Fail to Reject
BP-BRVM	1.73779	0.1250	Fail to Reject
BRVM-BP	0.29469	0.9158	Fail to Reject
COP-BRVM	0.57871	0.7163	Fail to Reject
BRVM-COP	0.66393	0.6510	Fail to Reject
CP-BRVM	1.78751	0.1144	Fail to Reject
BRVM-CP	0.61330	0.6898	Fail to Reject
GP-BRVM	0.26448	0.9323	Fail to Reject
BRVM-GP	0.90444	0.4781	Fail to Reject
TSU-DSE	0.86598	0.5040	Fail to Reject

DSE-TSU	0.20743	0.9593	Fail to Reject
BP-DSE	0.74509	0.5901	Fail to Reject
DSE-BP	0.76875	0.5727	Fail to Reject
COP-DSE	0.27478	0.9268	Fail to Reject
DSE-COP	2.09201	0.00657**	Reject
CP-DSE	0.19334	0.9650	Fail to Reject
DSE-CP	2.16099	0.0578***	Fail to Reject
GP-DSE	2.66905	0.0219**	Reject
DSE-GP	0.68113	0.6380	Fail to Reject
RU-JSE	10.3428	3.E-09*	Reject
JSE-RU	2.45880	0.0328**	Reject
BP-JSE	0.97893	0.4304	Fail to Reject
JSE-BP	0.19398	0.9648	Fail to Reject
COP-JSE	0.83118	0.5281	Fail to Reject
JSE-COP	0.61394	0.6893	Fail to Reject
CP-JSE	1.33638	0.2480	Fail to Reject
JSE-CP	0.90024	0.4809	Fail to Reject
GP-JSE	2.31829	0.0429*	Reject
JSE-GP	0.34846	0.8832	Fail to Reject
KSU-NSE	1.01565	0.4081	Fail to Reject
NSE-KSU	0.61373	0.6894	Fail to Reject
BP-NSE	0.03821	0.9992	Fail to Reject
NSE-BP	0.72801	0.6028	Fail to Reject

COP-NSE	1.22856	0.2949	Fail to Reject
NSE-COP	0.81580	0.5389	Fail to Reject
CP-NSE	1.47572	0.1968	Fail to Reject
NSE-CP	0.87740	0.4962	Fail to Reject
GP-NSE	1.79217	0.1135	Fail to Reject
NSE-GP	0.24420	0.9426	Fail to Reject
MRU-SEM	1.27364	0.2745	Fail to Reject
SEM-MRU	2.90103	0.0139**	Reject
BP-SEM	0.48132	0.7902	Fail to Reject
SEM-BP	2.58787	0.0256**	Reject
COP-SEM	0.37545	0.8655	Fail to Reject
SEM-COP	1.38818	0.2278	Fail to Reject
CP-SEM	1.04434	0.3912	Fail to Reject
SEM-CP	0.10252	0.9916	Fail to Reject
GP-SEM	0.71691	0.6110	Fail to Reject
SEM-GP	1.89727	0.0939***	Fail to Reject

Notes: ***,** and * shows significance at 10%, 5% and 1% levels, respectively.

Source: Authors computation

The Granger causality tests conducted across multiple stock exchanges during the Russia/Ukraine war period provide valuable insights into the relationships between various economic variables and regional stock markets. The analysis covers the Ghana Stock Exchange (GSE), the Bourse Régionale des Valeurs Mobilières (BRVM), the Dar es Salaam Stock Exchange (DSE), the Johannesburg Stock Exchange (JSE), the Nairobi Securities Exchange (NSE), and the Stock Exchange of Mauritius (SEM). These results offer a nuanced understanding of how geopolitical events and economic indicators interact with different African markets.

Ghana Stock Exchange (GSE):

The most significant finding is the strong Granger causality from the Cedis/US Dollar exchange rate to the GSE, indicating that fluctuations in the exchange rate significantly influenced the Ghanaian stock market during this period. This highlights the GSE's sensitivity to currency volatility, a crucial factor given Ghana's economic reliance on stable exchange rates. However, the absence of strong bidirectional causality suggests that while currency fluctuations impact the GSE, the stock exchange itself has limited feedback influence on the exchange rate.

BRVM:

The BRVM exhibited no significant Granger causality with any of the tested variables, including Commodity Futures Uncertainty (CFU), Bitcoin Prices (BP), and Crude Oil Prices (COP). This lack of causality suggests that the BRVM operates largely independently of these global economic indicators during the conflict period. It may reflect the unique market dynamics of the West African Economic and Monetary Union (WAEMU) countries, where the BRVM is based, or the relatively limited exposure of these economies to the direct effects of the Russia/Ukraine war.

DSE:

For the DSE, the only significant causality identified was from Gold Prices (GP) to the DSE, suggesting that fluctuations in gold prices directly influenced the Tanzanian stock market during the war period. This may reflect investor responses to gold as a safe-haven asset amid economic uncertainty. The absence of significant causality from other variables, such as the Tanzania Shilling (TSU) and Crude Oil Prices (COP), indicates that external economic pressures, like currency fluctuations and oil prices, were not the primary drivers of market movements in Tanzania during this time.

JSE:

The JSE exhibited a strong bidirectional Granger causality with the Rand/US Dollar exchange rate, highlighting the significant impact of currency fluctuations on the South African market. This suggests that the JSE both influenced and was influenced by changes in the exchange rate, reflecting South Africa's role as a key emerging market with substantial global economic connections. Additionally, the causality from Gold Prices to the JSE underscores the importance of gold market movements in shaping the dynamics of the South African stock market during turbulent periods.

NSE:

The NSE showed no significant Granger causality with any of the economic variables tested, including the Kenya Shilling Exchange Rate (KSU) and Cocoa Prices (CP). This indicates that the Kenyan market was relatively insulated from both domestic and global economic pressures during the conflict. This resilience may be attributed to strong economic fundamentals or effective market regulation, which buffered the NSE from the immediate effects of the Russia/Ukraine war.

SEM:

The SEM exhibited significant bidirectional Granger causality with Bitcoin (BP), indicating that movements in the Mauritian stock market were closely linked with Bitcoin price fluctuations. This suggests a strong interconnection between the SEM and the broader economic conditions influenced by cryptocurrency trends in Mauritius during the conflict period. However, the lack of significant causality with other variables indicates that the SEM's dynamics were primarily driven by its relationship with Bitcoin, rather than by external economic pressures.

In conclusion, the Granger causality analysis across these African stock exchanges reveals varied responses to the Russia/Ukraine war, with some markets showing significant sensitivity to global and domestic factors, while others remained relatively insulated. These findings underscore the importance of understanding the specific economic contexts of each market when assessing the impact of global events. For policymakers and investors, the results highlight the need for targeted strategies that consider both global uncertainties and local market conditions.

4.5 Patial Wavelet Coherence: Covid 19 Period Sample with Infection Rates

We re-examined the co-movement of the variables within COVID-19 era. In order to ascertain the actual relationship between the variables, we need to isolate the COVID-19 from the interaction. This is done through the partial wavelet coherence (PWC). The results of my analysis are presented in Fig. 2.

Ghana Stock Exchange (GSE) and Other Assets

Not much correlation is observed between GSE and EXC during the COVID-19 period. The few instances of correlation occur around the medium term in 2020, between frequency band 10 and 28, exhibiting anti-phase characteristics. Between 2021 and 2022, there is mostly no correlation, with only a few instances in the short to medium term in late 2021 and early 2022 showing high-frequency correlation with EXC leading GSE. In the medium to long term, the major part of the period shows no correlation, except for late 2021 and early 2022, revealing a high-frequency correlation with anti-phase characteristics. This suggests that the relationship between GSE and EXC during COVID-19 is limited, with intermittent correlations in specific periods.

No significant correlation is observed between GSE and Bitcoin in the short term during COVID-19, with only some pockets of correlation around the first quarter of 2021. The medium term also shows no correlation, except for mid-2020, early and late 2021, and early 2022, showing correlation. In the long term, correlation is noted between mid-2020 to mid-2021 between frequency band 32 and 64. The rest of the period shows no correlation between the two variables. This indicates that the relationship between GSE and Bitcoin during COVID-19 is sporadic, with certain periods showing correlation. This confirms (Maitra et al., 2022) findings hat cryptocurrencies cannot provide incremental gains by hedging stock market risk during the COVID-19 pandemic.

Limited correlation is observed between GSE and Gold during COVID-19, with no significant correlation in major times of the period. However, between 2021 and 2022, some pockets of

correlation emerge in the short term. In the medium term, around band 16 in mid-2021, correlation is noted, with evidence of correlation in the later part of 2021, where GSE leads Gold. The overall conclusion is that the relationship between GSE and Gold during COVID-19 is characterized by sporadic and short-term correlations.

Low or no correlation is observed between GSE and Cocoa in major times during the COVID-19 period, except for a few instances in the short to medium term around band 2 to 8 in 2020 and around band 2 to 32, particularly in the middle of 2021 to 2022, showing correlation with Cocoa leading GSE. In the long term, beyond frequency band 32, low or no correlation is observed between the two variables. This indicates that the relationship between GSE and Cocoa during COVID-19 is characterized by sporadic and short-term correlations.

The results show no correlation between GSE and Crude oil pair in almost all times within the COVID-19 period, except for a few instances. Around band 16 in the last quarter of 2020, there is correlation where Crude oil is leading GSE, and also in mid-2021 and the beginning of 2022 where GSE is leading Crude oil. Around frequency band 32 and 64, correlation is observed around early 2021 and late 2022. Overall, the relationship between GSE and Crude oil during COVID-19 is characterized by infrequent and short-term correlations.

In summary, the partial wavelet coherence analysis during the COVID-19 period reveals varying degrees of correlation and limited relationships between GSE and different variables. The effects of these relationships are observed in specific timeframes, suggesting that the dynamics of the financial market and various commodities were influenced differently during the global pandemic.

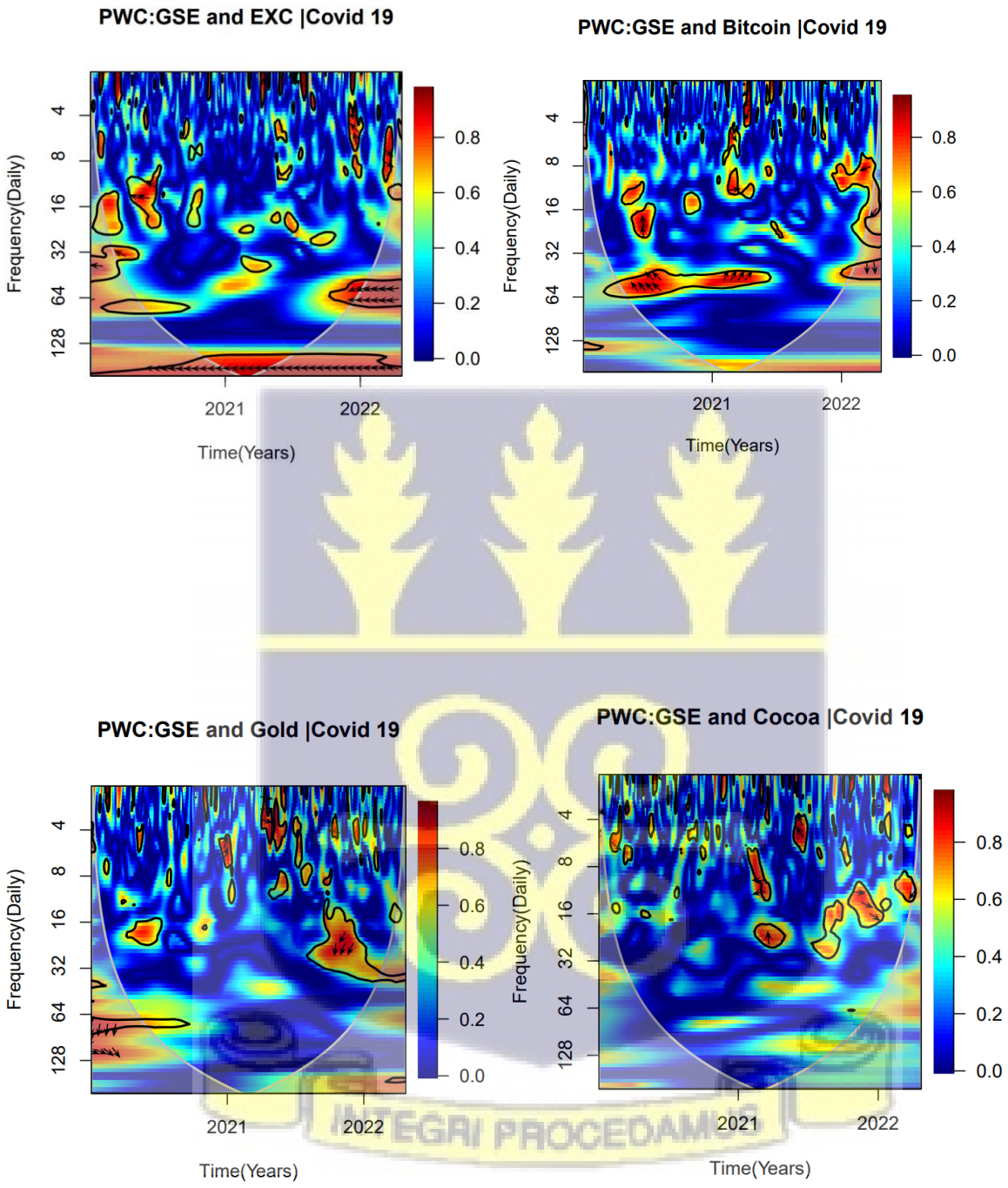


Fig. 2 Patial Wavelet Coherence: Covid 19 Period Sample with Infection Rates

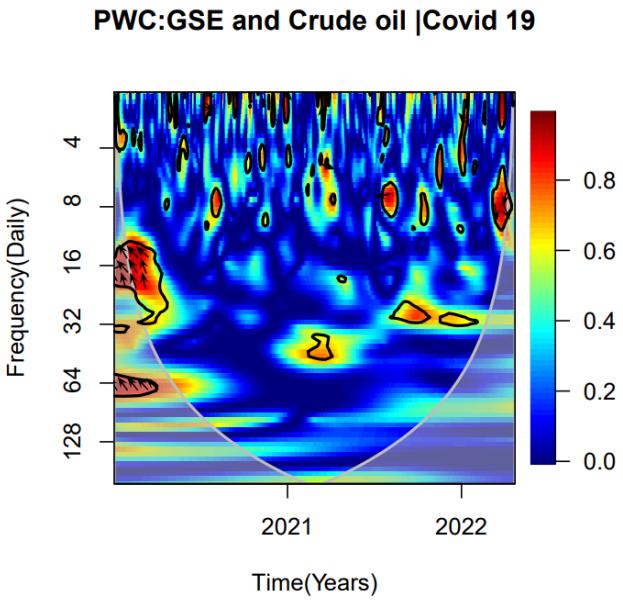


Fig. 2 Continued

Bourse Régionale des Valeurs Mobilières (BRVM) and other Assets

The BRVM and EXC pair shows correlation in the short term from 2020 to 2022, with mid-2020 up to the first quarter of 2021 showing high-frequency correlation in anti-phase. Late 2021 up to the start of 2022 also shows high-frequency correlation between them, with EXC leading BRVM. Not much correlation is seen in the medium term between frequency band 16 and 32 except late 2021 to the beginning of 2022 where it shows correlation with EXC again leading BRVM. In the long term beyond frequency band 32, the only time there was correlation between the two pairs is late 2020 up to mid-2021 in anti-phase. This suggests that the relationship between BRVM and EXC during COVID-19 is characterized by short-term and intermittent correlations, with the dynamics influenced by anti-phase characteristics. This finding is in line with (Aftab et al., 2015) findings that exchange rate and stock price are related negatively, which increases during financial crises period.

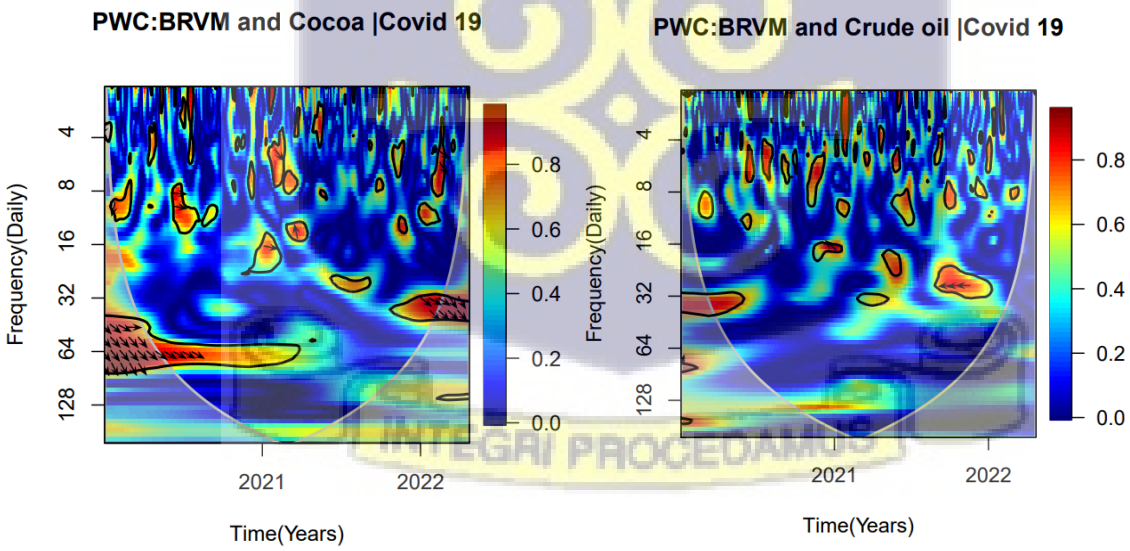
There is not much correlation between BRVM and Bitcoin except for a few times in the short to medium term around frequency band 16 at the beginning of 2021 and the beginning of 2022, which shows evidence of correlation. In the long term, from band 32 and beyond, there is no correlation between the two variables. This indicates that the relationship between BRVM and Bitcoin during COVID-19 is characterized by sporadic and short-term correlations, with no significant correlation observed in the long term.

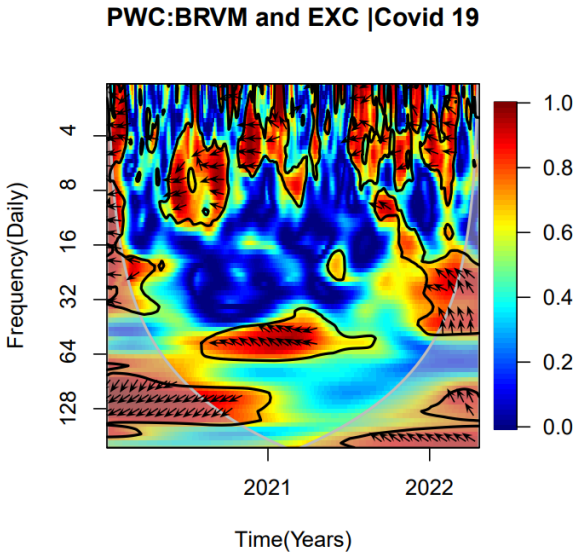
There is evidence of correlation between BRVM and Crude oil from the short to medium term, mainly between band 2 and 32, with mid-2020 to late 2021 showing signs of correlation between the two variables. There is no correlation in the period between BRVM and Crude oil in the long term beyond frequency band 32, except for 2021 around band 128, which shows evidence of low correlation between them. This suggests that the relationship between BRVM and Crude oil during COVID-19 is characterized by short to medium-term correlations, with some instances of low correlation in the long term.

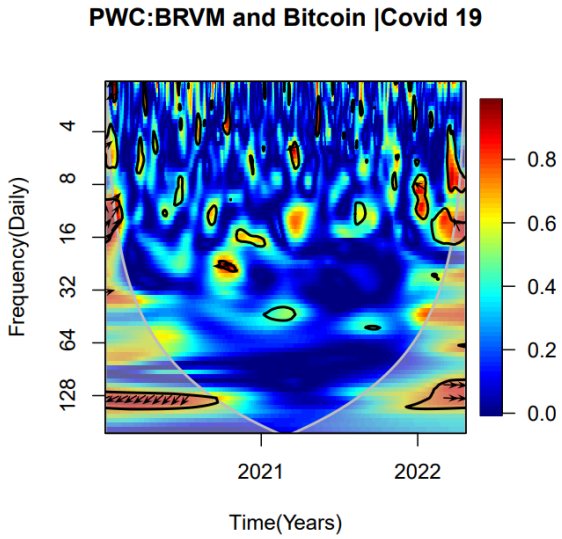
BRVM and Gold pair show no correlation between them in the greater part of the COVID-19 period, except for mid-2020 and early 2021 around band 4 and 16 showing correlation. In the long term, beyond band 32, the few times there is correlation between the two variables is late 2020 at band 32 and the last quarter of 2021 around band 60 and late 2020 up to mid-2021 around band 128 where they are in phase. This indicates that the relationship between BRVM and Gold during COVID-19 is characterized by sporadic and short-term correlations, with specific instances of in-phase characteristics in the long term.

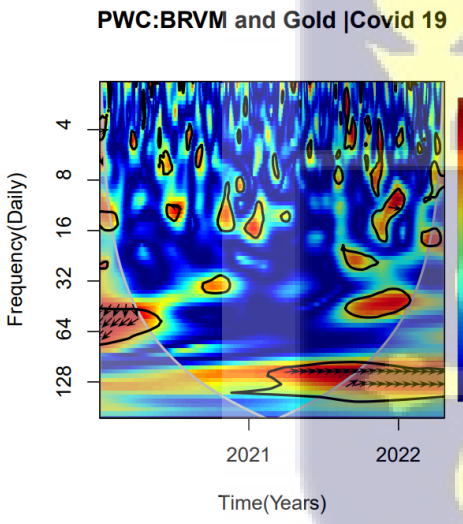
BRVM and Cocoa pair also show no correlation between the two in the greater part of the COVID-19 period, with only mid-2020, the beginning of 2021, and late 2021 showing correlation in the short to medium term. In the long term, beyond band 32, the only times that show correlation are mid-2020 up to the first quarter of 2021 and late 2021 up to the beginning of 2022 with BRVM leading Gold. The rest of the period shows no correlation between them. This suggests that the relationship between BRVM and Cocoa during COVID-19 is characterized by sporadic and short-term correlations, with specific instances of BRVM leading Cocoa in the long term.

In summary, the partial wavelet coherence analysis during the COVID-19 period reveals varying degrees of correlation and limited relationships between BRVM and different variables. The effects of these relationships are observed in specific timeframes, indicating the dynamic nature of the financial market and commodities during the global pandemic.









Nairobi Stock Exchange and other Assets

Between NSE and EXC, there is correlation only from the start to the medium term around frequency band 4 to 16 in early 2020 and late 2020. Also, between band 8 and 16 at the beginning of 2022 with NSE leading EXC. The long term shows no correlation between the two variables. This suggests that the relationship between NSE and EXC during COVID-19 is characterized by short to medium-term correlations, with intermittent dynamics influenced by NSE leading EXC in certain instances.

NSE and Bitcoin pair show scattered correlations between them at a few times within the period. However, no or low correlation areas overshadow the correlation areas. Late 2020 and early 2021 around band 32 shows correlation with Bitcoin leading NSE. This indicates that the relationship between NSE and Bitcoin during COVID-19 is sporadic, with Bitcoin leading NSE in certain instances.

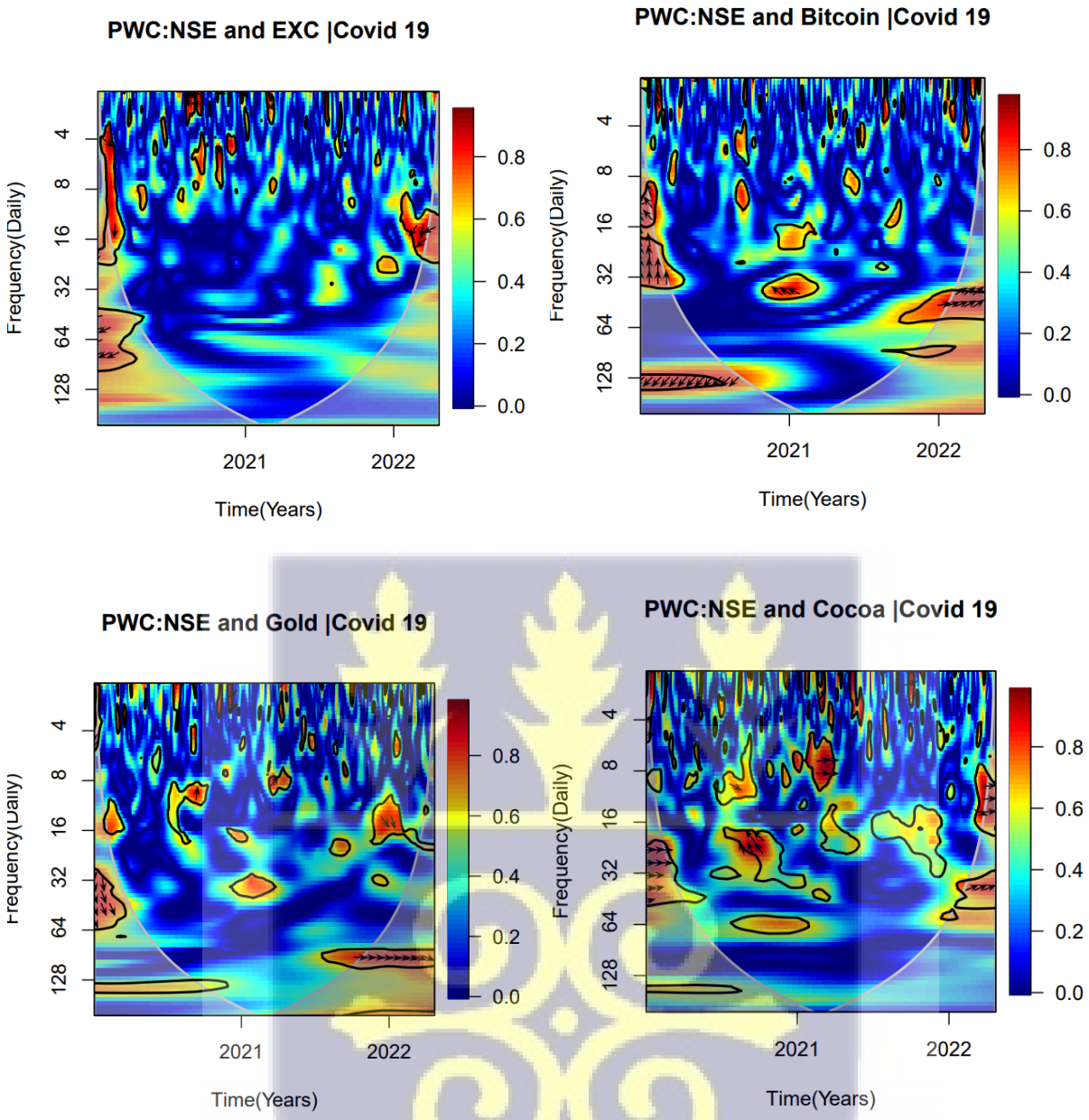
Between NSE and Gold, there are few points in the period which show correlation. The most significant among them is in the medium term between band 8 and 32, where there is correlation between the two variables in mid-2020 around band 16, in late 2020 between band 8 and 16. In late 2021, around band 16, there is correlation between them with NSE leading Gold. The long term shows no correlation between them with only the last quarter of 2021 showing correlation. This suggests that the relationship between NSE and Gold during COVID-19 is characterized by sporadic correlations, with NSE leading Gold in specific instances.

NSE and Cocoa pair show correlation between them from band 2 to 64, with the most significant among them at band 8 in late 2020 and early 2021. Again, between band 16 and 32, from mid-

2020 to 2021, shows correlation between them with Cocoa leading NSE. The second quarter of 2021 to the start of 2022 shows a low level of correlation. There is no correlation between them beyond frequency band 64, but there is evidence of correlation between them at band 64 from the last quarter of 2020 to the beginning of 2021. This indicates that the relationship between NSE and Cocoa during COVID-19 is characterized by varying degrees of correlation, with Cocoa leading NSE in certain instances.

NSE and Crude oil pair show significant correlation between them from frequency band 2 to 32 in mid-2020 to the beginning of 2021 between band 4 and 8 with Crude oil leading NSE at the beginning of 2021. There is also significant correlation between them from the beginning of 2021 to mid-2021 with NSE leading Crude oil between band 16 and 32. Again, there is evidence of correlation in the long term between the variables in late 2020 through to mid-2021 beyond band 64 with Crude oil leading NSE. This suggests that the relationship between NSE and Crude oil during COVID-19 is characterized by significant correlations in the short to medium term, with dynamics influenced by Crude oil leading NSE.

In summary, the partial wavelet coherence analysis during the COVID-19 period reveals varying degrees of correlation and intermittent relationships between NSE and different variables. The effects of these relationships are observed in specific timeframes, indicating the dynamic nature of the financial market and commodities during the global pandemic.



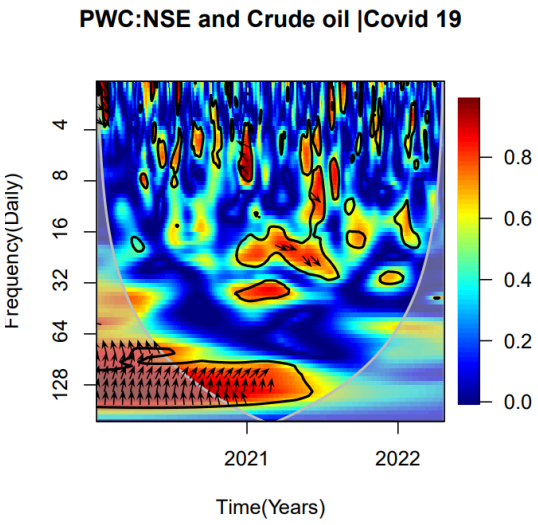


Fig. 2 Continued

Stock Exchange of Mauritius (SEM) and Other Assets

The analysis between SEM and EXC in the period shows no correlation in major parts of the period. The minor part in the period that shows significant correlation is between band 2 and 48, in the beginning of 2022 in band 8 and mid-2020, the third to the last quarter of 2021 with SEM leading EXC in the third quarter of 2021 and EXC leading SEM in the last quarter. This indicates that the relationship between SEM and EXC during COVID-19 is characterized by intermittent and significant correlations, with dynamics influenced by both SEM and EXC leading each other at different points.

SEM and Bitcoin pair show evidence of correlation between them in frequency band 2 to 48. Significant among them is between band 8 and 28 where it shows anti-phase in the last quarter of 2021, the same is replicated at band 128. There is also correlation between the beginning and mid-2021 around band 8 and 16. Again, between band 32 and 58 in the last quarter of 2021. The rest of the period between band 58 and 120 shows no correlation between the variables. This suggests

that the relationship between SEM and Bitcoin during COVID-19 is characterized by varying degrees of correlation, with intermittent anti-phase dynamics in certain time frames.

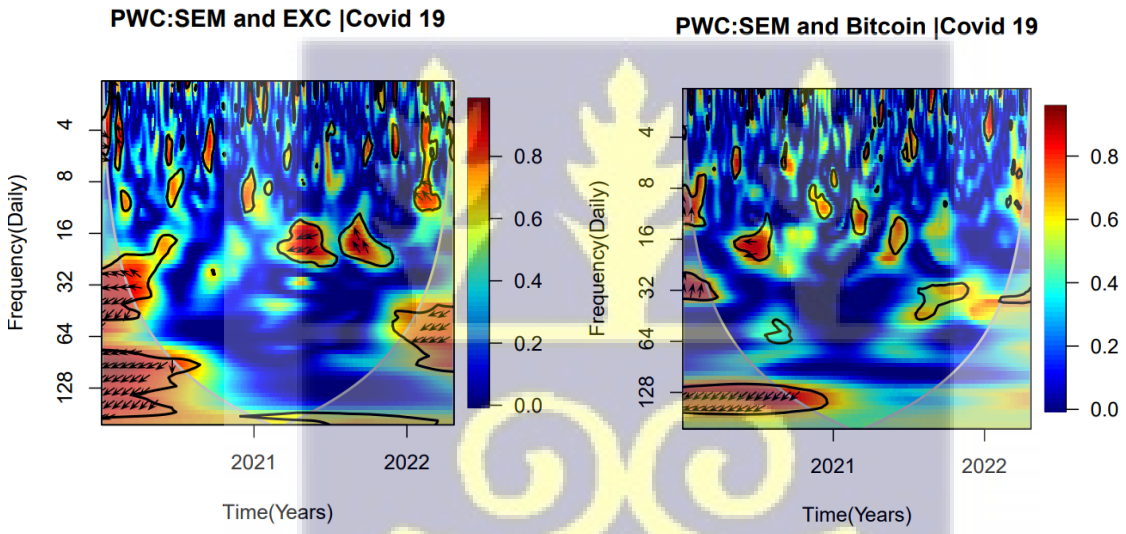
SEM and Gold pair show no correlation between them at major parts of the period under consideration. The only part within the period that shows significant correlation, apart from few pockets in the short to medium term, is between band 32 and 64 from mid to end of 2021. This indicates that the relationship between SEM and Gold during COVID-19 is characterized by sporadic correlations, with more pronounced correlations in specific time frames.

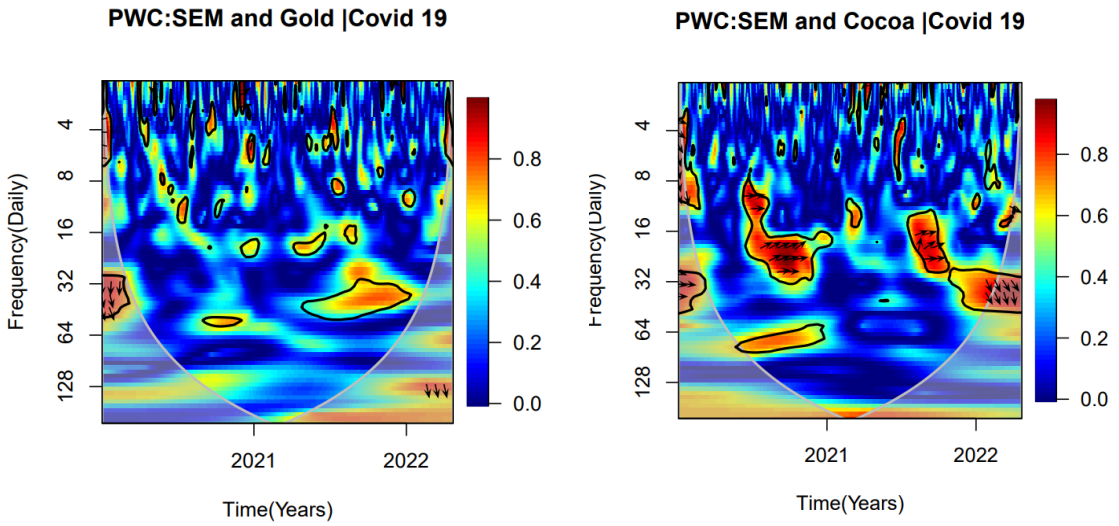
The evidence between SEM and Cocoa after the analysis shows no correlation in major parts of the period except for some minor times. Like between band 64 and 86 where there is a sign of correlation between the two variables from mid-2020 to the beginning of 2021. Also, between band 8 and 32 at the last quarter of 2020 to the beginning of 2021 show evidence of in-phase correlation between SEM and Cocoa. Finally, between band 16 and 48 shows in-phase correlation between the two variables at the last quarter of 2021 and the beginning of 2022. This suggests that the relationship between SEM and Cocoa during COVID-19 is characterized by sporadic correlations, with intermittent in-phase dynamics at specific time frames.

There is a correlation between SEM and Crude oil between band 4 and 8 in the last quarter of 2020, first quarter of 2021, and the last quarter of 2022. Another significant time that shows correlation between the two variables is between band 16 and 64 in mid-2020 where SEM is leading Crude oil. This suggests that the relationship between SEM and Crude oil during COVID-

19 is characterized by significant correlations, with dynamics influenced by SEM leading Crude oil at certain points.

In summary, the partial wavelet coherence analysis during the COVID-19 period reveals varying degrees of correlation and intermittent relationships between SEM and different variables. The effects of these relationships are observed in specific timeframes, indicating the dynamic nature of the financial market and commodities during the global pandemic.





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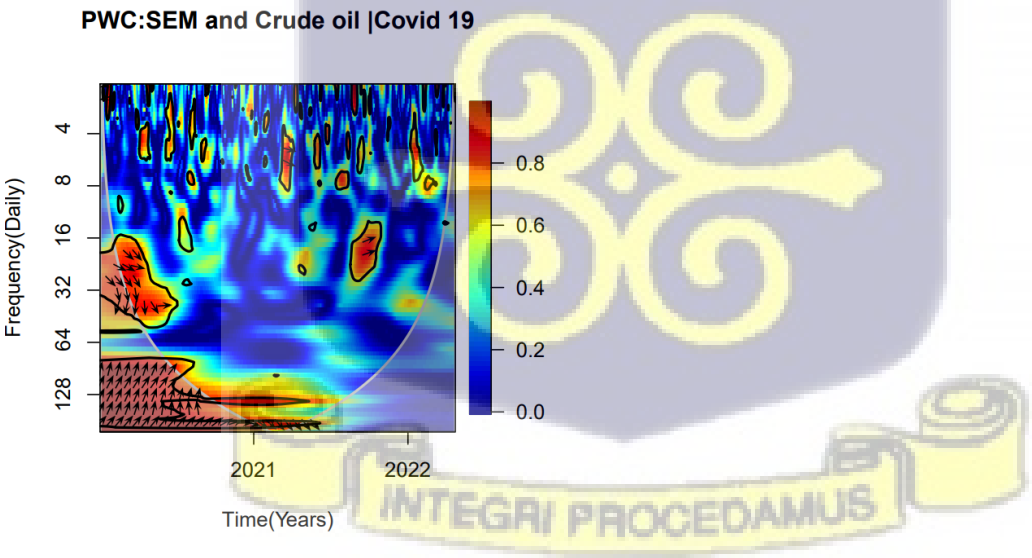


Dar Salaam Stock Exchange and Other Assets

The DSE and EXC pair after the analysis show correlation between them in mid-2020, early 2021, and the last quarter of 2021 between band 2 and 8. From band 12 to 96, there is correlation between them in mid-2020 and mid-2021. Beyond frequency band 128 shows high-frequency correlation between them from late 2020 to late mid-2021. The rest of the period shows no correlation between them. This suggests that the relationship between DSE and EXC during COVID-19 is characterized by sporadic but significant correlations, with high-frequency dynamics in specific time frames.

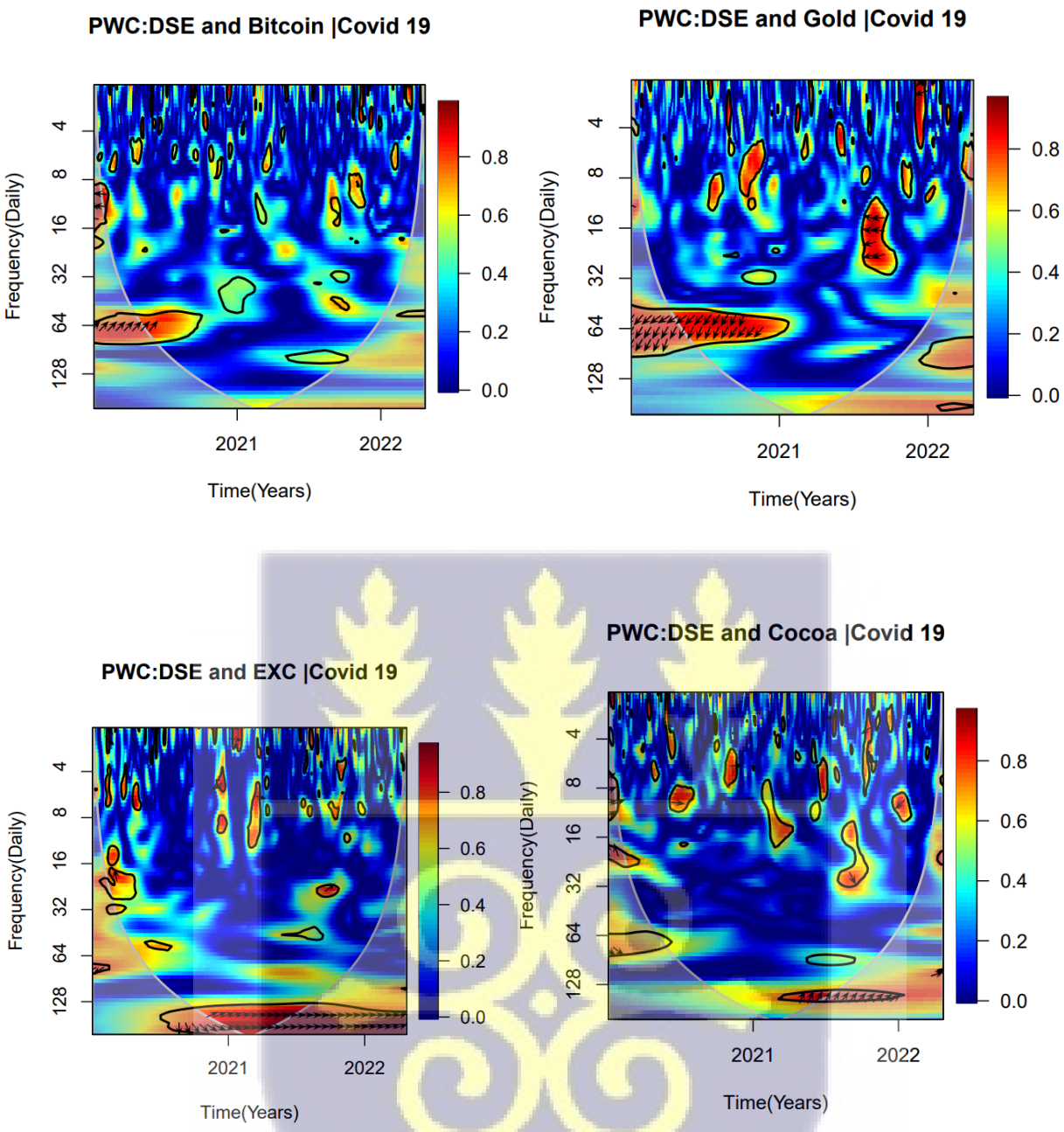
There is not much correlation between DSE and Bitcoin; the few times that show correlation exhibit low correlation between them, except for the third quarter of 2020, which shows high-frequency correlation with Bitcoin leading DSE around frequency band 64. This implies that the relationship between DSE and Bitcoin during COVID-19 is marked by intermittent and low correlations, with a notable exception in the third quarter of 2020.

The analysis shows correlation at few times within the period, like between band 2 and 8 at late 2021 where Gold is leading DSE. Also, there is correlation between the variables in the last quarter of 2021 around band 4 and 16. Furthermore, there is evidence of high-frequency anti-phase correlation around the last quarter of 2021, between band 14 and 32. The last point of correlation between them around band 48 and 96 at mid-2020 to the beginning of 2021 with DSE leading Gold. This indicates that the relationship between DSE and Gold during COVID-19 is characterized by sporadic correlations, with instances of high-frequency anti-phase dynamics.

The DSE and Cocoa pair analysis show pockets of correlation between them from band 2 and 32, with significant areas around late 2020, early 2021, mid and late 2021. Beyond band 32 doesn't show much correlation between the two variables except around band 128, in the first quarter of 2021 where there is evidence of correlation between them, with Cocoa leading DSE. This suggests that the relationship between DSE and Cocoa during COVID-19 is characterized by intermittent correlations, with distinct patterns observed in specific timeframes.

The analysis shows that a major part of the period shows no correlation between DSE and Crude oil. The only times there is correlation between the two is between band 4 and 32, around the first quarter of 2020, the last quarter of 2020, and the major part of 2021. There is not much correlation between them beyond frequency band 64. This indicates that the relationship between DSE and Crude oil during COVID-19 is characterized by sporadic correlations, with significant correlations observed in specific timeframes.

In summary, the partial wavelet coherence analysis during the COVID-19 period reveals varying degrees of correlation and intermittent relationships between DSE and different variables. The effects of these relationships are observed in specific timeframes, highlighting the dynamic nature of the financial market and commodities during the global pandemic.



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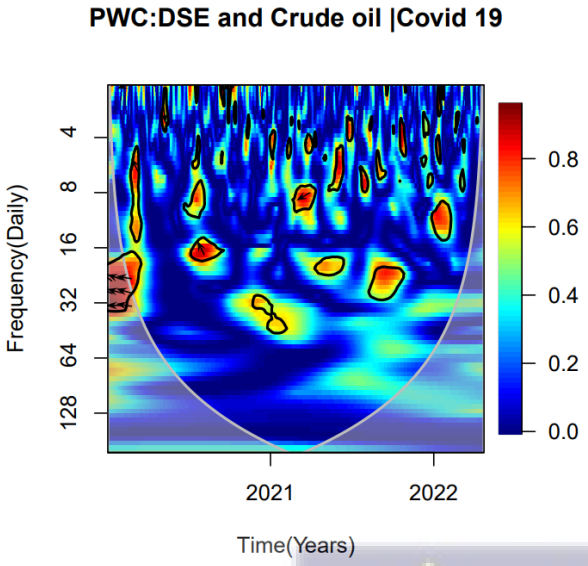


Johannesburg Stock Exchange and Other Assets

The analysis of the JSE and EXC pair during COVID-19 reveals correlation between them in major times, spanning from the short to long term. Significant correlations occurred around the beginning of 2020, mid-2020, and the end of 2020, with EXC leading JSE between band 2 and 16. Further evidence of correlation is found from 2021 to the beginning of 2022, between band 4 and 48, also showing EXC leading JSE in anti-phase. Beyond band 64, high-frequency correlation in anti-phase is observed in the last quarter of 2020 to the beginning of 2021, with JSE leading EXC. This suggests a dynamic relationship between JSE and EXC during COVID-19, characterized by varying degrees of correlation and anti-phase dynamics.

There is no significant correlation between JSE and Bitcoin pair in the period under consideration, except around the last quarter of 2020 between band 8 and 16, where Bitcoin leads JSE. Late 2020 and early 2021 around band 32 show Bitcoin again leading JSE. The last time the analysis shows

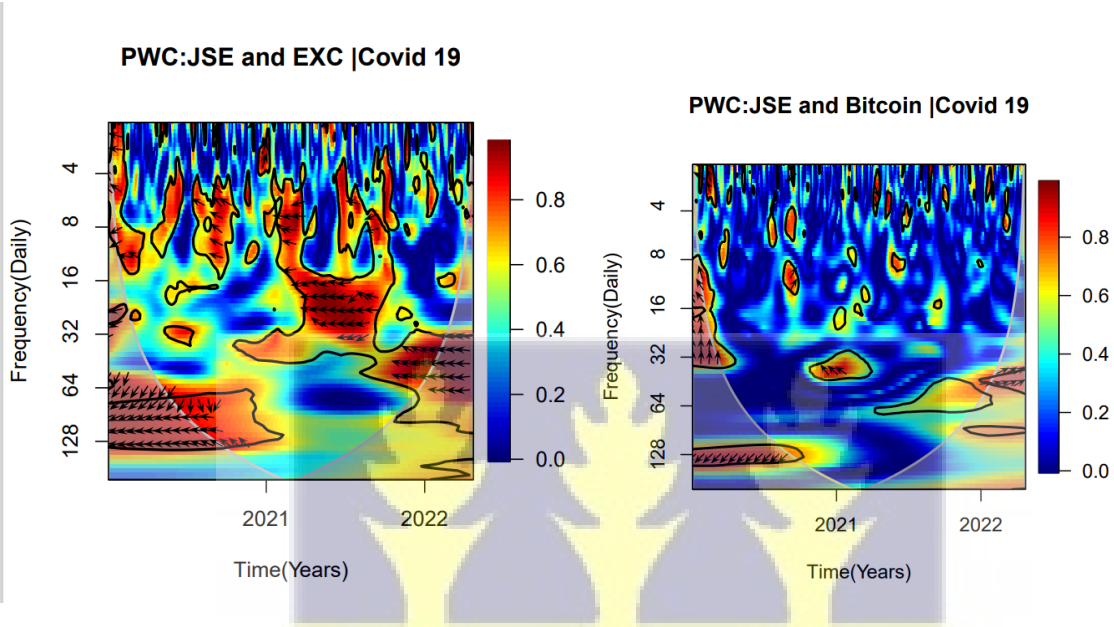
correlation between the two variables is from mid-2021 to the end of 2021. This implies that the relationship between JSE and Bitcoin during COVID-19 is characterized by sporadic correlations, with distinct patterns observed in specific timeframes.

The analysis of the JSE and Gold pair exhibits correlations at a few times within the period, such as the first and last quarter of 2020 between band 8 and 16, the beginning of 2021 around band 32, and mid to the last part of 2021 around band 16 and 64 respectively. This indicates that the relationship between JSE and Gold during COVID-19 is characterized by intermittent correlations, with distinct patterns observed in specific timeframes.

The correlation between JSE and Cocoa is seen between band 4 and 64 from mid-2020 to late 2020, with Cocoa leading JSE. Also, in the first quarter of 2021, JSE leads Cocoa. However, there is no correlation between them beyond frequency band 64. This suggests that the relationship between JSE and Cocoa during COVID-19 is characterized by intermittent correlations, with distinct patterns observed in specific timeframes.

The analysis between JSE and Crude oil pair shows correlation between them from band 4 to 32, from mid-2020 to late 2020, and also the first quarter of 2021, with JSE leading Crude oil. There is also high-frequency correlation between the two variables from band 64 and beyond, from mid-2020 all through the first quarter of 2021, with Crude oil leading JSE. This indicates that the relationship between JSE and Crude oil during COVID-19 is characterized by varying degrees of correlation and anti-phase dynamics, particularly in specific timeframes.

In summary, the partial wavelet coherence analysis during the COVID-19 period highlights dynamic relationships between JSE and different variables, with varying degrees of correlation, anti-phase dynamics, and distinct patterns observed in specific timeframes.



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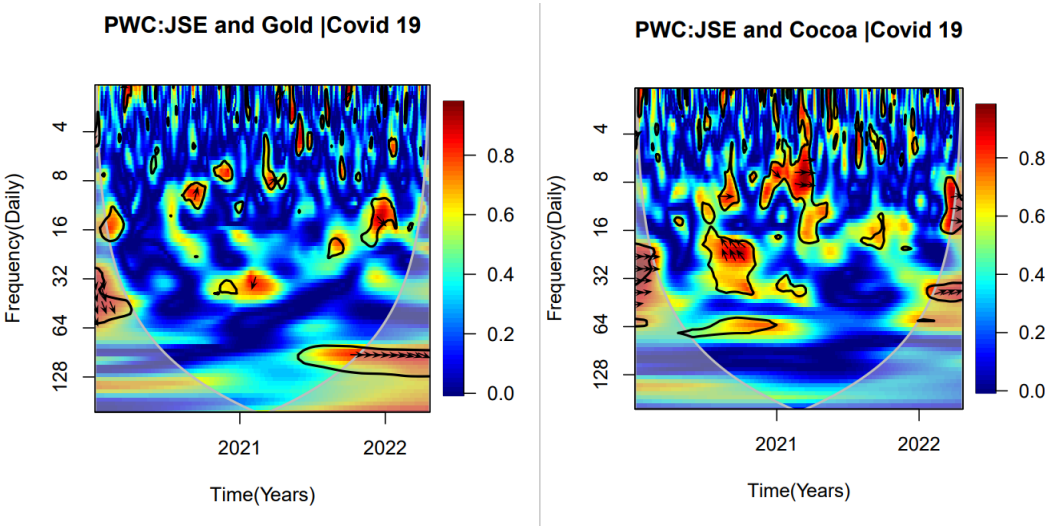


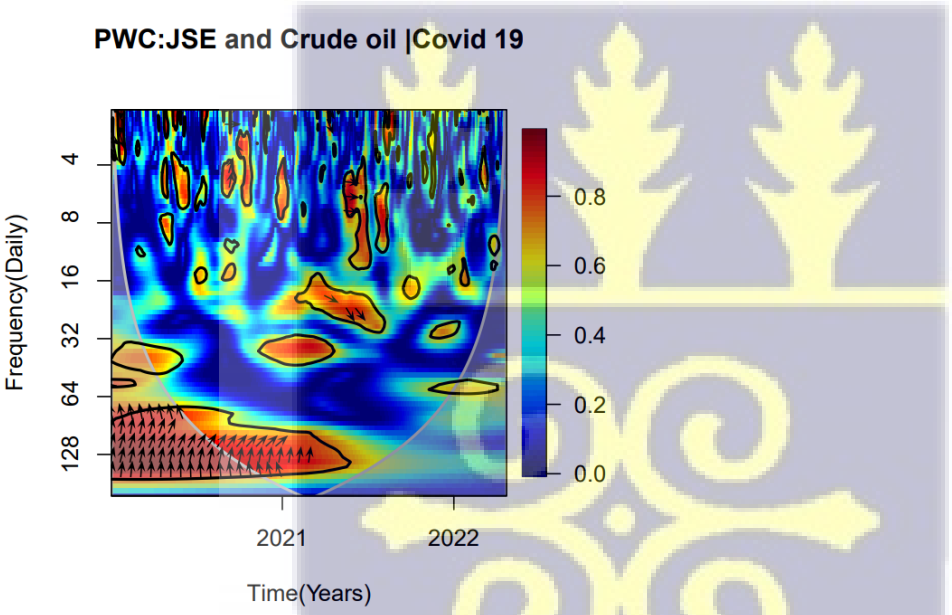
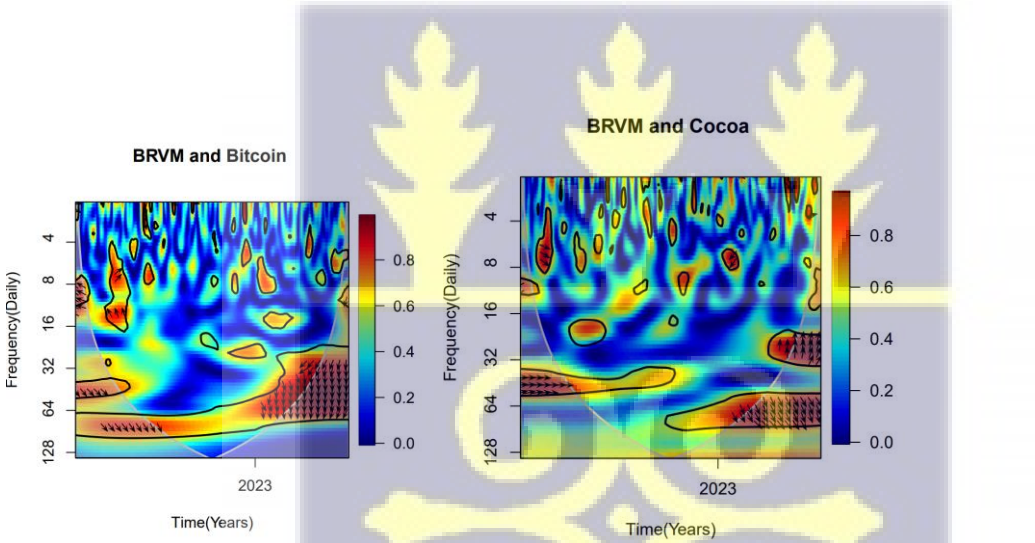


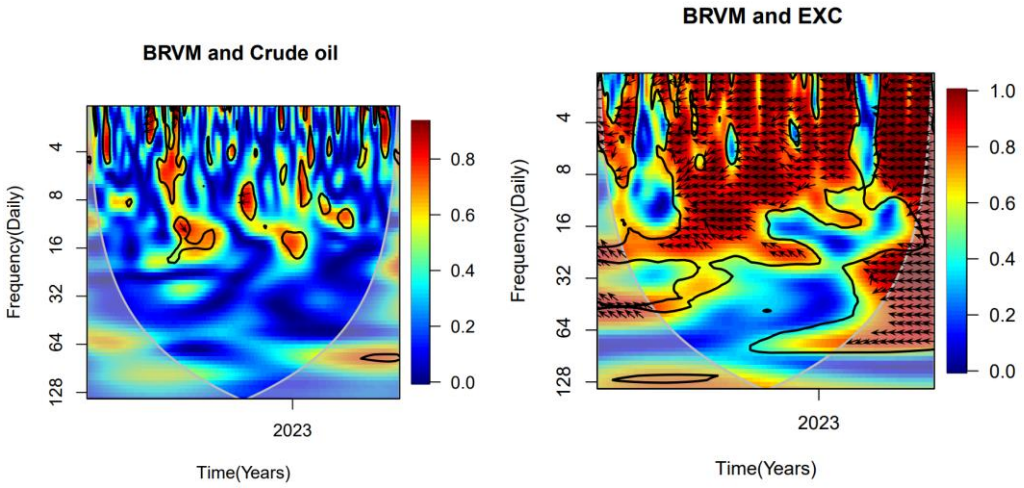
Fig. 2 Continued

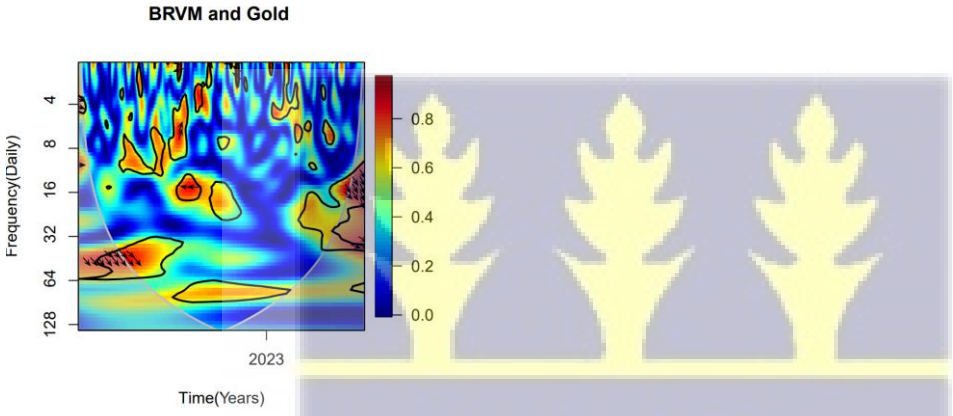
Bivariate wavelet coherence analysis (Russia/Ukraine disturbance period)

Bourse Régionale des Valeurs Mobilières (BRVM) and Other Assets

From early 2022 to early 2023, there was a link between BRVM (Bourse Régionale des Valeurs Mobilières) and Bitcoin, with BRVM outperforming Bitcoin. Furthermore, areas of association between Cocoa and BRVM were identified. Nevertheless, no correlation was seen above frequency band 16, despite evidence of correlation between BRVM and crude oil within frequency bands 2 to 16. Furthermore, BRVM and EXC showed a strong link in anti-phase, with BRVM outpacing EXC over the studied time. On the other hand, there was less of a correlation seen between Gold and BRVM.

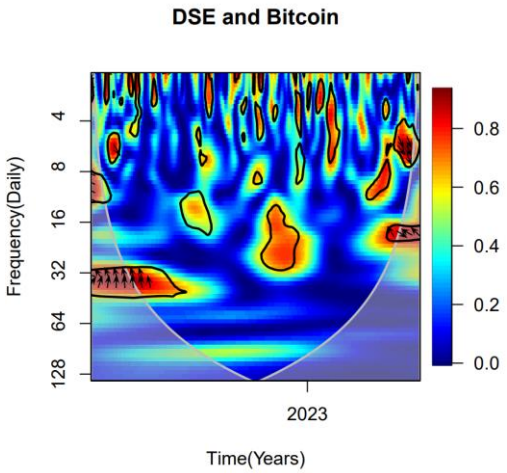


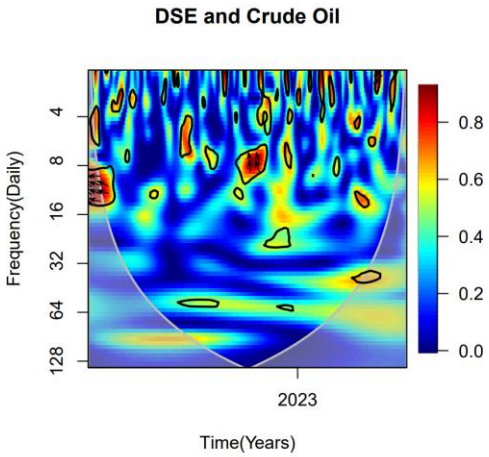


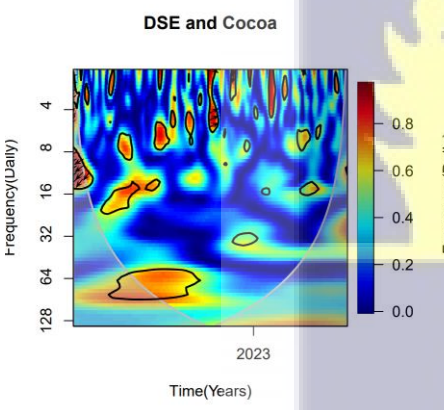


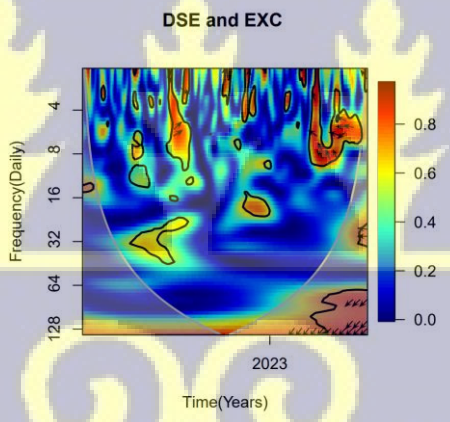
Dar Salaam Stock Exchange (DSE) and Other Assets

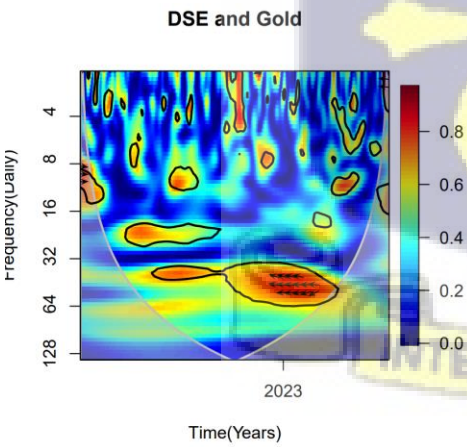
The degree of correlation between the DSE and different asset classes varied. The relationship between DSE and Cocoa and Bitcoin was not very significant. In a similar vein, little relationship was found between DSE and crude oil. Nonetheless, there were a few occasions where DSE and EXC were correlated, especially in the frequency range of 2 to 32 around the middle of 2022 and late 2023. Furthermore, a substantial association was observed beyond frequency band 32 in anti-phase, even though there was less correlation between DSE and Gold inside frequency bands 2 to 32.







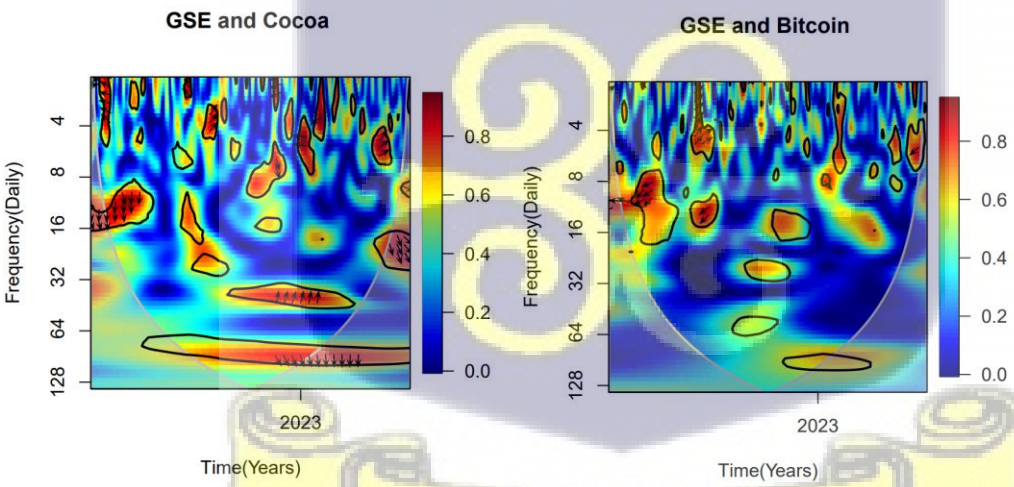


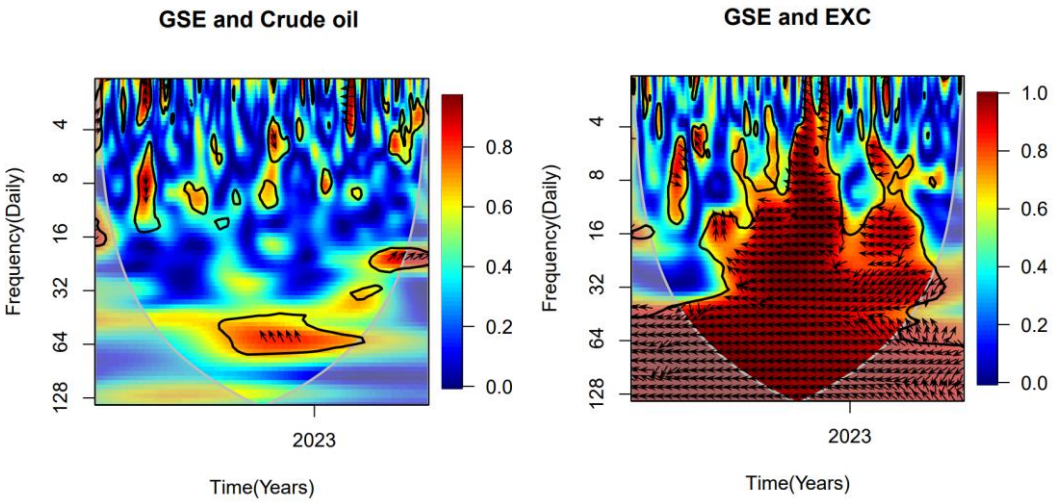


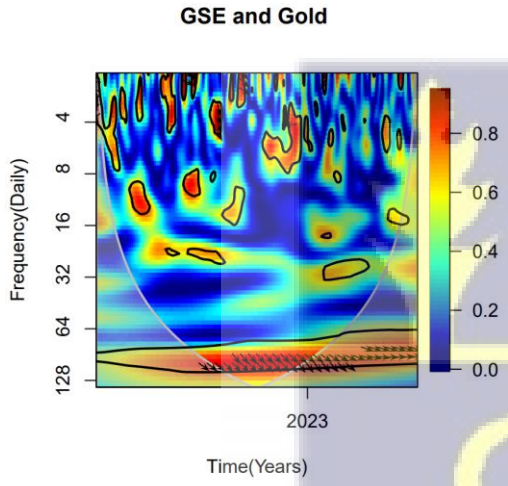
Ghana Stock Exchange (GSE) and Other Asset Classes

The GSE showed relationships with a number of commodities and financial instruments. Data showed that GSE and cocoa were correlated, with GSE outperforming cocoa in the short run and cocoa outperforming GSE in the long run. In the medium run, a medium frequency link between GSE and Bitcoin was also noted. On the other hand, over the long run, a medium frequency link was observed between GSE and crude oil, despite little association in the short to medium term.

Furthermore, there was a high frequency correlation from the medium to long term, with GSE leading EXC, and a short-term linkage between the two, especially in the final quarter of 2022. But there wasn't as much of a correlation seen between Gold and GSE.







Johanesburg Stock Exchange (JSE) and Other Asset Classes

The JSE showed varied levels of correlation with various commodities and financial instruments. With the exception of a strong link at frequency band 32, where JSE outperformed Bitcoin, there was no association between the two. Furthermore, a phase-by-phase analysis revealed evidence of linkage between JSE and Cocoa at frequency bands 4 and 32 in mid-2022 and 8 and 32 in the final quarter of 2022 to early 2023. Furthermore, there was no indication of a long-term association between the JSE and crude oil, and there was little correlation in the short to medium term. On the other hand, a strong frequency connection was noted between JSE and EXC over the long run,

with EXC outperforming JSE. Moreover, a low frequency correlation was observed between JSE and Gold, whereas a significant frequency correlation was observed in the frequency range 16 and 32, with Gold outperforming JSE.

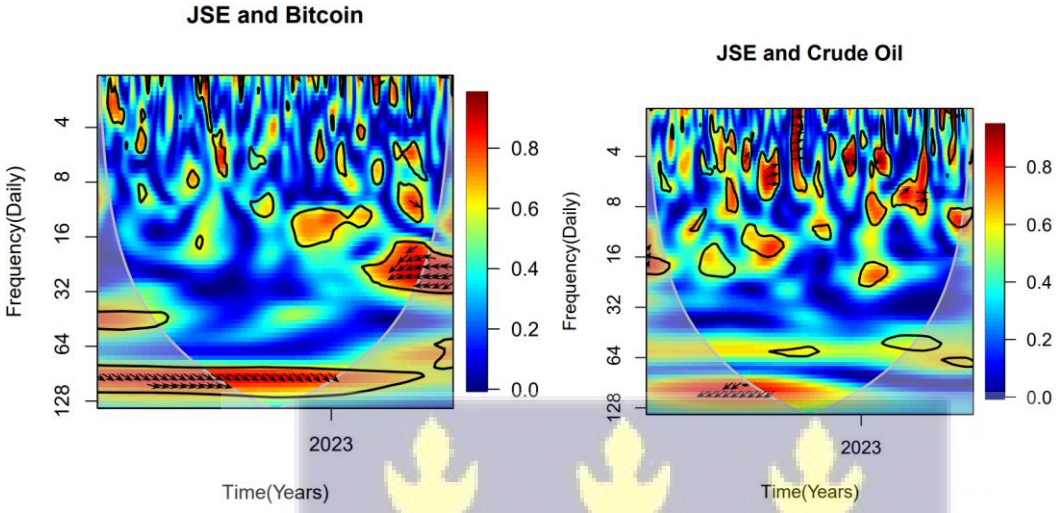
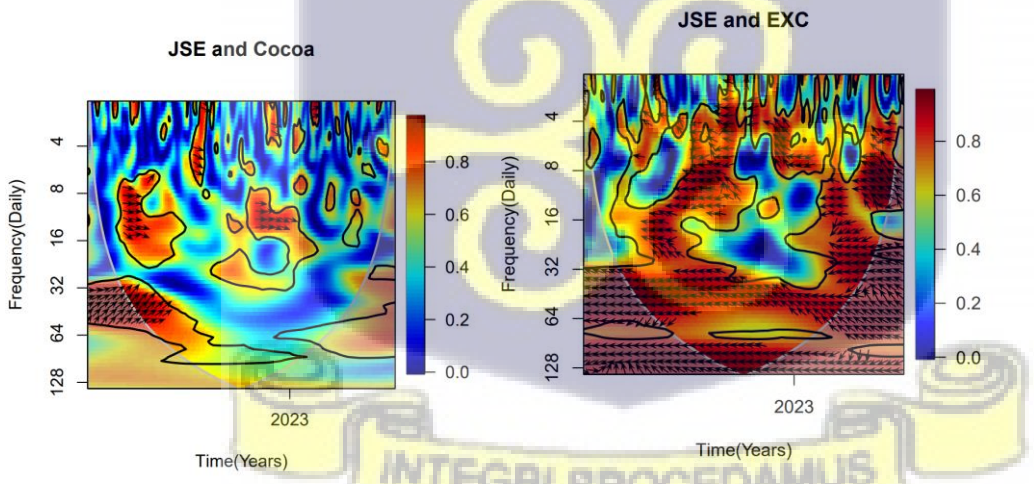
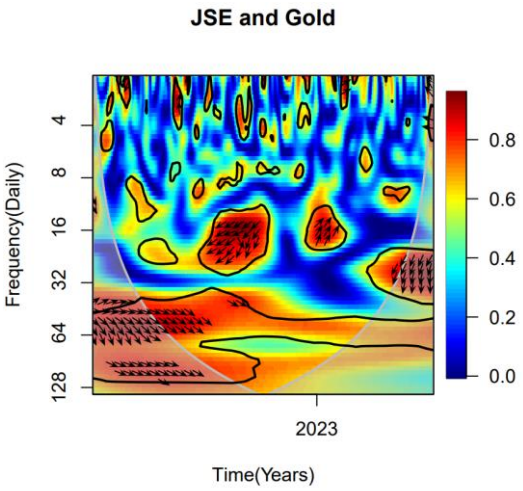


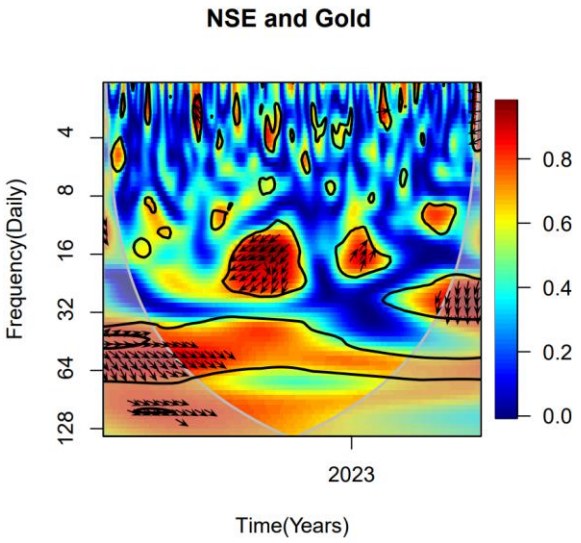
Fig. 3

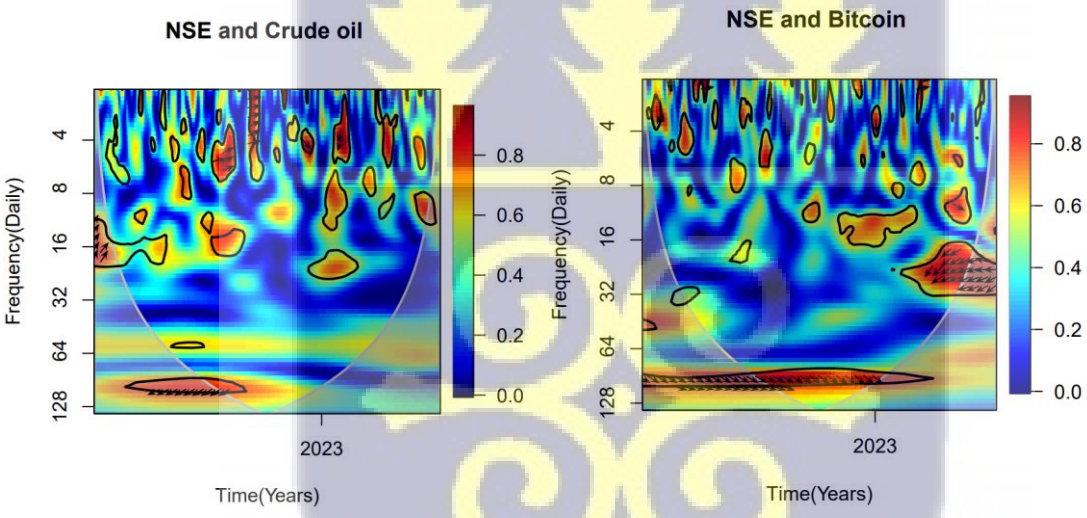


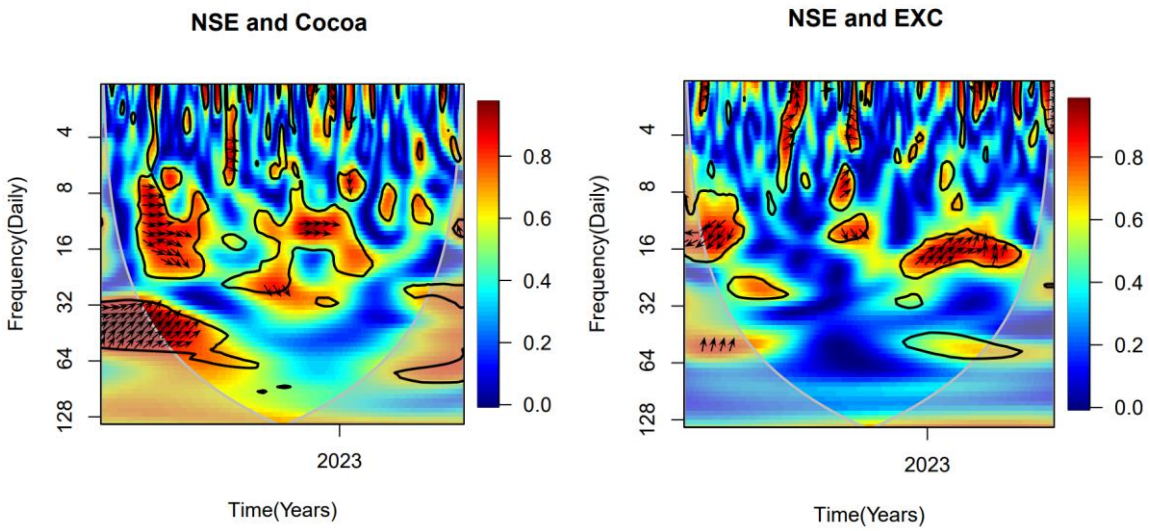


Nairobi Stock Exchange (NSE) and Other Asset Classes

The NSE showed relationships with a number of commodities and financial instruments. In the short to medium range, there was little correlation between NSE and Bitcoin; however, by the middle of 2023, there was a high frequency correlation, with NSE ahead of Bitcoin. NSE and Cocoa also correlated, with NSE outpacing Cocoa in the short- to medium-term range, above frequency band 32. But the only time they were correlated was in the middle of 2022, when Cocoa was ahead of NSE in phase. In addition, there was little to no association found beyond the medium term between the NSE and crude oil, while pockets of correlation were seen in the short to medium term. Furthermore, NSE and EXC showed little to no association outside of frequency band 32, and only a few pockets of correlation between them between frequency bands 2 and 32. Furthermore, there was evidence of a modest correlation between NSE and Gold in the vicinity of frequency bands 2 and 12, but a substantial correlation between frequency bands 16 and 32, with NSE leading Gold, beyond frequency band 12.

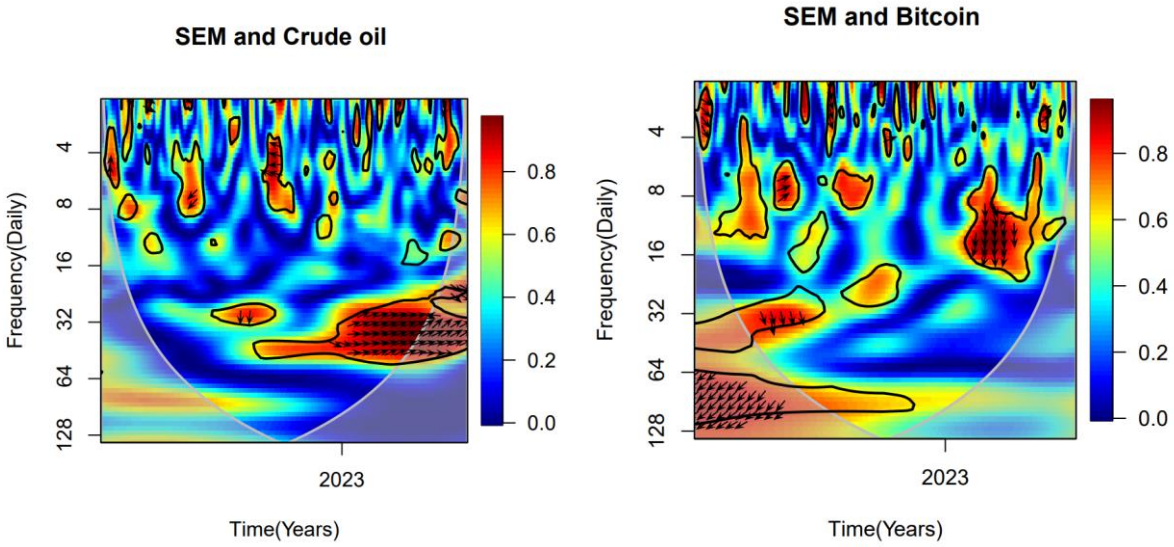


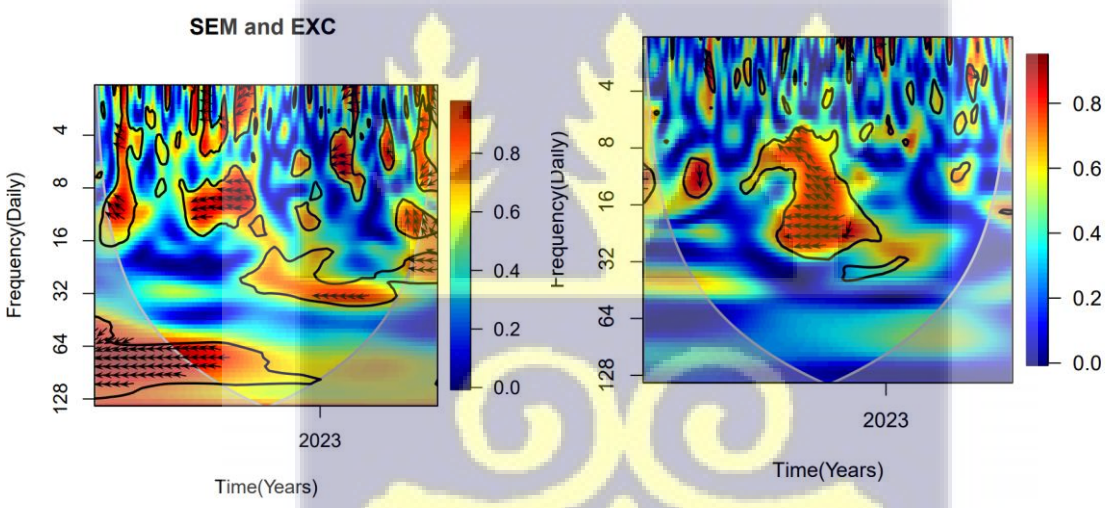




Stock Exchange of Mauritius (SEM) and Other Asset Classes

Correlations between SEM and different commodities and financial instruments were visible. SEM and Bitcoin were found to be correlated in the short to medium range; a long-term association was only found between mid-2022 and late 2022. In a similar vein, evidence of a short- to medium-term association between SEM and cocoa was found, with a high frequency correlation being apparent between mid-2022 and mid-2023. Furthermore, SEM and crude oil showed pockets of association between frequency bands 2 and 16, but no correlation between frequency bands 32 and 64 was seen until late 2022 or early 2023. Furthermore, from mid-2022 to early 2023, there was little correlation between SEM and Gold, with the exception of frequency band 8 and 32, where Gold outperformed SEM. Additionally, there was proof of a strong link between SEM and EXC, with SEM outperforming EXC during the studied period.





The study's findings, which are consistent with the larger body of research showing increased spillovers during significant global shocks, show a distinct pattern of time-varying and crisis-sensitive connection between African equity markets and global assets. This analysis supports the findings of Urom et al. (2022) and Yousaf et al. (2023) that times like COVID-19 and the conflict between Russia and Ukraine cause significant increases in co-movement and directional predictability. The idea that Sub-Saharan African (SSA) markets show conditional integration relatively segmented during calm times but highly exposed during stressful times is supported by these findings. Additionally, the data confirms previous research on market heterogeneity. While smaller, less liquid markets like the DSE and GSE showed greater susceptibility to peculiar commodity and currency moves, larger exchanges like the JSE and NSE showed closer connections with global markets. This validates the findings of Mensi et al. (2023) and Bello et al. (2022), who highlight market structure as a crucial factor influencing integration dynamics.

The results add complexity and contradiction even if they generally agree with the available data. Notably, the analysis contradicts claims of universal safe-haven features described in previous works by identifying Bitcoin as an intermittent rather than continuous diversifier. Instead, the findings are consistent with more recent research that indicates the hedging function of cryptocurrencies depends on the regime. throughout a similar vein, the BRVM demonstrated conditional insulation from global shocks, supporting the notion that contagion is evenly transmitted through regional exchanges throughout Africa. In terms of methodological contribution, the combination of Granger causality and wavelet coherence makes it possible to identify multi-scale, directionally specific links that are frequently missed by VAR and GARCH-based research. Divergences from certain previous findings, particularly with regard to the

identification of asymmetric causal directions, such as crude oil and exchange-rate leadership over specific markets, may be explained by this.

By providing a time-frequency map of spillovers across several crises across a lengthy time horizon (2012–2023) and by showing that spillover strength and causal direction change not just across time but also across investment horizons, the study expands on prior knowledge. Compared to conventional time-domain methods, this offers deeper, more useful insights. Furthermore, a path for a more locally grounded interpretation of global-financial transmission mechanisms is created by identifying market-specific drivers, such as the impact of exchange rates on the DSE or crude oil on the GSE.

These realizations have significant real-world ramifications. The results highlight the necessity of dynamic, frequency-aware hedging for risk management because co-movements differ significantly across investment horizons. Since coherence spikes are trustworthy markers of impending contagion, risk managers should integrate wavelet-based early-warning signals into their stress-testing frameworks. The risk of perceiving SSA economies as a homogenous block is highlighted for investors by the diverse responses across markets. Markets with structural resource dependency should prioritize long-term commodities hedges, whereas markets heavily impacted by currency dynamics should prioritize tactical foreign exchange hedges. Asset allocation methods should be market-specific and horizon-specific. These findings can also be used by policymakers to make practical decisions. Stabilizing domestic currency circumstances and bolstering FX reserve buffers should lessen equity-market risk, as exchange-rate fluctuations have a significant impact on a number of markets. Additionally, the potential advantages of regional financial integration as a shock-absorption mechanism are supported by the partial insulation seen in the BRVM.

Overall, by identifying novel patterns of regime-dependent, frequency-specific, and market-level variability, the analysis not only confirms a large portion of the current evidence on financial connection but also expands and deepens the literature. These findings emphasize the significance of analytical approaches that can capture the multifaceted dynamics of emerging and frontier economies while offering investors and policymakers insights that are both practically applicable and theoretically sound.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The entire investigation is summarized and conclusions are drawn in this chapter. The study's findings, some policy recommendations, and ultimately, research directions are also presented.

5.2 Summary of Findings

The first objective was to investigate the lead-lag relationship for African Stock Markets, Commodities and Financial Assets, using data on selected equity markets, commodities and international assets, analyzed with Bivariate Wavelet Coherence method. The findings of (Wadud et al., 2023) also corroborate our results which show uncovered intricate patterns in the relationships among stock exchanges (GSE, BRVM, NSE, DSE, and JSE) and important variables such as exchange rates (EXC), Bitcoin, gold, cocoa, and crude oil spanning from 2012 to 2023. This implies the findings have revealed complex and detailed patterns in their relationships. In essence, the study has brought to light the intricate nature of how these stock exchanges relate to and are influenced by important financial variables over the specified time frame.

The second objective was to investigate the causality between African stocks, commodities and financial assets under different market conditions. The Granger causality tests conducted on African stock markets during the Russia-Ukraine war show that the markets' responses varied significantly. While some markets were directly influenced by global economic factors like currency fluctuations and commodity prices, others remained relatively insulated, which is due to implementation of proper regulation measures. Key findings include the GSE's sensitivity to

currency volatility, the BRVM's independence, the DSE's reliance on gold, the JSE's exposure to both currency and gold, the NSE's resilience, and the SEM's close link to Bitcoin. These results highlight the importance of understanding individual market dynamics when assessing the impact of global events.

The third objective was to examine the link between currencies, commodities and African equity markets in the period of COVID-19 and Russia/Ukraine Disturbances. Using data on selected equity markets, commodities and international assets, analysed with Partial Wavelet Coherence method. The results show there were diverse degrees of correlation and anti-phase dynamics between the Ghana Stock Exchange (GSE) and numerous variables, such as EXC, Bitcoin, Gold, Cocoa, and Crude oil, throughout specific intervals. This means, the study uncovered varied levels of correlation and opposing trends between the Ghana Stock Exchange (GSE) and key variables like EXC (exchange rates), Bitcoin, Gold, Cocoa, and Crude oil. These relationships were not consistent but exhibited fluctuations and reversals during specific timeframes within the overall study period from 2012 to 2023.

Understanding how markets interact is crucial for financial decision-making, therefore for an investor or financial institution holding a variety of assets, market dynamics are crucial. Using Wavelet Analysis, we examine the co-movement of Africa's stock markets and currencies, commodities and emerging assets. Also, we seek to determine how these relationships' dynamics have been affected by the COVID-19 pandemic. The study relied heavily on secondary data from DataStream database for its findings. To offer a description of the data used for the empirical studies, plots and tables were created. The study uncovered intricate patterns in the relationships

among stock exchanges (GSE, BRVM, NSE, DSE, and JSE) and important variables such as exchange rates (EXC), Bitcoin, gold, cocoa, and crude oil spanning from 2012 to 2023. This data offers valuable information regarding the varying degrees of correlation, interactions with opposing phases, and shifting patterns observed throughout different time periods and frequency ranges. Furthermore, the examination of partial wavelet coherence throughout the COVID-19 period unveiled complex and ever-changing connections among different financial indicators and commodities. The results indicate that there were diverse degrees of correlation and anti-phase dynamics between the Ghana Stock Exchange (GSE) and numerous variables, such as EXC, Bitcoin, Gold, Cocoa, and Crude oil, throughout specific intervals.

Findings from Russia/Ukraine disturbances show, BRVM outperformed Bitcoin from early 2022 to early 2023, showing an established connection with the cryptocurrency throughout that time. Within frequency bands 2 to 16, BRVM likewise exhibited a relationship with crude oil; however, no significant correlation was seen above frequency band 16. There were connections found between BRVM and Cocoa as well as a robust anti-phase association with EXC; however, the correlations with Gold were much less. The dynamics of the correlations between the DSE and different asset classes changed over time. There were sporadic links with EXC, particularly in the middle and end of 2022 and 2023, but there were generally no relationships with Bitcoin or crude oil. There were correlations between GSE and crude oil, bitcoin, and cocoa that varied in intensity and duration. There was a significant medium-to long-term link with EXC, where GSE was leading. Comparably, throughout a range of time periods, SEM showed connections with Bitcoin, cacao, crude oil, gold, and EXC, suggesting dynamic links between these assets and the stock market.

The findings of the Granger causality study shed light on a number of causal links between various variable pairs. Notably, there is evidence of a one-way causal link between GSE and CU, with CU strongly influencing GSE but not the other way around. Nevertheless, there are no discernible causal relationships between GSE and BP, GP, COP, or CP, indicating that they are independent of one another. Similarly, NSE and KSU demonstrate a reciprocal causal relationship, whereas SEM displays a causal relationship from MRU. On the other hand, there is no discernible Granger causality between SEM and other variables such as BP, GP, COP, or CP, suggesting that there are no causal linkages between them. Furthermore, there are no meaningful causal relationships between JSE and other variables like GP, BP, COP, or CP. Instead, JSE shows a direct relationship from RU but not the other way around. Furthermore, although there is a strong cause-and-effect relationship between BVRM and CFU, there is no proof that BVRM causes CFU. These results highlight the intricate interactions among different economic variables and the significance of comprehending their causal connections in order to make well-informed decisions.

The study's conclusions show complex, time-varying links between important global factors such exchange rates (EXC), crude oil, cocoa, gold, and Bitcoin and African stock markets (GSE, BRVM, NSE, DSE, JSE). Policymakers, regulators, and investors working in Sub-Saharan Africa can benefit greatly from these dynamics, which are captured by wavelet coherence, partial coherence, and Granger causality.

Policy Consequences for Financial Markets in Africa includes but not limited to the following:

Strengthen economic diversification and lessen reliance on commodities

Currency and commodity shocks were particularly sensitive to markets like the GSE and DSE. To

lessen susceptibility to fluctuations in global prices, policymakers should encourage diversification into non-commodity industries like ICT and services.

Enhance Risk Management and Exchange Rate Stability; Strong medium- and long-term connections between EXC and markets such as the GSE and JSE underscore the necessity of: greater buffers for foreign reserves, more dynamic frameworks for managing foreign exchange risk, and improved regional monetary coordination in accordance with the stable shared-currency paradigm of BRVM.

Expand Local Marketplaces and Boost Liquidity: There was little shock absorption and uneven co-movement in thin markets (GSE, DSE). In order to mitigate global risks, regulators ought to support deeper listings, institutional investment, cross-listing among African blocs, and the growth of derivative markets.

Boost Regulatory Surveillance and Crisis Response: Variations in reactions to the shock between Russia and Ukraine reveal unequal regulatory readiness. Robust monitoring was advantageous to stronger markets (NSE, BRVM). Adopting real-time surveillance tools, standardizing crisis management procedures, and enhancing stress testing capabilities are all recommendations for regulators.

5.3 Conclusion

The bi-wavelet coherence analysis has revealed complex dynamics in the interactions between stock exchanges (GSE, BRVM, NSE, DSE, and JSE) and key variables including exchange rates (EXC), Bitcoin, gold, cocoa, and crude oil from 2012 to 2023. These data provide insight into the variable levels of correlation, opposite-phase interactions, and changing patterns observed in various periods and frequency ranges. The Ghana Stock Exchange (GSE) demonstrated a predictive ability to forecast changes in exchange rates during certain time periods, showing significant inverse connections and changing patterns, which corroborate the findings of (Owusu Junior et al., 2019) which narrowly identified lead-lag relationship between GSE and Currency. The linkages between gold, cocoa, and crude oil exhibited fluctuating patterns of correlation and periods of low or nonexistent correlation, highlighting the dynamic character of these interactions.

The Regional Stock Exchange (BRVM) exhibited an intricate correlation with currency exchange rates, Bitcoin, gold, cocoa, and crude oil. The prominent association between BRVM and exchange rates, as well as sporadic correlations with other variables, emphasize the intricate nature of these financial relationships. The Nairobi Stock Exchange (NSE) exhibited sporadic associations with exchange rates, Bitcoin, gold, cocoa, and crude oil, indicating a fluctuating connection with these assets. The forecast accuracy of currency rates on the NSE during specific time periods emphasizes the dynamic factors at work.

The Dar es Salaam Stock Exchange (DSE) shown dynamic correlations with currency rates, Bitcoin, gold, cocoa, and crude oil. The sporadic connections and influential connections highlight the changing dynamics of financial transactions in the Tanzanian market.

The Johannesburg Stock Exchange (JSE) demonstrated intricate correlations with currency exchange rates, Bitcoin, gold, cocoa, and crude oil. The JSE is influenced by these assets in the short to medium term, and their long-term dynamics add complexity to global financial markets. The bi-wavelet coherence analysis offers a significant framework for comprehending the complex connections between stock exchanges and crucial financial factors. The guidelines are designed to assist market participants in understanding the intricacies of these linkages and making well-informed decisions in a constantly changing financial environment.

Ultimately, the examination of partial wavelet coherence throughout the COVID-19 period unveiled complex and ever-changing connections among different financial indices and assets. The results indicate that there were diverse degrees of correlation and anti-phase dynamics between the Ghana Stock Exchange (GSE) and numerous variables, such as EXC, Bitcoin, Gold, Cocoa, and Crude oil, throughout specific time periods. The association between GSE and EXC showed sporadic patterns, especially in the short to medium term, with occasional occurrences of being out of sync. Intermittent relationships were noted between GSE and other commodities like Bitcoin, Gold, Cocoa, and Crude oil. The linkages appeared to be driven by the changing dynamics of the global financial market amidst the pandemic (Aftab et al., 2015).

Moreover, the research was expanded to include the correlation between numerous regional stock markets such as BRVM, NSE, SEM, DSE, and JSE, and different variables. The correlations exhibited a wide range of variations, with short to medium-term correlations displaying distinct patterns. The connections exhibited anti-phase dynamics, resulting in sporadic correlations between the stock exchanges and the variables under investigation.

Based on these data, it is clear that the financial markets and commodities reacted in distinct ways to the problems presented by the global epidemic. The ever-changing nature of these relationships highlights the necessity for a sophisticated comprehension of the market dynamics amid extraordinary occurrences such as the COVID-19 epidemic but none can be said about the Russia/Ukraine disturbances.

By showing how African equity markets interact with global financial assets in ways that both challenge and improve conventional finance theories, the empirical findings of this study provide important theoretical contributions. Specifically, the findings expand the applicability of Behavioral Finance, the Efficient Market Hypothesis (EMH), and Modern Portfolio Theory (MPT) to the distinct macroeconomic and structural characteristics of Sub-Saharan African (SSA) markets. This section summarizes how the evidence enhances theoretical understanding of market behavior in emerging economies and alters these frameworks.

Implications for MPT (Modern Portfolio Theory): MPT assumes stable covariances and suggests that low or negative correlations between assets provide advantages for diversification. The wavelet-based findings of this study, however, defy the notion of steady and static correlations. Rather, it is demonstrated that the connections between African equities markets and international assets—like exchange rates, crude oil, cocoa, gold, and Bitcoin—are extremely time-varying, frequency-dependent, and susceptible to shocks from around the world. Previously weak or moderate correlations rapidly increased during crises like COVID-19 and the Russia-Ukraine conflict, indicating moments of correlation breakdown when diversification advantages are most needed. Additionally, the assumption of consistent behavior throughout frontier markets is challenged by the heterogeneity across markets (e.g., the broader global links of the JSE versus the commodity-driven dynamics of the GSE or DSE). These results suggest that dynamic portfolio

theory, which takes into account multi-scale, regime-dependent co-movements and permits horizon-specific risk management strategies, should replace classical MPT.

Implications for the Efficient Market Hypothesis (EMH): According to the EMH, market prices accurately reflect the facts at hand and historical trends cannot forecast future results. However, recurrent patterns that are at odds with strong or even semi-strong forms of market efficiency are suggested by the identification of persistent lead-lag and causal links, such as crude oil leading the GSE, exchange-rate swings impacting the DSE, and Bitcoin affecting the SEM. These trends, which include thin trading, slower information diffusion, and a heavy reliance on macroeconomic fundamentals driven by commodities, draw attention to structural constraints and information transmission asymmetries in SSA markets. The results thus lend credence to a more context-specific interpretation of EMH, according to which African markets might function more like weak-form efficiency, with predictable dynamics developing in situations of increased uncertainty. By demonstrating that EMH assumptions must be adjusted to the institutional and structural realities of frontier markets, the data advances the theoretical discussion.

Behavioral Finance Implications: Behavioral finance emphasizes how sentiment, irrational behavior, and cognitive biases influence market results, particularly in times of crisis. Strong empirical evidence for behavioral explanations is provided by the sharp coherence spikes seen after global shocks, which correlate to herding behavior, flight-to-safety reactions, and sentiment-driven trading. While the erratic behavior of Bitcoin as a diversifier supports the idea that investor sentiment, rather than fundamentals, shapes its interaction with African markets, markets like the GSE and DSE demonstrated increased sensitivity to exchange-rate movements, suggesting

overreaction to currency risk. Furthermore, behavioral biases may be exacerbated by the very small investor base, reduced liquidity, and structural flaws in many SSA markets. These findings expand the field of behavioral finance by showing how psychological dynamics are more pronounced in developing markets with distinctive institutional features.

Synthesis and Theory Contribution: Overall, the results cast doubt on the applicability of conventional theories and show that theoretical modification, as opposed to direct application, is necessary for the African financial environment. Models that account for non-linearities, structural breaks, varied market depths, and time-frequency variability are necessary, according to the research. This study broadens existing theoretical frameworks and increases their applicability to frontier markets by demonstrating the high regime dependence of correlations, causality, and investor behavior. There are two contributions:

It supports the claim that dynamic, context-sensitive theoretical models are necessary for emerging economies, and it offers factual proof that the financial integration and behavioral patterns of Africa are more intricate, asymmetrical, and multilayered than previously thought.

5.4 Policy Recommendations

Diversify Foreign Exchange Reserves: Countries, particularly those with significant currency exposure like Ghana and South Africa, should diversify their foreign exchange reserves to reduce dependence on a single currency. This can help mitigate the impact of currency fluctuations on stock markets.

Strengthen Monetary Policy Frameworks: Central banks should implement robust monetary policies to maintain currency stability and manage inflation expectations. This can help instill investor confidence and reduce volatility in both currency and stock markets.

Promote Commodity Diversification: Countries heavily reliant on commodities, such as Ghana and Tanzania, should diversify their economies to reduce exposure to commodity price fluctuations. This can be achieved through targeted investments in sectors beyond commodities, such as manufacturing and services.

Strengthen Regional Integration: Foster deeper regional integration among African countries to create larger and more diversified markets. This can enhance resilience to global shocks and provide opportunities for cross-border investment.

Coordinate Economic Policies: Encourage coordinated economic policies among regional blocs to mitigate the impact of external shocks and promote stability.

Financial decision-making methods should carefully analyze the impact of external factors, such as global economic conditions and geopolitical events. These factors have a substantial influence on the correlations between stock exchanges and important variables. International collaboration and coordination are vital in the interdependent global financial system. Policymakers should

collaborate in collaborative endeavors to tackle global economic difficulties, guaranteeing stability and flexibility in order to effectively respond to unforeseen occurrences.

Suggestions for Investment Strategies includes the following; Make use of multi-horizon and multi-asset diversification: Correlations change throughout frequencies, according to wavelet data. Investors should modify their positions according to short-, medium-, or long-term co-movement patterns, diversifying across time scales and assets.

Adapt Strategies to Specific Market Behavior; The variety of answers points to customized tactics:

GSE: Keep an eye on currency volatility and manage FX risk.

BRVM: A stable environment for long-term investments.

NSE: Suitable for balanced portfolios because to its strong resiliency.

DSE: During shocks, gold-linked solutions are helpful.

JSE: Excellent exposure to emerging markets due to its high global integration.

Use Bitcoin Sparingly to Increase Diversification

Bitcoin may act as an additional diversifier during low-correlation times, particularly during geopolitical shocks, according to intermittent co-movement (e.g., with SEM, BRVM).

Utilize Causality Pattern-Based Dynamic Hedging:

Crude oil and currency variables frequently lead African markets, according to Granger causality research. When commodities prices or currencies fluctuate, investors should make proactive portfolio adjustments, particularly in times of crisis like pandemics or geopolitical wars.

Regional Integration Consequences:

Deeper African capital-market integration is supported by the findings. The advantages of uniform listing regulations, shared regulatory frameworks, and cross-border trading infrastructure are

demonstrated by BRVM's stability under a single currency. Crisis readiness would be improved by a regional early-warning system that uses wavelet-based indicators.

It is crucial to prioritize continuous monitoring, robust risk management, flexibility in response to changing market conditions, and international cooperation in order to successfully navigate the ever-changing global financial markets, especially in a world characterized by uncertainties. Market players should utilize stringent risk management techniques to appropriately address uncertainties revealed throughout the study. This entails subjecting portfolios to stress testing utilizing diverse associated scenarios and preparing for unforeseen market changes. Overall, the partial wavelet coherence analysis provides useful insights into the complex relationships between financial indicators and commodities throughout the COVID-19 period. In order to successfully traverse this ever-changing environment, it is essential for both market participants and regulators to possess a proactive and flexible mindset.

Explore Commodity Futures Markets: Consider using commodity futures markets to hedge against price risks. This can help stabilize domestic prices and reduce the impact of commodity price volatility on stock markets.

Enhance Risk Management Frameworks: Stock exchanges should implement robust risk management measures, such as circuit breakers and margin requirements, to prevent excessive volatility and protect investors.

Promote Investor Education: Invest in investor education programs to raise awareness about market risks and best practices. This can help investors make informed decisions and reduce the likelihood of panic selling during times of crisis.

Promote Digital Financial Services: Expand access to digital financial services to facilitate efficient transactions and reduce dependence on traditional banking systems. This can enhance market liquidity and resilience.

By implementing these policies, African countries can enhance their economic resilience, mitigate the impact of global shocks, and create a more stable and sustainable investment environment.

5.5 Limitations of the study

The sample population may be too small to represent the whole of Africa. Thus, not all Africa equity markets could be used in the study due to the unavailability of data. Secondly, the study's scope is confined to the COVID-19 and the Russia/Ukraine disturbances period, thereby constraining the applicability of its findings to diverse market situations. Financial markets are subject to a multitude of causes, and the specific circumstances of the international disturbances may not completely reflect the overall market dynamics.

Financial markets are volatile and susceptible to swift fluctuations. The study examines links within certain time intervals, although changes in market dynamics over time may introduce new patterns or modify existing correlations.

5.6 Directions for further research

The findings of this analysis present prospects for further exploration into the underlying mechanisms that influence the observed connections. Thorough examination of certain elements influencing market dynamics within the international disturbances might improve understanding of financial market patterns. The ongoing progress in research methods and improved data accessibility, particularly in developing countries, will provide a more thorough comprehension of the correlations between stock markets and global factors. This encompasses continuous endeavors to collect accurate statistics on cryptocurrencies such as Bitcoin.

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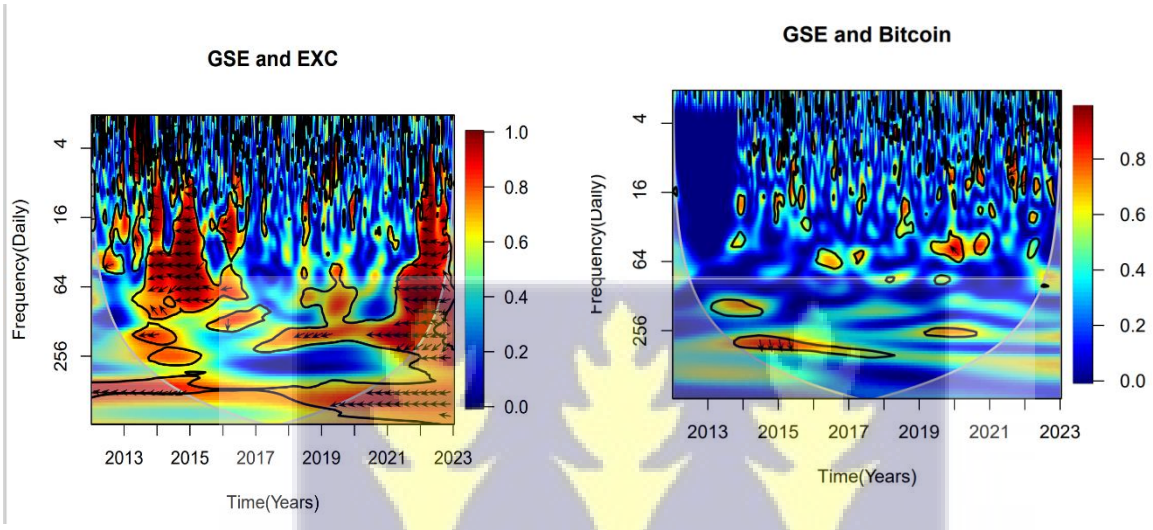
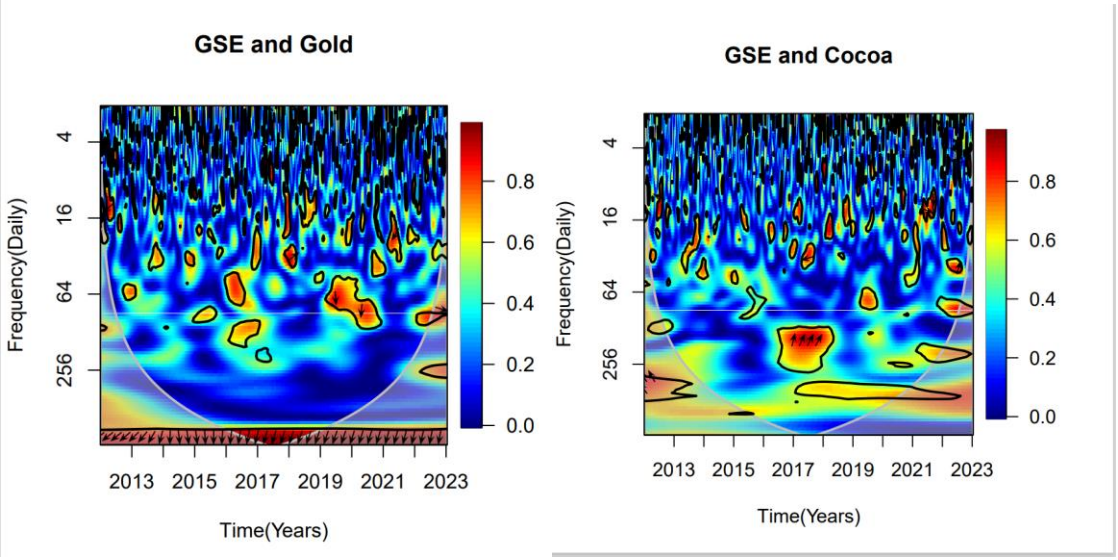
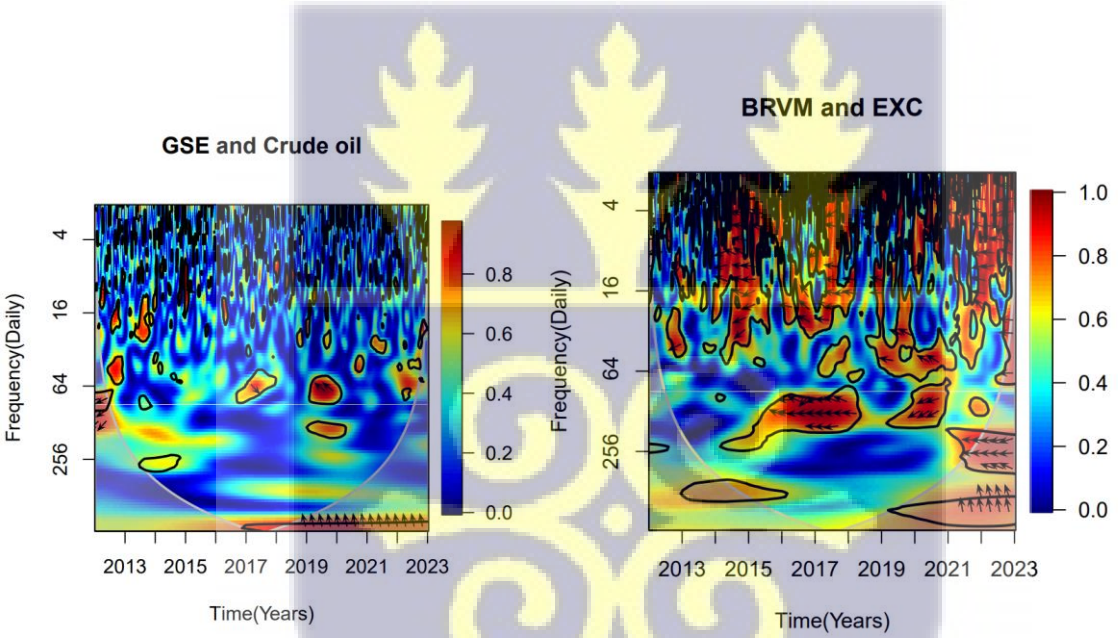
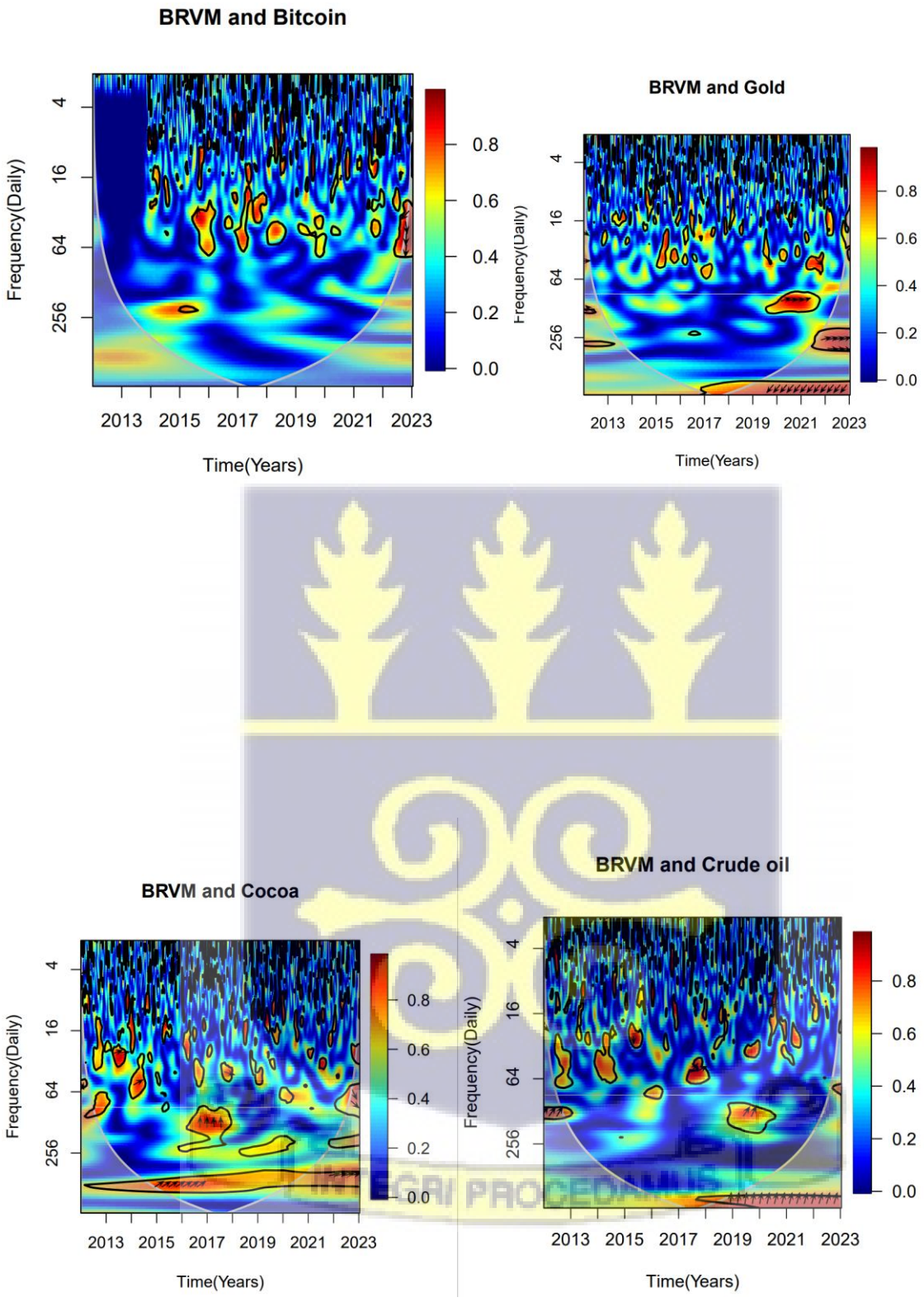
APPENDICES

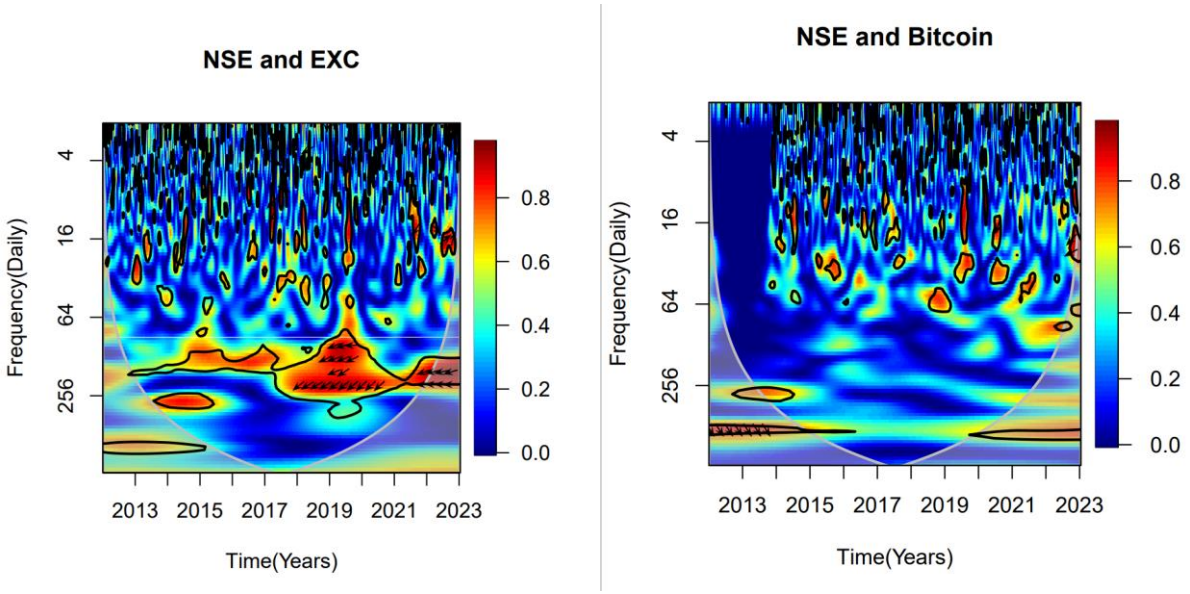
Appendix A1: Analysis with Bivariate Wavelet Coherence for full sample

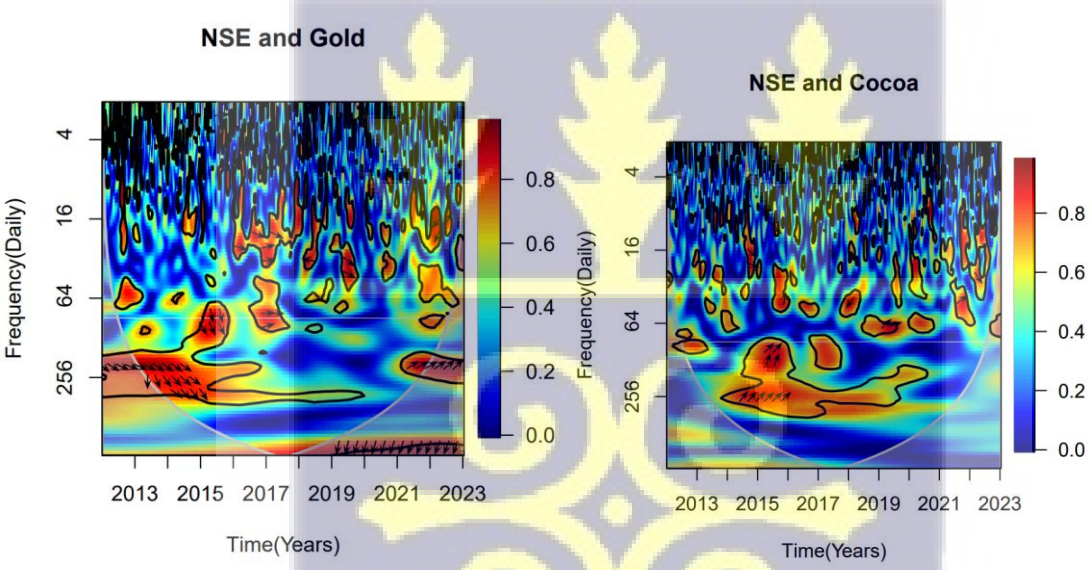


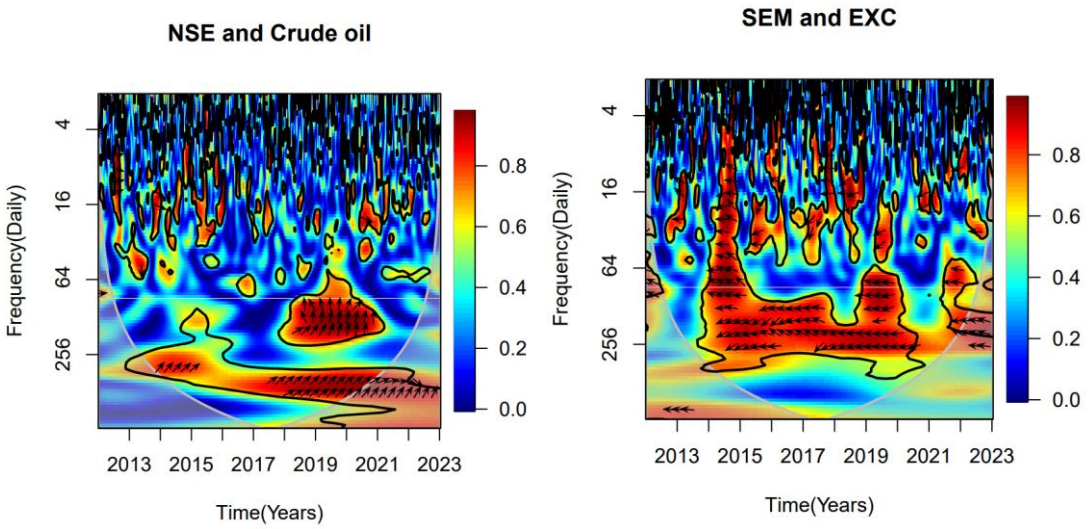


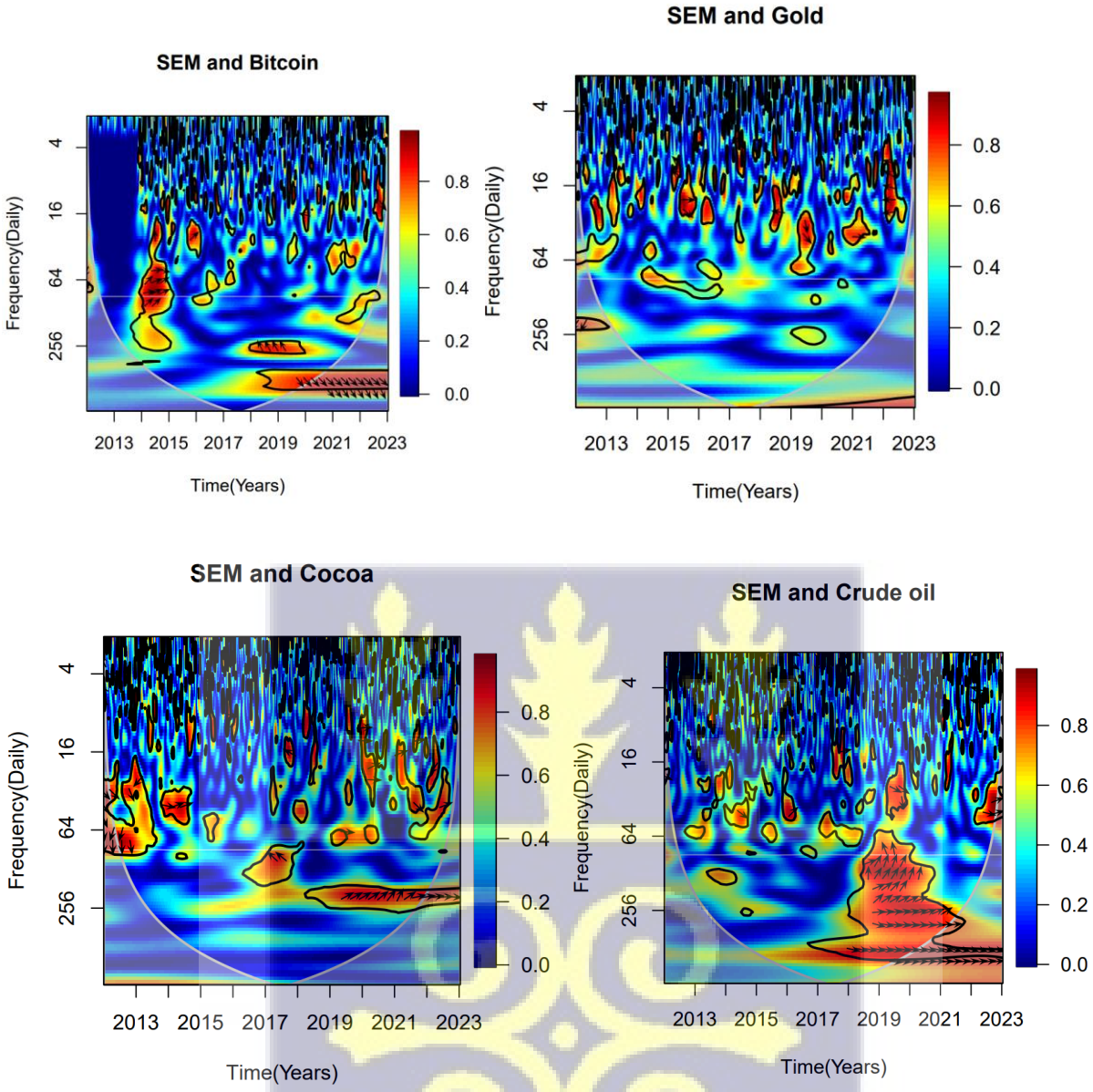


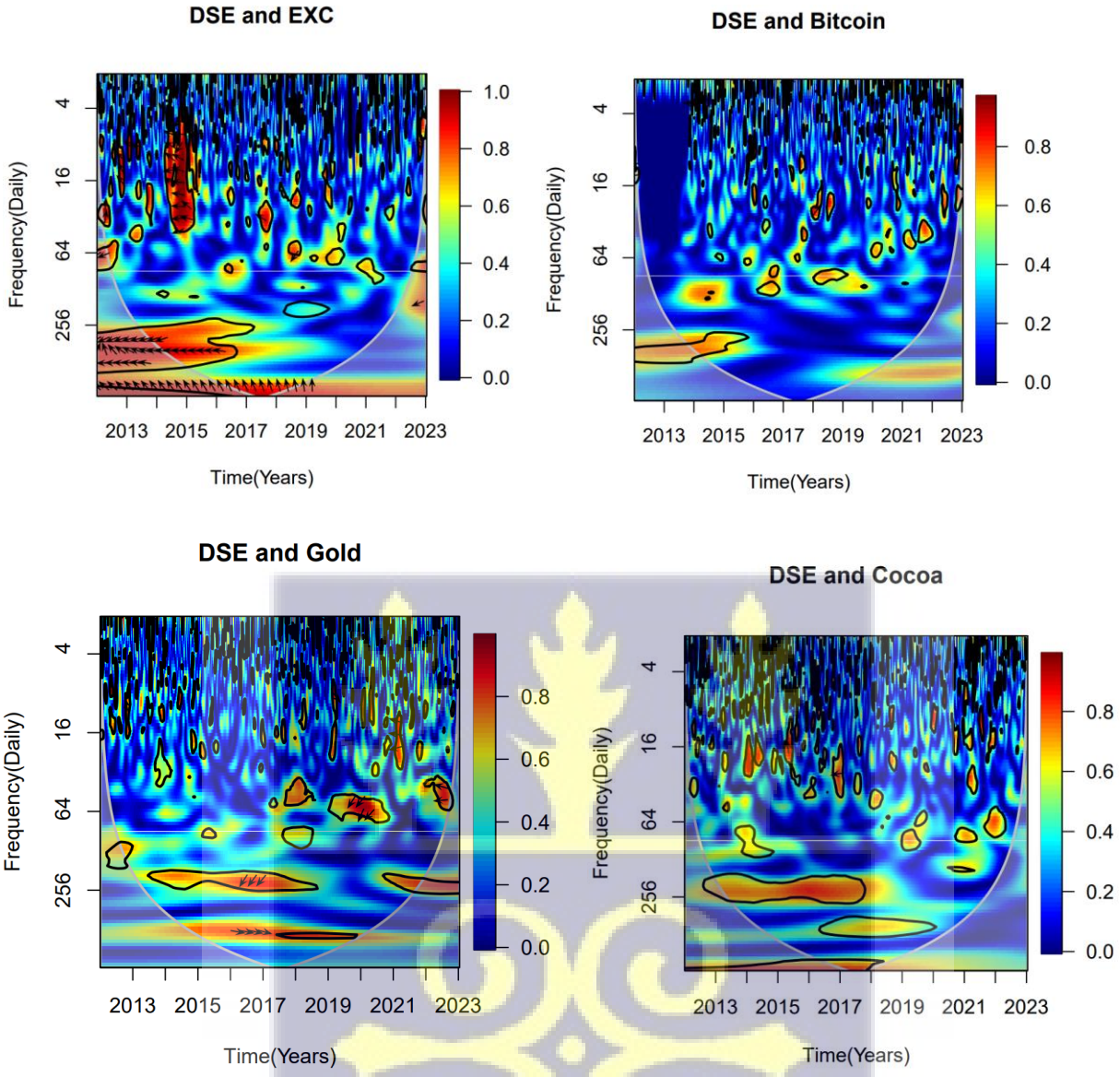


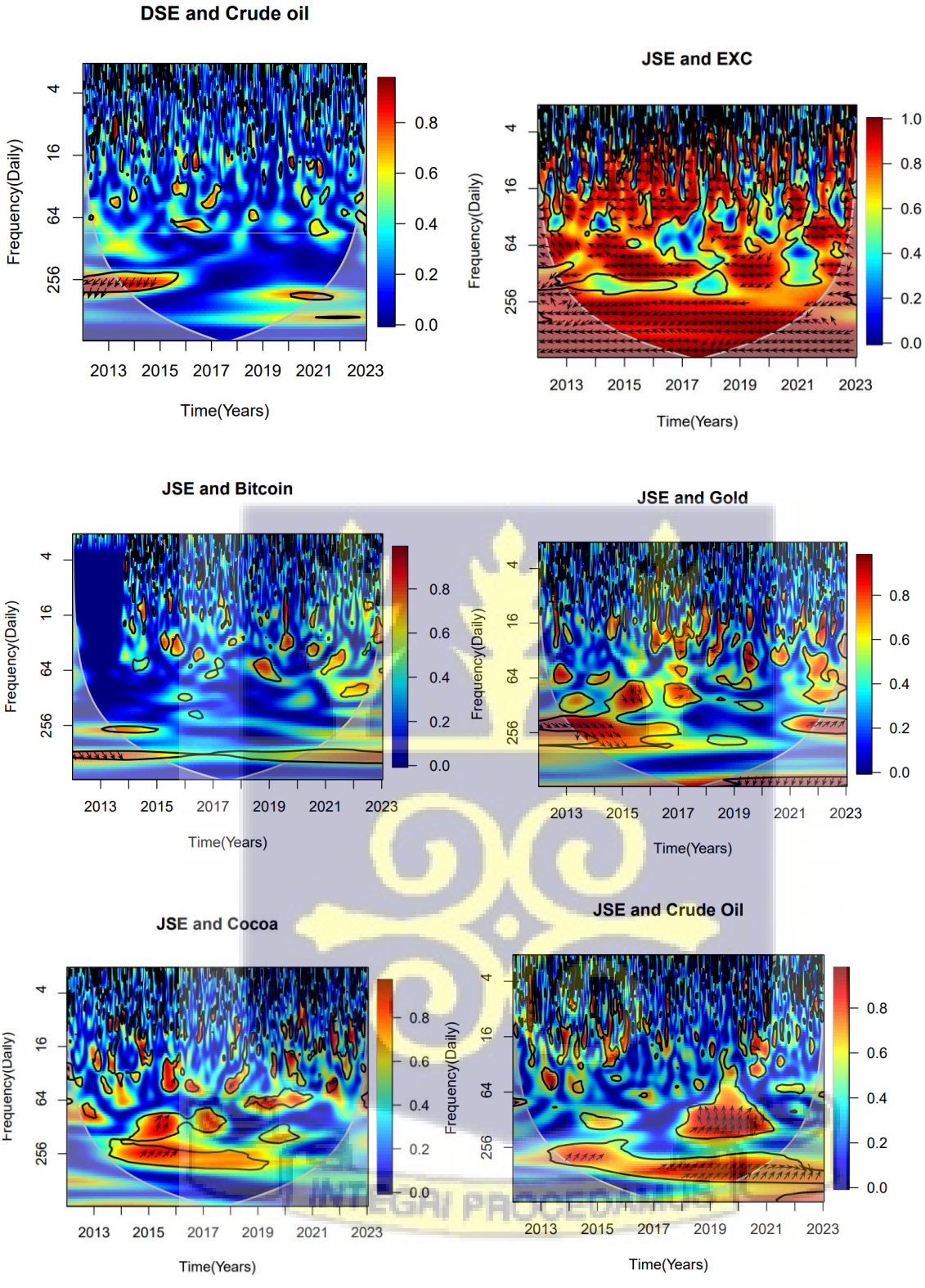




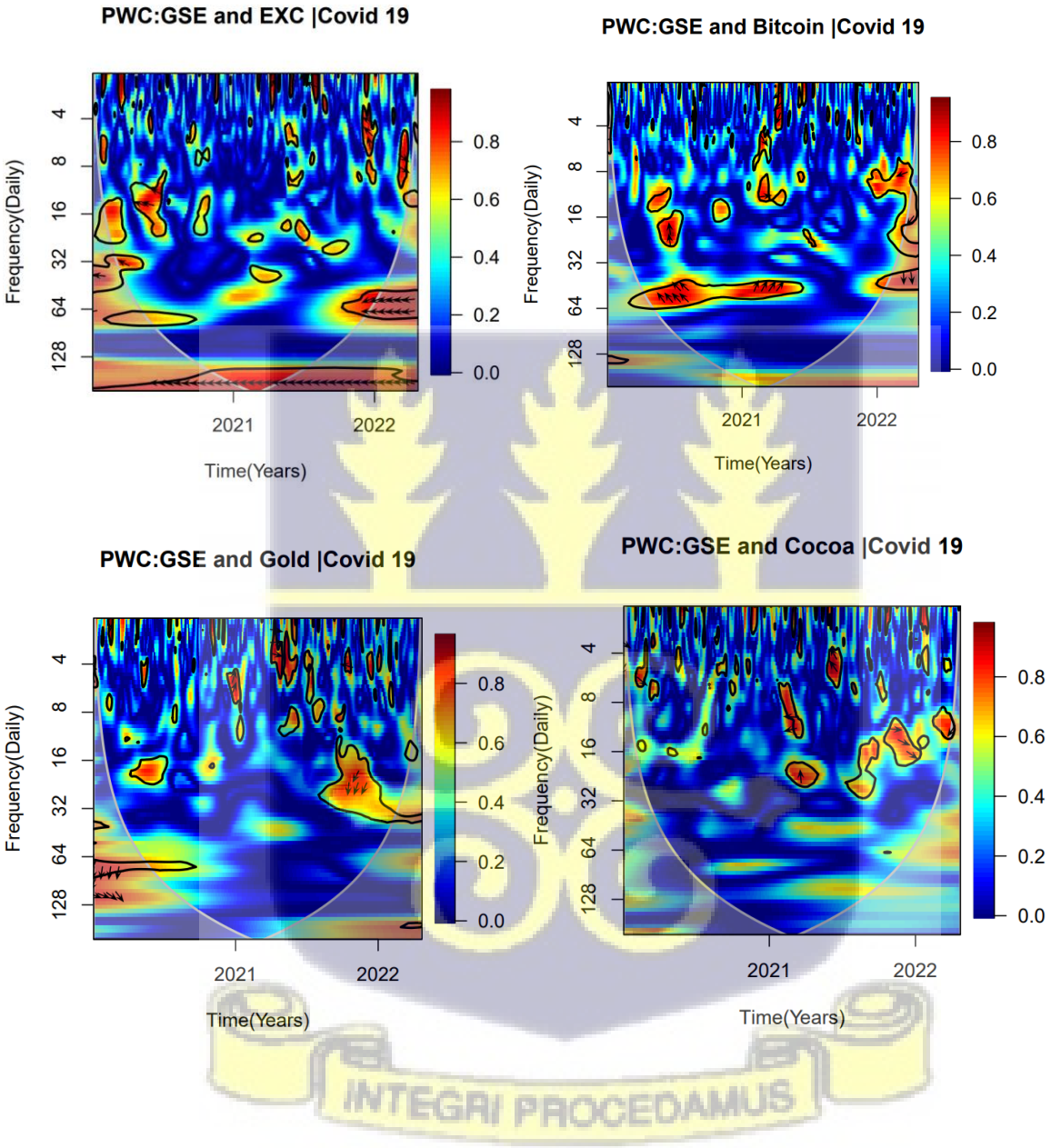


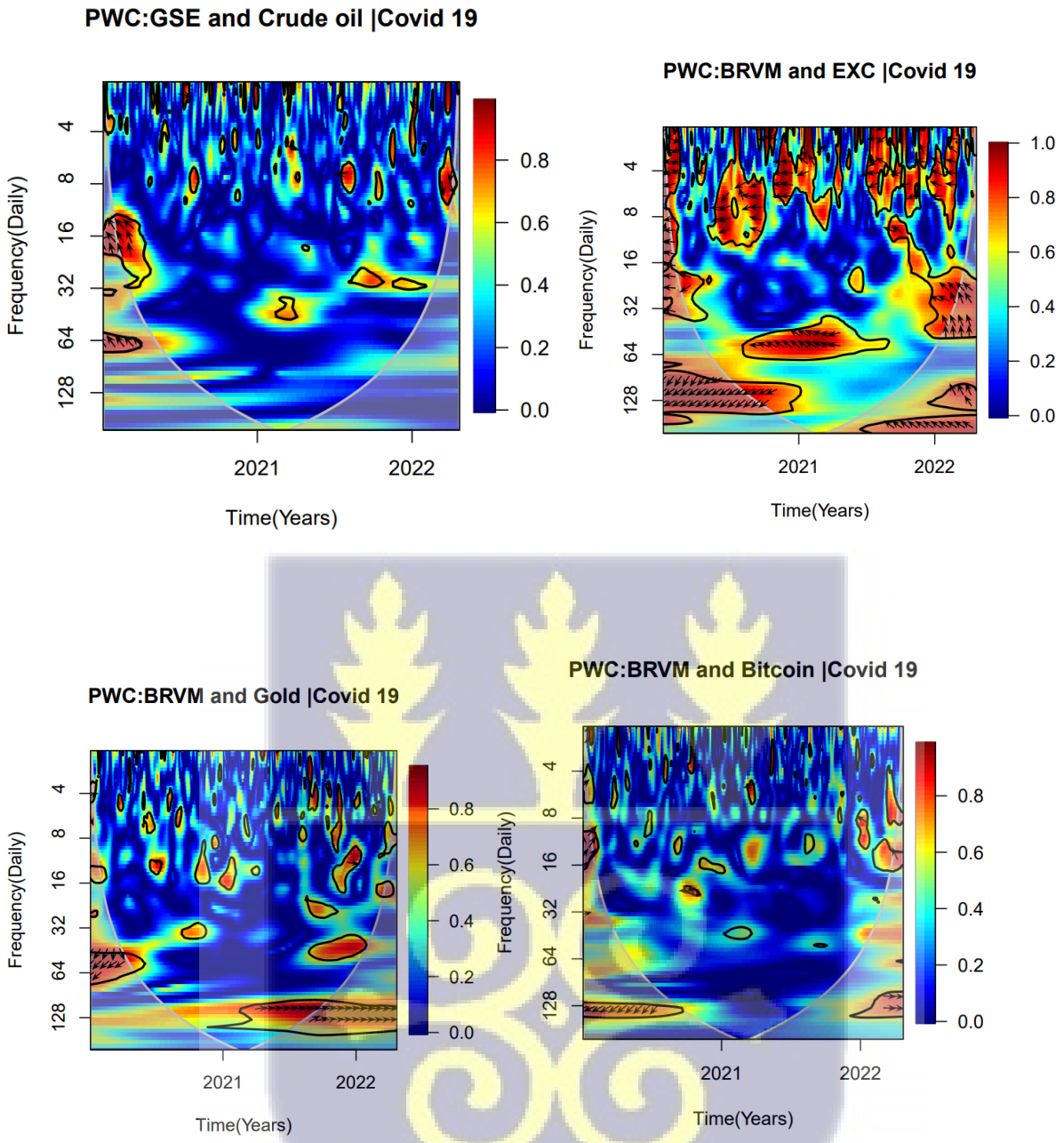


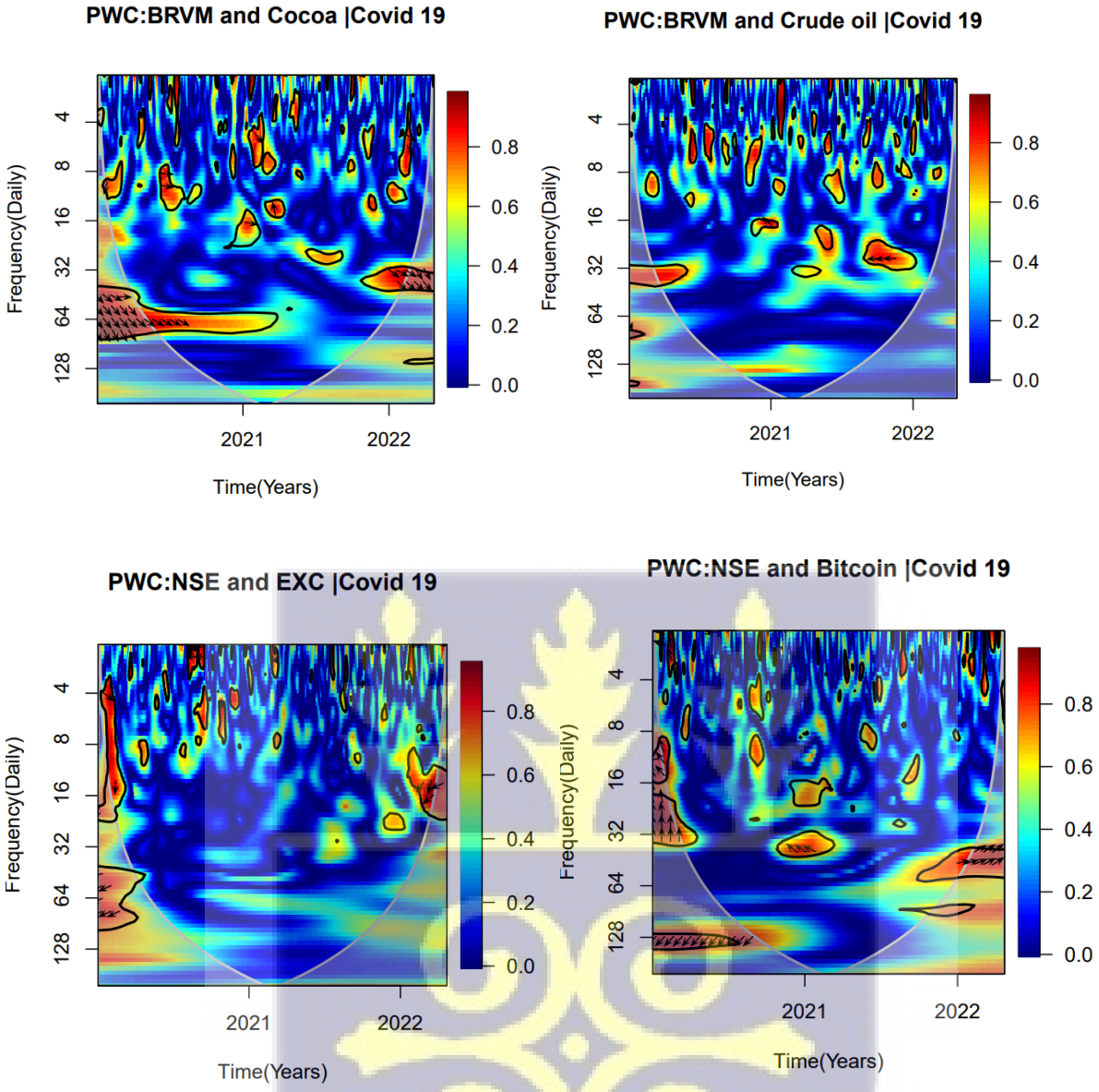


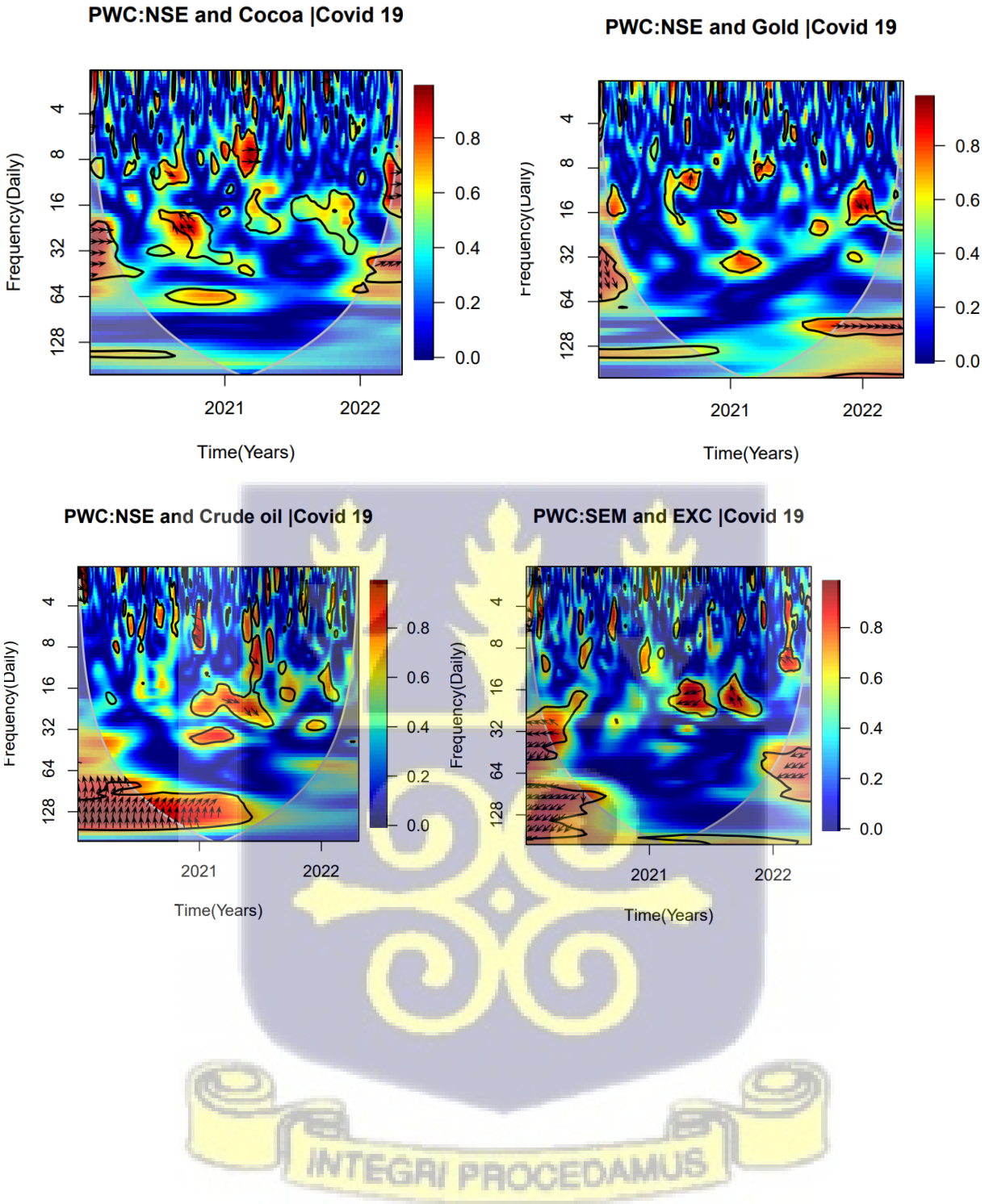


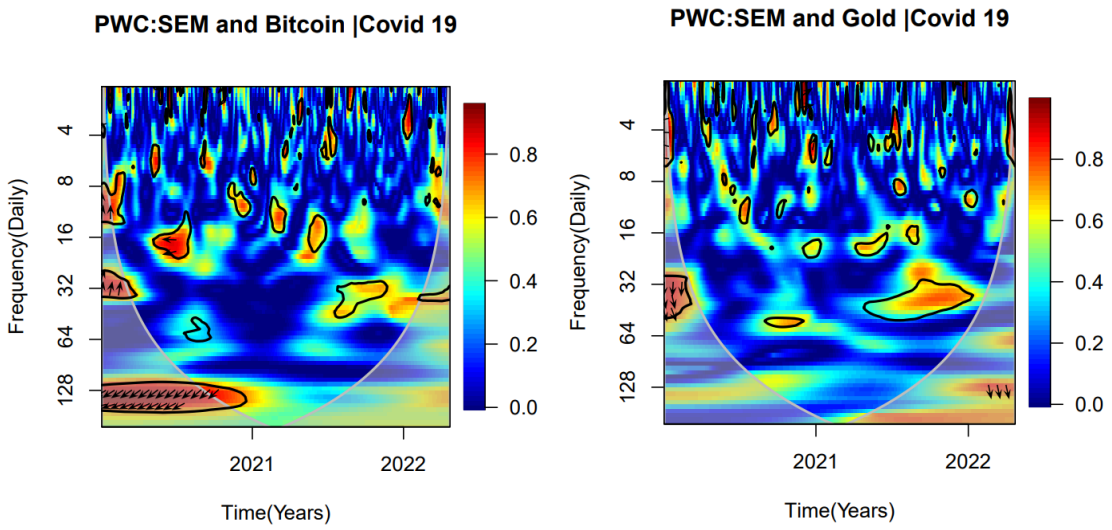
Appendix A2: Analysis with Patial Wavelet Coherence: Covid 19 Period Sample with Infection Rates

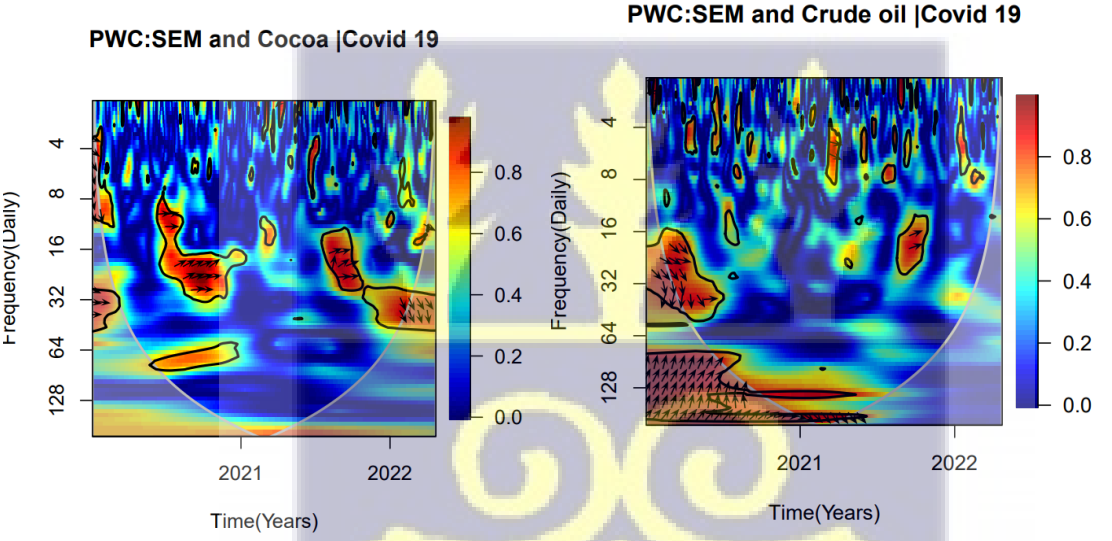


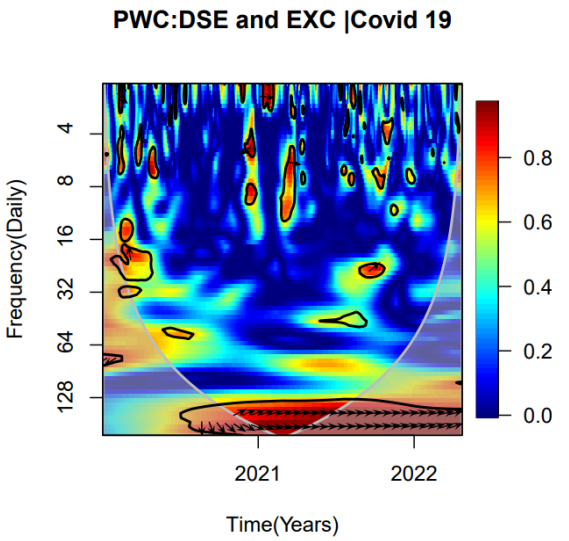


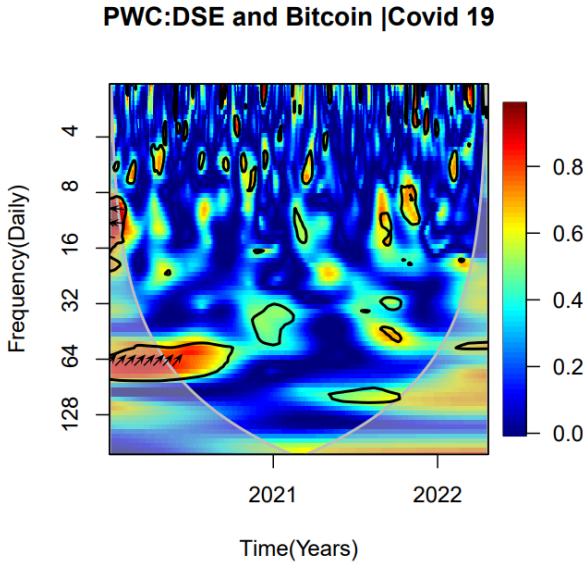


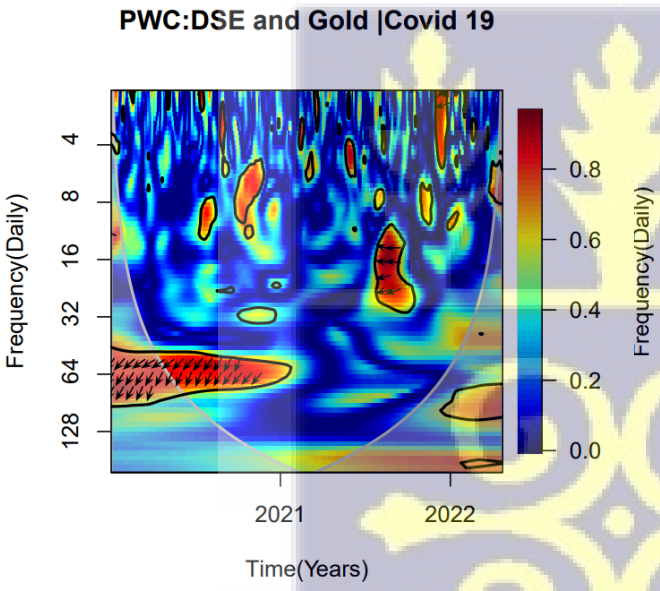


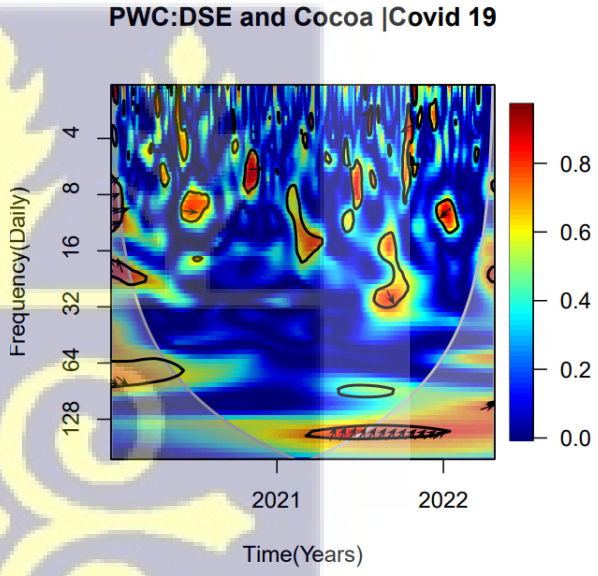


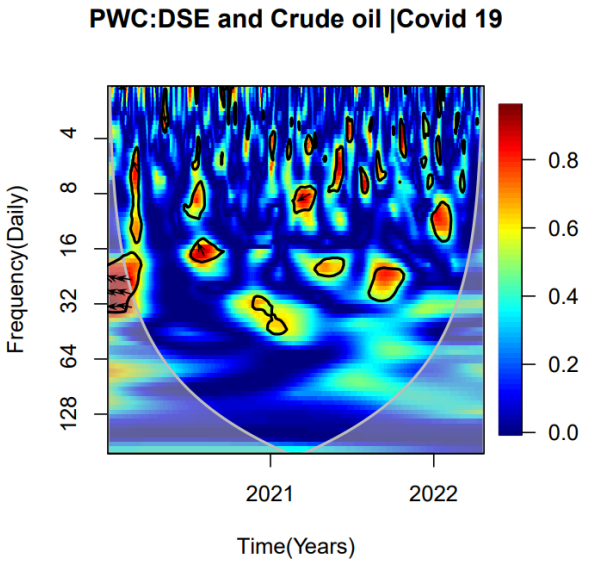


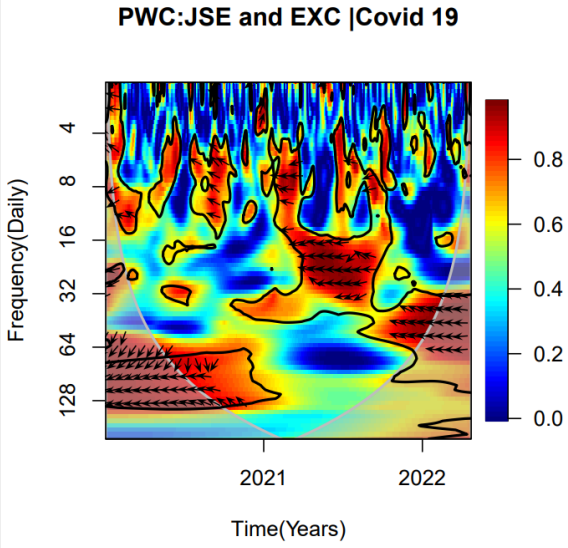


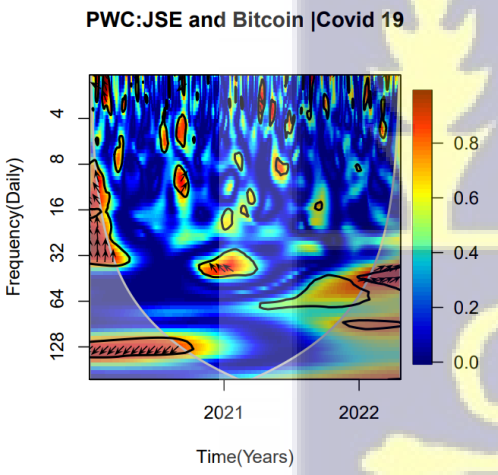


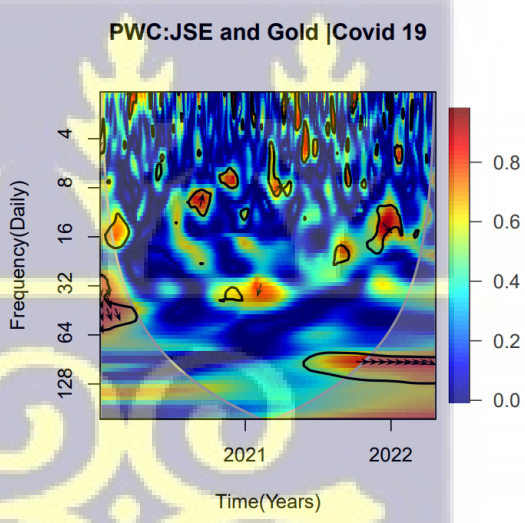


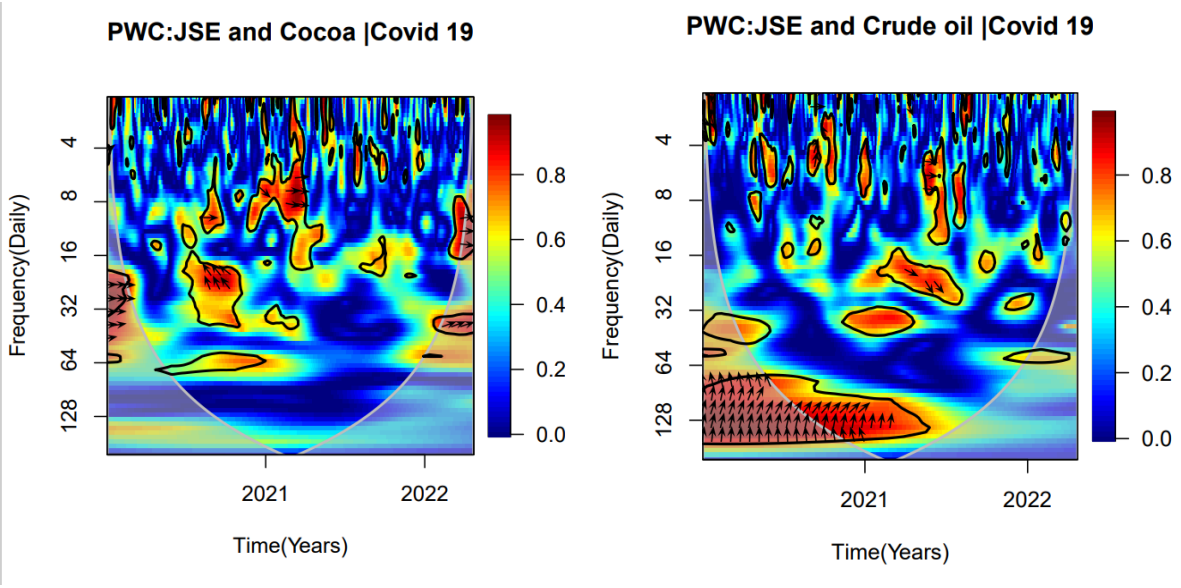




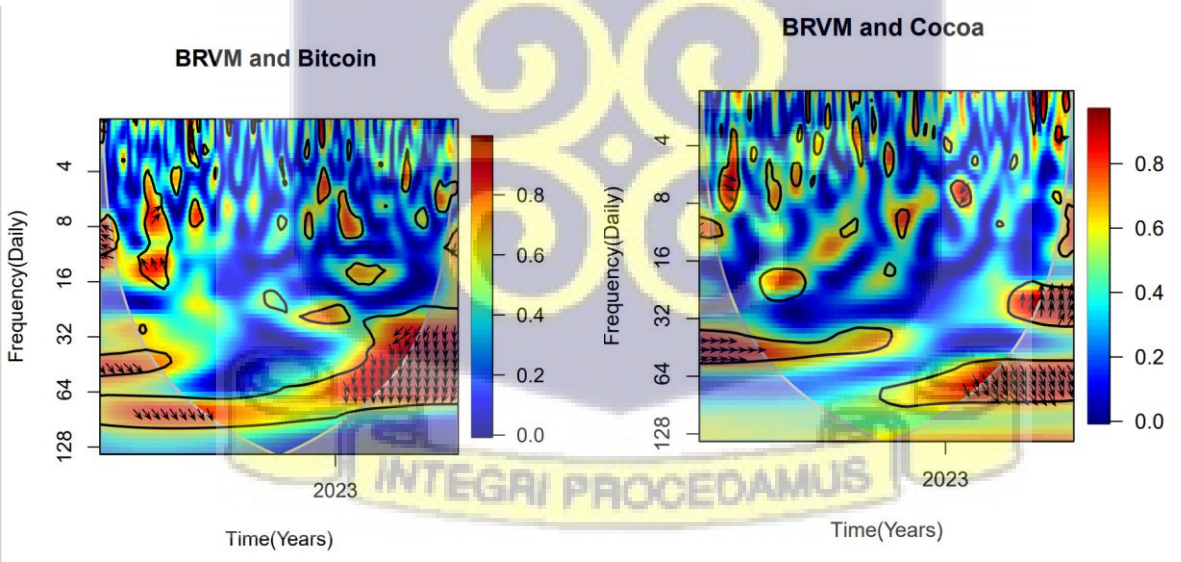


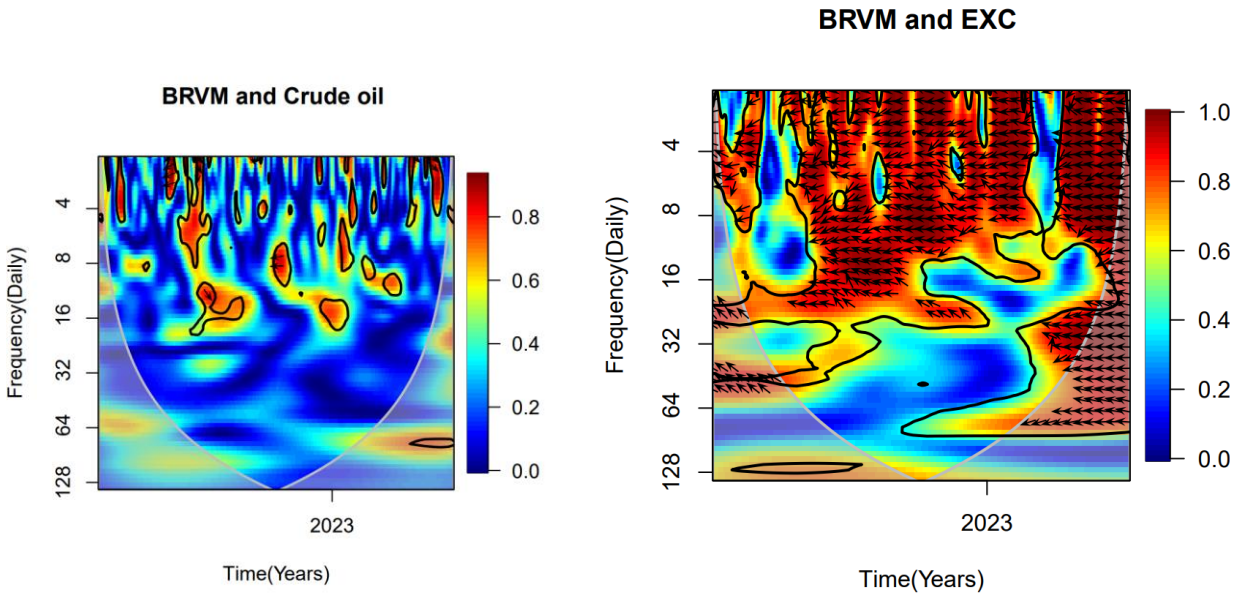


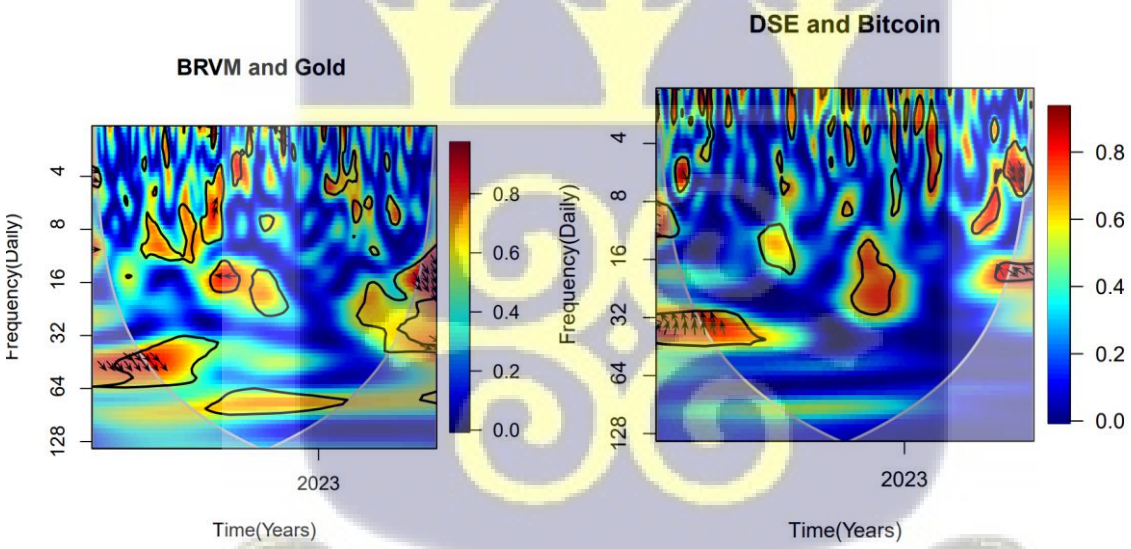




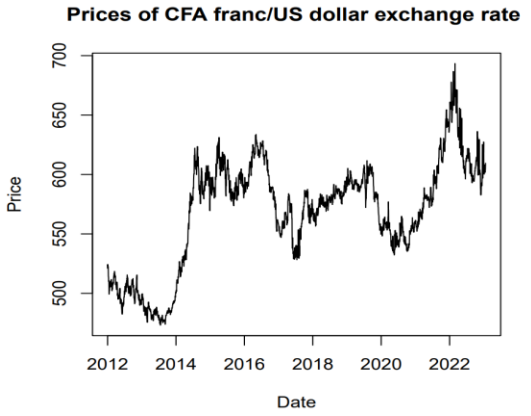
Appendix A3: Bivariate wavelet coherence analysis (Russia/Ukraine disturbance period)

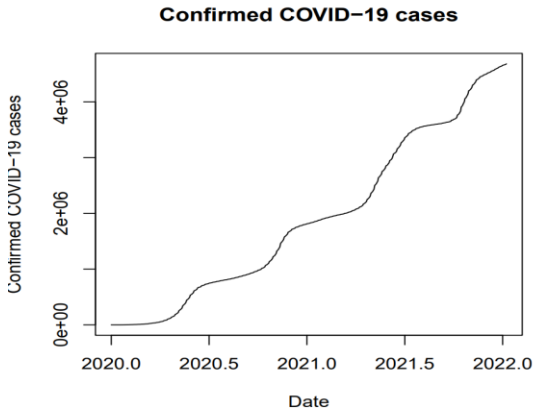


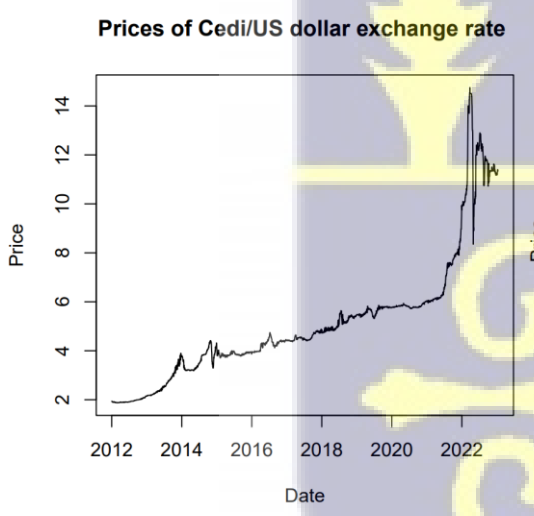


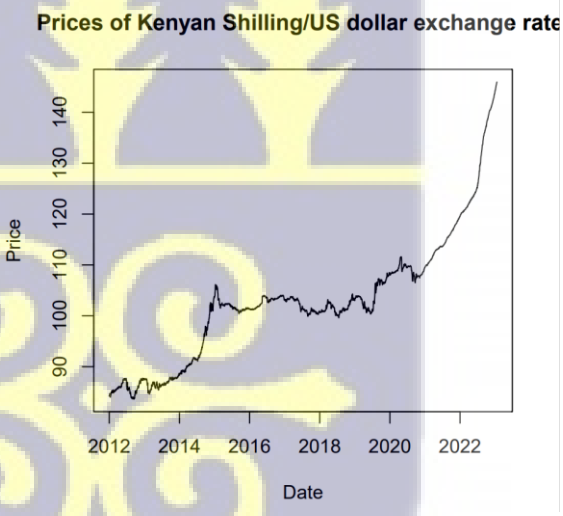


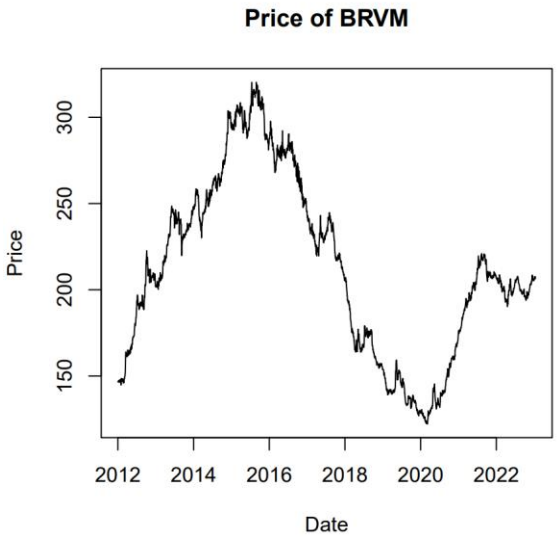
Apendix B1: Price Series Plot

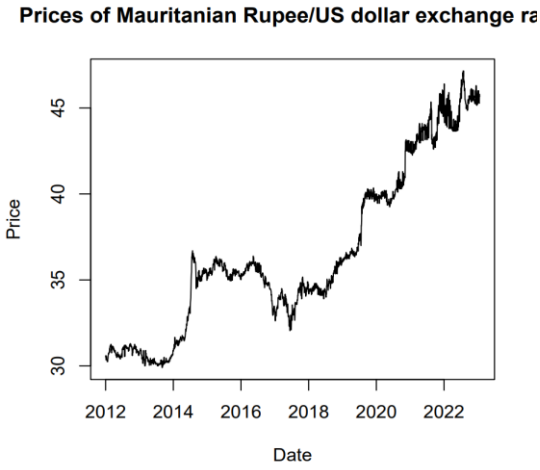


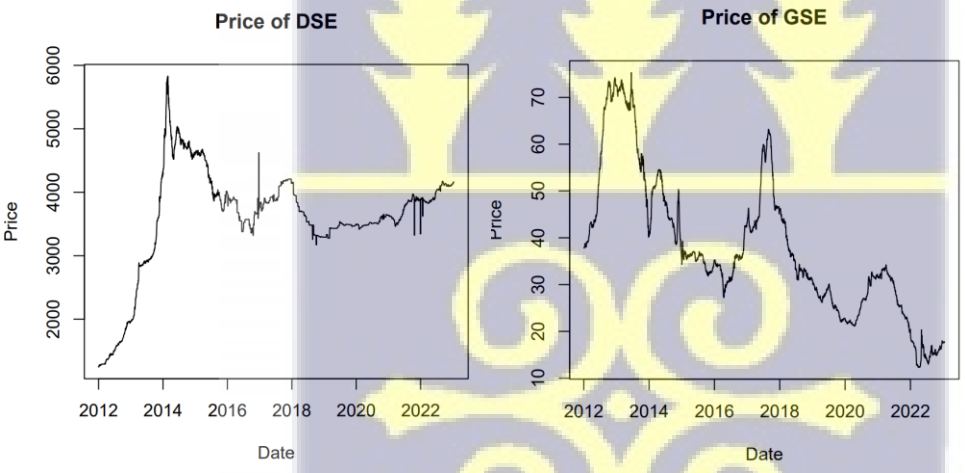


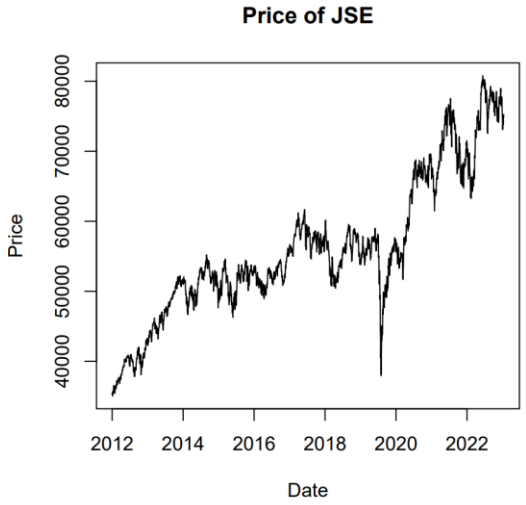


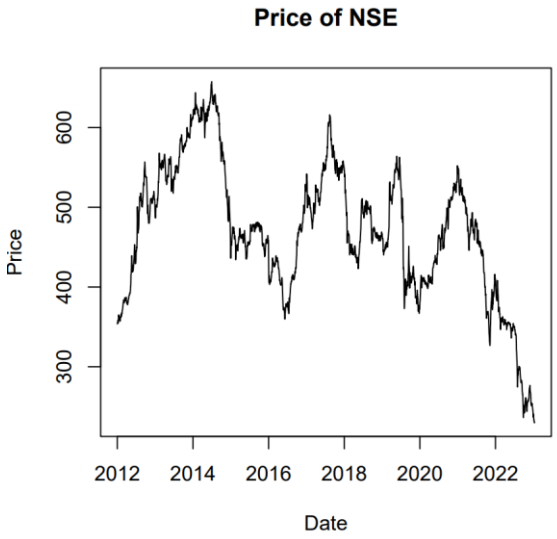


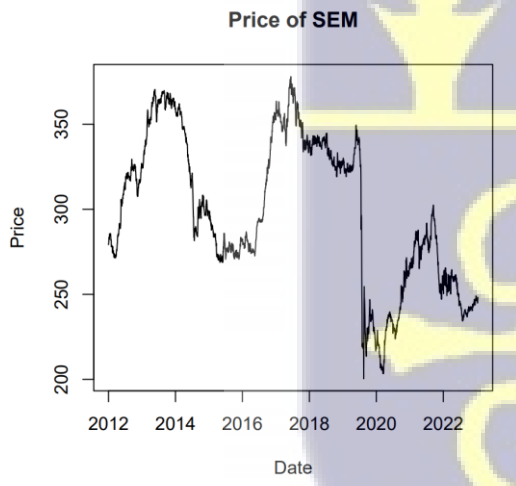


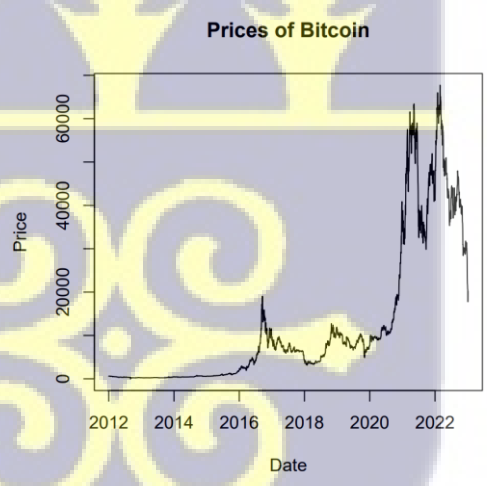


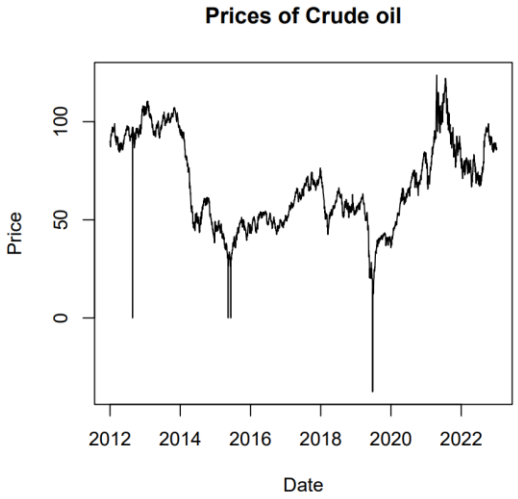


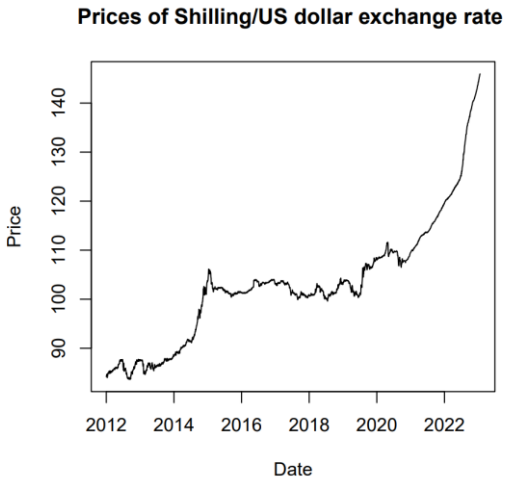


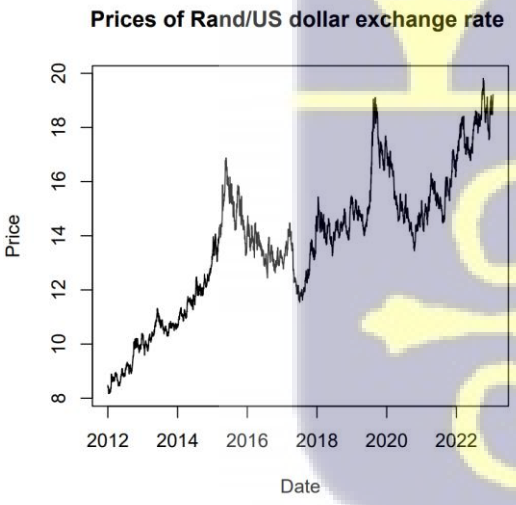


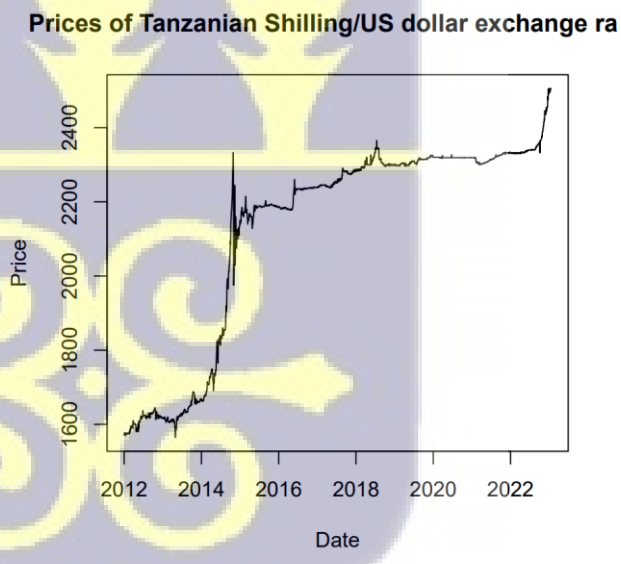




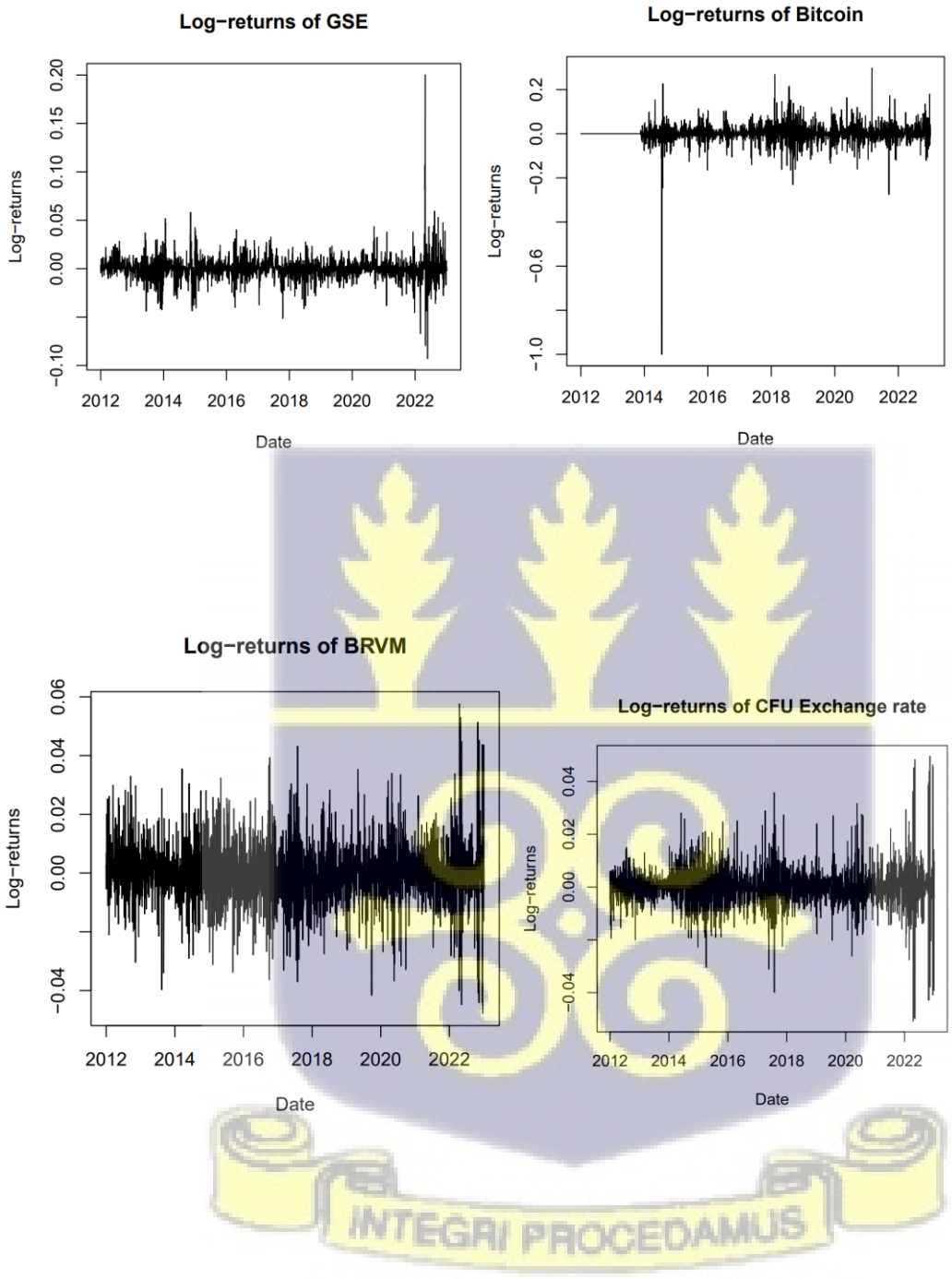


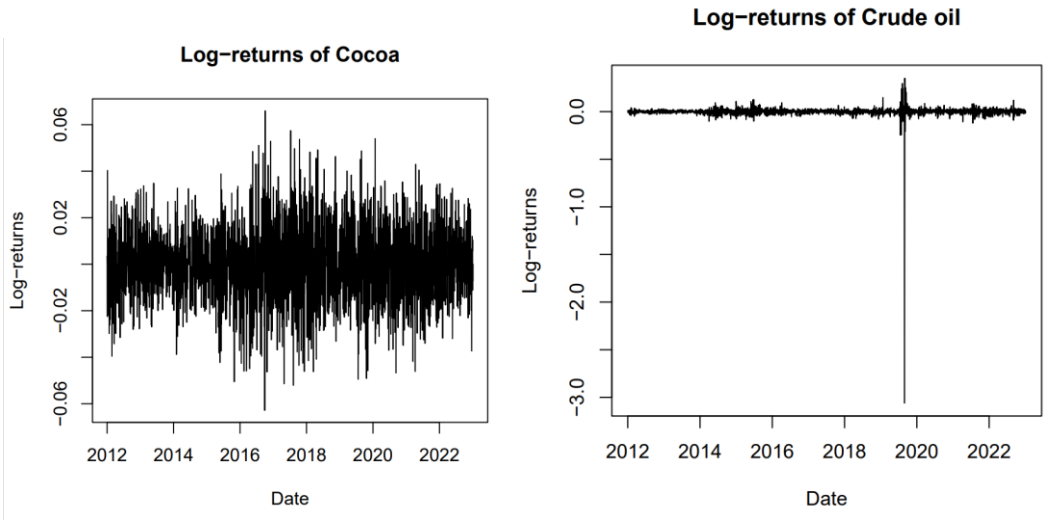


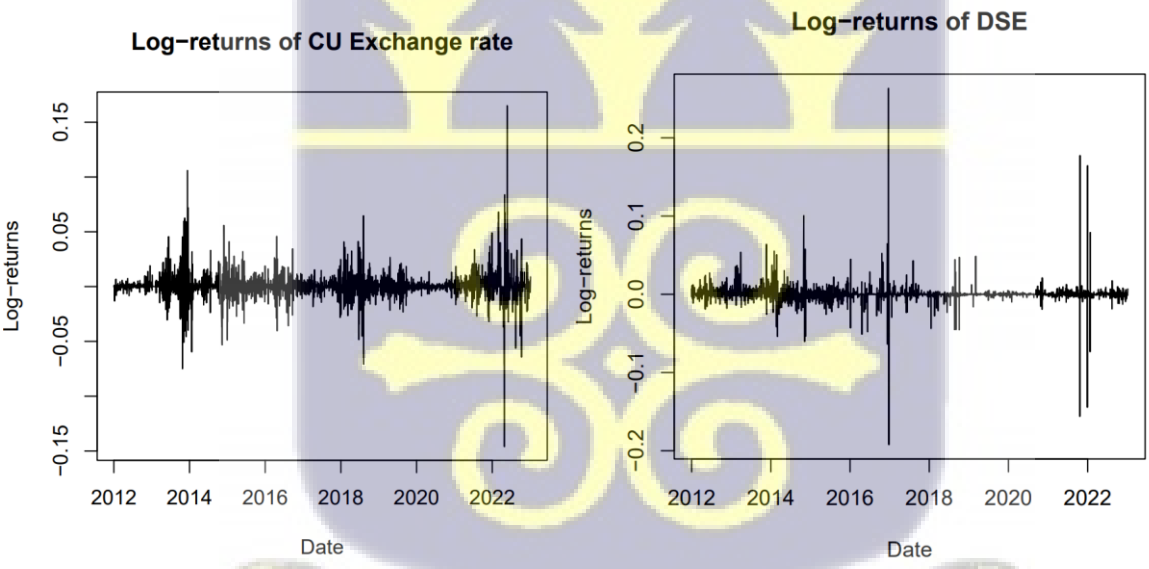


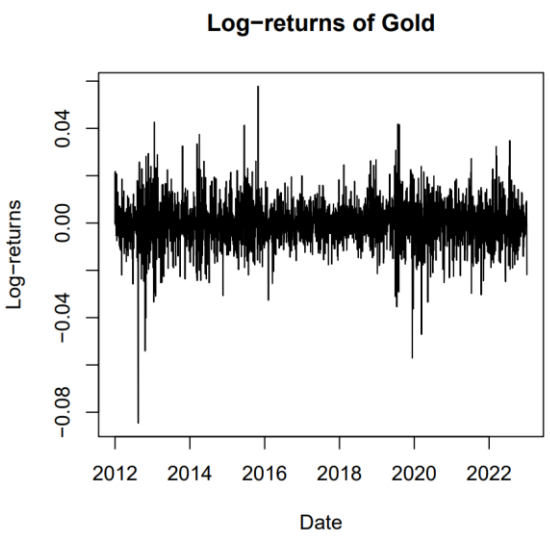


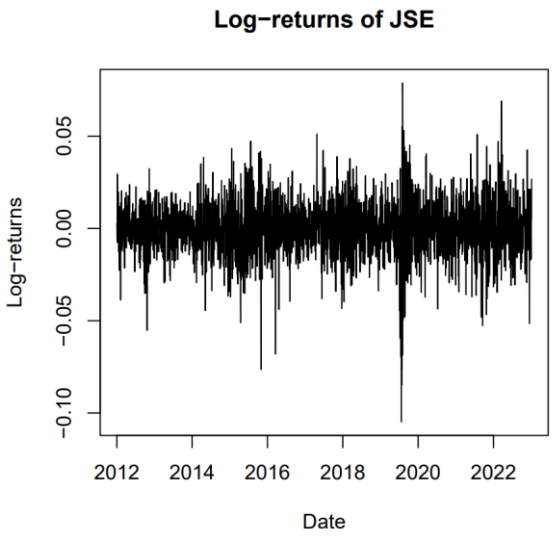
Appendix B2: Log Returns Plot

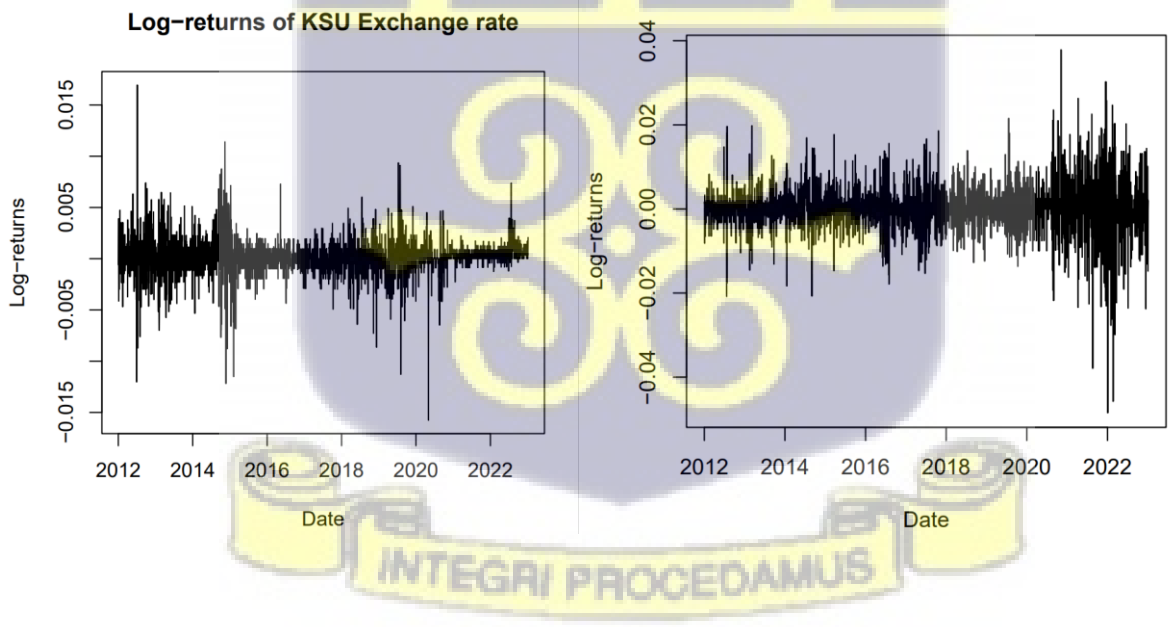


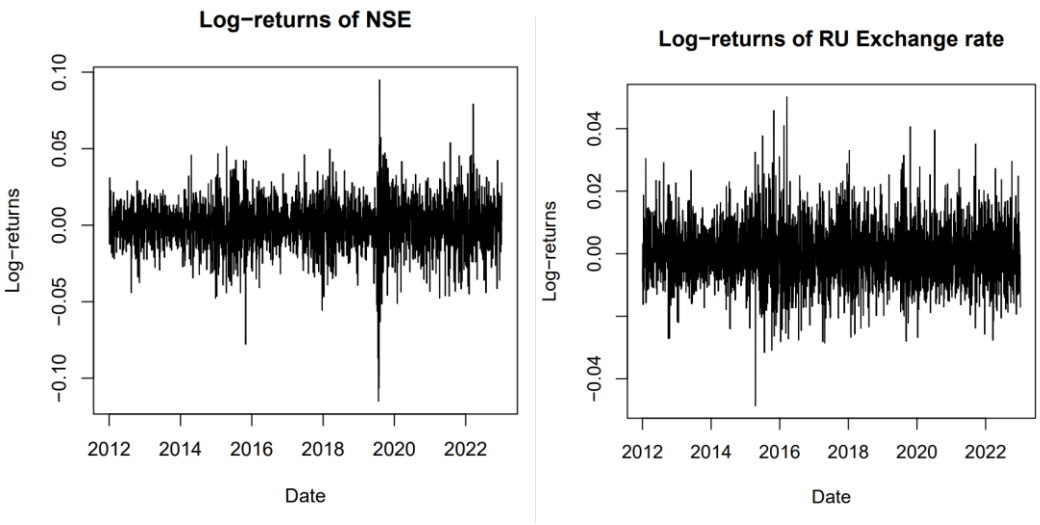


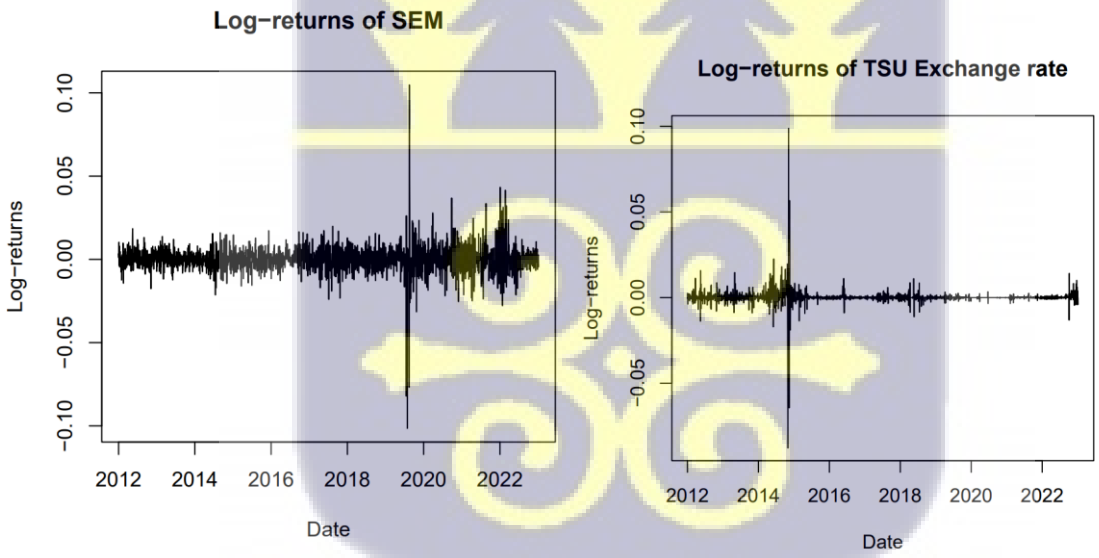












Appendix C: Descriptive Statistics

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability	Observations
BP	0.0019	0	0.2974	-1	0.0405	-5.1158	138.756	2214859	0	2868
BRVM	0.0001	0.0001	0.0576	-0.0477	0.0101	0.1257	6.0442	1115.377	0	2869
CFU	7.41E-05	0	0.0496	-0.0509	0.0071	0.1334	13.8696	14132.18	0	2869
COP	-0.0009	0	0.3502	-3.0597	0.0679	-33.8005	1472.969	2.59E+08	0	2869
CU	0.0007	0	0.165	-0.1461	0.0118	0.3395	38.3248	149224.1	0	2869

CP	0.0002	0	0.0659	-0.0629	0.0151	0.0133	3.8159	79.6648	0	2869
DSE	0.0003	0	0.2633	-0.1923	0.0117	3.4292	170.6017	33612.42	0	2867
GP	9.71E-05	9.30E-05	0.0578	-0.0846	0.0092	-0.3793	8.7588	4033.23	0	2869
GSE	-0.0002	0	0.2001	-0.0929	0.0115	1.9024	42.9602	19261.71	0	2869
JSE	8.92E-05	0.0004	0.0788	-0.1048	0.0143	-0.3486	6.7039	1697.923	0	2869
KSU	0.0002	0	0.017	-0.0158	0.0018	-0.3352	13.0494	12126.4	0	2869
MRU	0.0002	0	0.0379	-0.0485	0.0057	-0.3718	11.2072	8118.201	0	2869
NSE	0.0001	0.0003	0.0949	-0.115	0.0154	-0.4231	7.2744	2269.669	0	2869

RU	0.000324	-3.35E-05	0.0502	-0.0486	0.0097	0.2741	4.1014	180.9371	0	2869
SEM	-1.23E-05	0	0.1048	-0.1014	0.0076	-0.6593	43.058	19202 9.7	0	2869
TSU	0.00017	0	0.0988	-0.0878	0.004	0.5087	274.0642	8783543	0	2869

Table 4.2 Stationarity and Correlation Matrix.

	GSE	BRVM	NSE	SEM	DSE	JSE	CU
GSE	1.0000						
BRVM	0.0219 0.2412	1.0000					
NSE	0.0212 0.2563	0.0770* 0.0000	1.0000				
SEM	0.0279 0.1349	0.0563* 0.0026	0.1301* 0.0000	1.0000			
DSE	-0.0009 0.9615	0.0079 0.6739	-0.0131 0.4844	-0.0335 0.0726	1.0000		
JSE	0.0185 0.3217	0.0650* 0.0005	0.8445* 0.0000	0.1558* 0.0000	-0.0309 0.0975	1.0000	
CU	-0.4282* 0.0000	0.0261 0.1615	-0.0088 0.6377	-0.0050 0.7872	-0.0098 0.5982	-0.0207 0.2678	1.0000
CFU	0.0037 0.8441	-0.7003* 0.0000	-0.1208* 0.0000	-0.0449* 0.0161	-0.0023 0.9032	-0.1056* 0.0000	-0.0347 0.0634
RU	-0.0132 0.4807	-0.1103* 0.0000	-0.7349* 0.0000	-0.0927* 0.0000	0.0024 0.8983	-0.4305* 0.0000	-0.0013 0.9454
KSU	-0.0208 0.2654	-0.0084 0.6533	-0.0357 0.0557	-0.0790* 0.0000	-0.0011 0.9517	-0.0501* 0.0073	0.0041 0.8278
TSU	0.0230 0.2186	0.0157 0.3998	0.0162 0.3858	0.0209 0.2640	-0.1857* 0.0000	0.0173 0.3550	-0.0111 0.5538
MRU	-0.0133 0.4752	-0.0299 0.1098	-0.0366* 0.0499	-0.2712* 0.0000	0.0312 0.0950	-0.0630* 0.0007	0.0126 0.5002
BP	0.0170	-0.0127	-0.0262	0.0076	0.0157	-0.0277	0.0178

	0.3635	0.4950	0.1612	0.6822	0.3996	0.1377	0.3412
GP	-0.0185	0.0092	0.0149	-0.0362	0.0081	0.0194	0.0088
	0.3227	0.6233	0.4237	0.0523	0.6651	0.2994	0.6386
CP	0.0056	0.0349	0.1767*	0.0399*	-0.0268	0.1636*	0.0148
	0.7649	0.0619	0.0000	0.0326	0.1519	0.0000	0.4284
COP	-0.0145	-0.0071	0.1272*	0.0863*	-0.0068	0.1112*	-0.0078
	0.4378	0.7046	0.0000	0.0000	0.7167	0.0000	0.6776

	CFU	**RU**	**KSU**	**TSU**	**MRU**	**BP**	**GP**	**CP**	**COP**
CFU	1.0000								
RU	0.1553*	1.0000							
	0.0000								
KSU	0.0349	0.0296	1.0000						
	0.0618	0.1124							
TSU	-0.0138	-0.0035	0.0569*	1.0000					
	0.4590	0.8506	0.0023						
MRU	0.0565*	0.0170	0.0044	-0.0020	1.0000				
	0.0025	0.3633	0.8153	0.9161					
BP	0.0289	0.0410*	0.0315	0.0025	-0.0137	1.0000			
	0.1217	0.0279	0.0916	0.8926	0.4633				
GP	-0.0196	-0.0431*	-0.0048	-0.0145	0.0020	0.0195	1.0000		
	0.2929	0.0210	0.7971	0.4370	0.9140	0.2964			
CP	-0.0612*	-0.1129*	-0.0017	-0.0013	0.0019	-0.0070	-0.0148	1.0000	
	0.0010	0.0000	0.9260	0.9442	0.9210	0.7064	0.4272		
COP	0.0053	-0.0786*	-0.0168	-0.0026	-0.0246	-0.0147	0.0015	0.0491*	1.0000
	0.7749	0.0000	0.3683	0.8914	0.1875	0.4306	0.9360	0.0085	

Appendix D: Granger Causality Test Results

Variables	F-Statistic	Probability	Significance
CU → GSE	19.6551	3.E-19*	Reject
GSE → CU	23.6752	2E-23*	Reject
BP → GSE	1.41093	0.2170	Fails to Reject
GSE → BP	0.41560	0.8382	Fails to Reject
GP → GSE	1.41093	0.2170	Fails to Reject
GSE → GP	0.41560	0.8382	Fails to Reject
COP → GSE	0.89429	0.4839	Fails to Reject
GSE → COP	0.15330	0.9791	Fails to Reject
CP → GSE	0.73703	0.5956	Fails to Reject
GSE → CP	1.02611	0.4004	Fails to Reject
MRU → SEM	2.70162	0.0192*	Reject
SEM → MRU	9.02636	2.E-08*	Reject
BP → SEM	1.37206	0.2316	Fails to Reject
SEM → BP	1.53621	0.1751***	Fails to Reject
GP → SEM	2.41759	0.0339**	Reject
SEM → GP	0.63005	0.6768	Fails to Reject
COP → SEM	6.93940	2.E-06*	Reject
SEM → COP	3.83891	0.0018*	Reject

CP→SEM	6.93940	2.E-06*	Reject
SEM→CP	3.83891	0.0018*	Reject
KSU→NSE	0.65599	0.6569	Fails to Reject
NSE→KSU	5.09412	0.0001*	Reject
BP→NSE	0.58267	0.7133	Fails to Reject
NSE→BP	0.95686	0.4430	Fails to Reject
GP→NSE	1.06494	0.3778	Fails to Reject
NSE→GP	1.09084	0.3633	Fails to Reject
COP→NSE	2.48436	0.0297**	Reject
NSE→COP	7.29610	8.E-07*	Reject
CP→NSE	0.88014	0.4934	Fails to Reject
NSE→CP	1.02857	0.3989	Fails to Reject
TSU→DSE	25.4626	3.E-25*	Reject
DSE→TSU	5.61583	4.E-05*	Reject
BP→DSE	1.22290	0.2956	Fails to Reject
DSE→BP	0.59995	0.7000	Fails to Reject
GP→ DSE	1.32419	0.2507	Fails to Reject
DSE→GP	0.96753	0.4362	Fails to Reject
COP→DSE	0.06259	0.9974	Fails to Reject
DSE→COP	0.21828	0.9548	Fails to Reject
CP→DSE	0.50805	0.7704	Fails to Reject
DSE→CP	1.32622	0.2499	Fails to Reject

RU ⟶ JSE	100.287	1.E-97*	Reject
JSE ⟶ RU	1.75116	0.1196	Fails to Reject
BP ⟶ JSE	1.36753	0.2334	Fails to Reject
JSE ⟶ BP	0.64780	0.6632	Fails to Reject
GP ⟶ JSE	0.88052	0.4932	Fails to Reject
JSE ⟶ GP	1.27102	0.2735	Fails to Reject
COP ⟶ JSE	6.49753	5.E-06*	Reject
JSE ⟶ COP	5.25968	8.E-05*	Reject
CP ⟶ JSE	0.16999	0.9737	Fails to Reject
JSE ⟶ CP	0.81694	0.5374	Fails to Reject
CFU ⟶ BRVM	9.22232	1.E-08*	Reject
BRVM ⟶ CFU	1.31638	0.2540	Fails to Reject
BP ⟶ BRVM	0.65520	0.6575	Fails to Reject
BRVM ⟶ BP	1.59610	0.1577	Fails to Reject
GP ⟶ BRVM	0.79637	0.5521	Fails to Reject
BRVM ⟶ GP	1.33101	0.2479	Fails to Reject
COP ⟶ BRVM	0.46720	0.8009	Fails to Reject
BRVM ⟶ COP	0.66399	0.6508	Fails to Reject
CP ⟶ BRVM	3.63366	0.0028*	Reject
BRVM ⟶ CP	0.83693	0.5233	Fails to Reject

COVID-19 DATA

VARIABLES	F-STATISTIC	PROBABILITY	SIGNIFICANCE
CU – GSE	15.7540	7.E-15*	Rejected
GSE - CU	3.71805	0.0025*	Rejected
BP- GSE	0.79491	0.5534	Fails to Reject
GSE- BP	0.20191	0.9617	Fails to Reject
CP- GSE	0.59380	0.7048	Fails to Reject
GSE-CP	0.72426	0.6053	Fails to Reject
COP-GSE	0.49681	0.7788	Fails to Reject
GSE-COP	0.16367	0.9758	Fails to Reject
GP-GSE	1.22474	0.2954	Fails to Reject
GSE-GP	0.45953	0.8065	Fails to Reject
CFU-BRVM	5.57221	5.E-05*	Reject
BRVM-CFU	1.09884	0.3594	Fail to Reject
BP-BRVM	1.67327	0.1384	Fail to Reject
BRVM-BP	0.38395	0.8600	Fail to Reject
COP-BRVM	0.38889	0.8566	Fail to Reject
BRVM-COP	0.29852	0.9138	Fail to Reject
CP-BRVM	3.05581	0.0096*	Reject
BRVM-CP	0.45440	0.8102	Fail to Reject

GP-BRVM	0.68084	0.6380	Fail to Reject
BRVM-GP	0.85804	0.5089	Fail to Reject
RU-JSE	14.4551	1.E-13*	Reject
JSE-RU	1.43190	0.2102	Fail to Reject
BP-JSE	0.27253	0.9282	Fail to Reject
JSE-BP	0.41553	0.8382	Fail to Reject
COP-JSE	3.16008	0.0078*	Reject
JSE-COP	2.80386	0.0160**	Reject
CP-JSE	1.05087	0.3864	Fail to Reject
JSE-CP	1.42577	0.2124	Fail to Reject
GP-JSE	0.39907	0.8496	Fail to Reject
JSE-GP	2.08870	0.0647***	Fail to Reject
TSU-DSE	1.14512	0.3347	Fail to Reject
DSE-TSU	0.39958	0.8493	Fail to Reject
BP-DSE	0.80965	0.5428	Fail to Reject
DSE-BP	0.69705	0.6258	Fail to Reject
COP-DSE	0.05106	0.9984	Fail to Reject
DSE-COP	0.16472	0.9754	Fail to Reject
CP-DSE	0.14473	0.9816	Fail to Reject
DSE-CP	1.69036	0.1343	Fail to Reject
GP-DSE	2.79005	0.0165**	Reject
DSE-GP	0.51263	0.7669	Fail to Reject

KSU-NSE	2.21719	0.0507***	Fail to Reject
NSE-KSU	4.29976	0.0007*	Reject
BP-NSE	0.30500	0.9100	Fail to Reject
NSE-BP	0.23366	0.9478	Fail to Reject
COP-NSE	1.71404	0.1287	Fail to Reject
NSE-COP	3.80510	0.0020*	Reject
CP-NSE	1.18270	0.3157	Fail to Reject
NSE-CP	1.32383	0.2516	Fail to Reject
GP-NSE	0.37215	0.8679	Fail to Reject
NSE-GP	2.37754	0.0372**	Reject
MRU-SEM	1.92525	0.0877	Fail to Reject
SEM-MRU	3.45644	0.0042*	Reject
BP-SEM	0.87765	0.4954	Fail to Reject
SEM-BP	1.17714	0.3184	Fail to Reject
COP-SEM	3.12993	0.0083*	Reject
SEM-COP	2.01990	0.0736***	Fail to Reject
CP-SEM	5.41378	6.E-05*	Reject
SEM-CP	0.41831	0.8362	Fail to Reject
GP-SEM	3.21621	0.0069**	Reject
SEM-GP	0.83799	0.5228	Fail to Reject

RUSSIA/UKRAINE DATA

VARIABLES	F-STATISTIC	PROBABILITY	

CU-GSE	11.0118	6.E-10*	Reject
GSE-CU	1.97102	0.0821***	Fail to Reject
BP-GSE	1.13427	0.3416	Fail to Reject
GSE-BP	0.18849	0.9669	Fail to Reject
COP-GSE	0.34732	0.8839	Fail to Reject
GSE-COP	1.50804	0.1863	Fail to Reject
CP-GSE	0.89400	0.4851	Fail to Reject
GSE-CP	0.94550	0.4514	Fail to Reject
GP-GSE	1.93157	0.0882***	Fail to Reject
GSE-GP	0.19724	0.9635	Fail to Reject
CFU-BRVM	1.63370	0.1501	Fail to Reject
BRVM-CFU	0.89029	0.4875	Fail to Reject
BP-BRVM	1.73779	0.1250	Fail to Reject
BRVM-BP	0.29469	0.9158	Fail to Reject
COP-BRVM	0.57871	0.7163	Fail to Reject
BRVM-COP	0.66393	0.6510	Fail to Reject
CP-BRVM	1.78751	0.1144	Fail to Reject
BRVM-CP	0.61330	0.6898	Fail to Reject
GP-BRVM	0.26448	0.9323	Fail to Reject
BRVM-GP	0.90444	0.4781	Fail to Reject
TSU-DSE	0.86598	0.5040	Fail to Reject
DSE-TSU	0.20743	0.9593	Fail to Reject
BP-DSE	0.74509	0.5901	Fail to Reject

DSE-BP	0.76875	0.5727	Fail to Reject
COP-DSE	0.27478	0.9268	Fail to Reject
DSE-COP	2.09201	0.00657**	Reject
CP-DSE	0.19334	0.9650	Fail to Reject
DSE-CP	2.16099	0.0578***	Fail to Reject
GP-DSE	2.66905	0.0219**	Reject
DSE-GP	0.68113	0.6380	Fail to Reject
RU-JSE	10.3428	3.E-09*	Reject
JSE-RU	2.45880	0.0328**	Reject
BP-JSE	0.97893	0.4304	Fail to Reject
JSE-BP	0.19398	0.9648	Fail to Reject
COP-JSE	0.83118	0.5281	Fail to Reject
JSE-COP	0.61394	0.6893	Fail to Reject
CP-JSE	1.33638	0.2480	Fail to Reject
JSE-CP	0.90024	0.4809	Fail to Reject
GP-JSE	2.31829	0.0429*	Reject
JSE-GP	0.34846	0.8832	Fail to Reject
KSU-NSE	1.01565	0.4081	Fail to Reject
NSE-KSU	0.61373	0.6894	Fail to Reject
BP-NSE	0.03821	0.9992	Fail to Reject
NSE-BP	0.72801	0.6028	Fail to Reject
COP-NSE	1.22856	0.2949	Fail to Reject
NSE-COP	0.81580	0.5389	Fail to Reject

CP-NSE	1.47572	0.1968	Fail to Reject
NSE-CP	0.87740	0.4962	Fail to Reject
GP-NSE	1.79217	0.1135	Fail to Reject
NSE-GP	0.24420	0.9426	Fail to Reject
MRU-SEM	1.27364	0.2745	Fail to Reject
SEM-MRU	2.90103	0.0139**	Reject
BP-SEM	0.48132	0.7902	Fail to Reject
SEM-BP	2.58787	0.0256**	Reject
COP-SEM	0.37545	0.8655	Fail to Reject
SEM-COP	1.38818	0.2278	Fail to Reject
CP-SEM	1.04434	0.3912	Fail to Reject
SEM-CP	0.10252	0.9916	Fail to Reject
GP-SEM	0.71691	0.6110	Fail to Reject
SEM-GP	1.89727	0.0939***	Fail to Reject